"An Intertidal Voyage"

A Qualitative Study of Six Children's Understanding of the Physical Adaptations and Survival Behaviours of Intertidal Organisms

by

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Abstract

An Intertidal Voyage is a case study of children’s understanding of the survival behaviours and physical adaptations of intertidal organisms. The intent of the study was to analyze and interpret student language and to document the changes in student knowledge as they explored the seashore.

Six students participated in three individual interviews and nine group field trips. The first interview determined the student’s prior seashore knowledge and interviews two and three revealed changes in their knowledge. The field trips enabled the students to explore, investigate, observe, and discuss the inhabitants of the intertidal zone. The student’s use of descriptive language and metaphor was recorded during the interviews and field trips and is presented through the students’ styles of knowing of aesthete, scientist, and warrior.

The findings of “An Intertidal Voyage” showed that field trips enhance student learning. The students employed descriptive language and metaphor to express their seashore knowledge and retained their preferred style of knowing throughout the study. The study shows that students used their previous knowledge as a bridge to new ideas. The findings also highlight the importance of a facilitator in experiential learning and demonstrate that students learn in social situations as they interpret new knowledge and exchange ideas through observation and discussion. As the study progressed the students developed a sense of environmental stewardship for the seashore and expressed an awareness and appreciation of the inhabitants of the intertidal zone.
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Forward

If a child is to keep alive his inborn sense of wonder without any such gift from the fairies, he needs the companionship of at least one adult who can share it, rediscovering with him the joy, excitement and mystery of the world we live in.

(Carson, 1956, p.45)

The Hermit Crab Dilemma

My personal experiences from summers spent on the beach formed the foundation of “An Intertidal Voyage”. Every day, rain or shine, I cruised the intertidal zone with my beach pals investigating the myriad of organisms concealed under barnacle encrusted rocks, secreted in tidepools, and hidden among the swaying beds of eelgrass.

We often discovered unknown organisms which inspired further research. On one occasion we were keen to identify a strange shelled animal that scuttled about the tidepools on long, spindly legs. We asked the local Customs officer for help but learned that his impressive uniform and official hat and badge did not indicate a fellow seashore enthusiast. Without an expert to guide us we were on our own.

As we shared our collective knowledge we agreed that the animal’s legs were “spider-like” and its skittish behaviour reminded us of the familiar shore crab. Someone suggested that the animal needed to use a snail shell for protection as it might not have the tough protective shell of other crabs. We knew that crabs needed their hard shells for
Chapter 1: Statement of the Problem

1.1 Background To The Study

This study makes a modest contribution to current knowledge by gaining understanding of students’ developing knowledge and descriptive language of physical adaptations and survival behaviours of selected intertidal organisms. The study is set in a limited time frame to provide a practical and feasible framework for research. The seashore was chosen as it holds a fascination for children, is easily accessible to the school, and its organisms show clearly and dramatically physical adaptations and survival behaviours.

1.2 The Problem

In contemporary society children are often alienated from their natural environment and lack of environmental understanding of the interdependency of organisms and their habitats. Snively (1986, 1995), Fortner and Teates (1980), and Baron (1993), express concern about students’ lack of understanding and suggest that schools develop programmes and activities to help them gain a rich understanding of the interrelationships between humankind and other organisms in the physical world. “An Intertidal Voyage” explores children’s seashore knowledge and ways in which educators can interpret that knowledge.
1.3 The Problem Statement

To provide the richest detail and understanding of children's knowledge the study is a qualitative one. The study elicits the students' prior knowledge of the survival behaviours and physical adaptations of common seashore organisms using research methodologies developed by Driver and Erickson (1983) and Shapiro (1995). The work is situated within three contemporary and important research strands. As in Driver and Erickson the study reveals student prior knowledge and its use as building blocks in the construction of new knowledge. The study acknowledges current understandings that student knowledge is socially constructed (Lave and Wenger, 1991; Hennessy, 1993). It recognizes that language is a crucial vehicle for communication and learning and examines student use of metaphor in the interpretation and description of seashore life (Lakoff and Johnson, 1980; Snively, 1986, 1995). By situating the study within these three strands the research can be described as constructivist in its goals and methodology.

The activities which compose this study are designed to encourage and explore student learning. The three sets of field trips enable the students to explore the intertidal zone and its inhabitants. The interviews encourage students to articulate their knowledge of the survival behaviours and physical adaptations of selected intertidal organisms. This study represents the changes in student knowledge before, during, and after the field trips, and examines the use of student descriptive language and metaphor.
1.4 The Research Questions

This study examines six grade 4/5 students and their knowledge of the physical adaptations and survival behaviours of selected intertidal organisms. Three research questions guided the study.

1. How does student knowledge change through the field trips and interviews?
2. How do students use language to represent and explain their seashore knowledge?
3. What implications for classroom teaching can be drawn from the understandings gained in this study?

1.5 Scope and Limitations of the Study

This study was conducted in a lower mainland school in a class of grade 4/5 students. The students, all volunteers, participated in three sets of field trips over a four month period. The students investigated the intertidal zone and discussed their findings during conversation and group discussion.

The six students who participated in the interviews were asked to examine six intertidal organisms and comment on their findings. The interview questions were designed to probe for student understanding, and to encourage the students to use descriptive language and metaphor in their explanations.

The study involved one elementary school in an upper middle socio-economic neighbourhood, and students were selected by the classroom teacher in conjunction with the researcher. The participants in this study represent a small sample and is not representative of all Grade 4/5 students. The learning environment of Acadia beach, the

\footnote{For the purpose of this study the word \textit{How} is defined as \textit{In what ways}.}
serendipitous experiences, and the organisms encountered during the field trips define the boundaries of this study.

1.6 Strengths of the Study

Eisner (1991) suggests that if educators increase the ways in which the educational world is interpreted, described, and evaluated, students will experience a more complete and informative education. Exploring the seashore is one way students can interpret the natural world through relevant and engaging activities. The field trips provided the students with the opportunity to share their knowledge and utilize their talents of observation and discussion. They acquired "an enlightened eye" (Eisner, 1991) which enabled them to see beyond the obvious and employ their language and cognitive abilities to perceive and describe the physical adaptations and survival behaviours of intertidal organisms.

The study encouraged the students to use their own language in their description of intertidal life. Placing a value on student language promotes the active role of metaphorical language in the learning and teaching of science. The study also promotes an awareness and appreciation for the seashore. It is hoped that students will extend this interest to other areas of marine and environmental education.

1.7 Outline of the Remainder of the Thesis

This chapter outlined the problem, foundation, and goals of this study. Chapter two discusses the study's theoretical foundation in terms of constructivism and situated
learning. The literature relating to student language, metaphor, marine education, and the interview is reviewed. Chapter three defines "An Intertidal Voyage" as a qualitative work and outlines the study's methodology. Chapter four presents the changes in student knowledge over time. Chapter five defines the students' styles of knowing through their use of language. Chapter six answers the research questions and details personal reflections, and implications for future research and teaching. The appendices contain a glossary of terms used on the Changes in Student Knowledge Charts, an explanation and examples of the students' scientific and confused knowledge, one complete interview transcript, and a detailed account of the field trips. Many terms and words unfamiliar to non-biologists are included in this study. These words are defined in the Glossary of Terms located on Table 1.

This document is written in two distinct styles. Some sections are written in the first person as I wished to relate certain elements of the study in my own voice. In areas where a more formal approach was appropriate I have written in a less personal way.
Table 1.

Glossary of Terms Used in the Study

**Alga.** A primitive organism which uses sunlight in the process of photosynthesis to manufacture its food. The most common algae at Acadia Beach were sea lettuce (*Ulva sp.*) and rockweed (*Fucus sp.*).

**Amphipod.** (Phylum *Arthropoda*, Class *Crustacea*) A small crustacean which has two kinds of feet. Beach hoppers or sand fleas are a common type of amphipod at Acadia Beach. Both the small beach hopper (*Orchestria traskiana*) and the larger California beach hopper (*Orche ostioidea californiana*) were common on Acadia Beach.

**Appendage.** A leg, arm, and any other structure which projects from an organism's body.

**Arthropod.** (Phylum *Arthropoda*) An invertebrate with an exoskeleton and jointed legs. Crabs, shrimp, barnacles, and isopods were common arthropods of Acadia Beach.

**Barnacle.** (Phylum *Arthropoda*, Class *Crustacea*) A familiar crustacean of the intertidal zone that attaches itself to rocks, shells, and other hard surfaces. The small acorn barnacle (*Chthamalus dalli*) and common acorn barnacle (*Balanus glandula*) were residents of Acadia Beach. The giant acorn barnacle (*Balanus nubilus*) was discussed during the interviews.

**Barnacle Scar.** A white circular patch left behind when a barnacle is removed from its home base.

**Bivalve.** (Phylum *Mollusca*, Class *Pelecypoda*) A type of mollusc with two shells which are hinged at the umbo. Bivalves found on Acadia Beach included the Pacific or Japanese oyster (*Crassostrea gigas*) the Japanese little-neck clam (*Venerupis japonica*), edible blue mussels (*Mytilus edulis*), and the native little-neck clam (*Protothaca staminea*).

**Bryozoan.** (Phylum *Bryozoa*) Animals that live in colonies on rocks and kelp which are commonly referred to as moss animals. At Acadia Beach patches of bryozoans (*Eurystomella sp.*) were found on blades of bull kelp.

**Carapace.** The hard exoskeleton of crabs and shrimp. The carapace protects the body and backs of the organism from predators and desiccation.

**Cast-off.** Crabs shed their exoskeletons as they grow. The old exoskeleton, called a molt or cast-off, is discarded and washed ashore during storms and high tides. Some crabs eat their old exoskeleton for the calcium content.
Crab. (Phylum Arthropoda, Class Crustacea) An animal with a hard skeleton, four legs, and two pincers. The purple shore crab (Hemigrapsus nudus) and the green shore crab (Hemigrapsus oregonensis) were the most common crab species at Acadia Beach.

Crustacean. (Phylum Arthropoda, Class Crustacea) An aquatic animal with a hard exoskeleton, eight legs, two pincers, mouthparts, antennae, and eyes. Crabs, shrimp, amphipods, and barnacles were the most common crustaceans found on Acadia Beach.

Desiccation. Moisture loss due to exposure to air, extreme heat, or wind.

Dungeness Crab. (Cancer magister) A large edible crab which frequents sandy bottom environments and eelgrass beds. Though the mature Dungeness inhabits the subtidal zone its molt or cast off was a common find on Acadia Beach. The Dungeness crab was discussed during the interviews.

Echinoderm. (Phylum Echinodermata) Animals with spiny skin and radial symmetry. Sea urchins, seastars, sand dollars, and sea cucumbers are echinoderms. Echinoderms were not common at Acadia Beach.

Filter feeder. Organisms which feed by straining the water using hair, appendages, and other feeding apparatus.

Gastropod. (Phylum Mollusca, Class Gastropoda) An animal that travels on a large foot which it also uses for feeding. Limpets, snails and sea slugs were common gastropods of Acadia Beach.

Ghost shrimp. (Callianssa californiensis) A burrow dwelling shrimp which inhabits sandy beaches.

Goldeneye Duck. (Bucephala sp.) A gregarious sea duck which congregates in large rafts off the Pacific coast in winter. The common goldeneye (Bucephala clangula) and the Barrows goldeneye (Bucephala islandica) congregate in large rafts during the winter months off Acadia Beach.

Hermit Crab. (Phylum Arthropoda, Class Crustacea) A small crab that borrows a shell to protect its soft back and abdomen. The hairy hermit crab (Pagarus hirsutiusculus) and the granular hermit crab (Pagarus granosimanus) were both found on Acadia Beach.

Holdfast. The structure which anchors some species of marine algae to hard surfaces.

In-berry. A female crab carrying eggs.

Intertidal zone. The zone between high and low tides.
Isopod. (Phylum *Arthropoda*, Class *Crustacea*, Order *Isopoda*) A small, elongated crustacean with seven pairs of short legs which are equal in size. The rockweed isopod (*Idotea wosnesenskii*) and the pill bug (*Gnorimosphaeroma oregonensis*) were common amphipods of Acadia Beach.

Jet-set wildlife. A non-indigenous or alien species that is introduced to non-native environments either by accident or design. The Pacific oyster (*Crassostrea gigas*) and oyster drill (*Ocenebra japonica*) are examples of jet-set wildlife. I used this term to describe non-native wildlife during my work as a park naturalist.

Kelp. A brown marine alga anchored by a holdfast. Bull kelp (*Nereocystis luetkeana*) and sugar kelp (*Laminaria saccharina*) were common on Acadia Beach. The sugar kelp was discussed during the interviews.

Larva. The developmental stage which follows the egg in some animals’ lifecycles. In many cases the larva does not resemble the adult and is free swimming or planktonic.

Limpet. (Phylum *Mollusca*, Class *Gastropoda*) An animal with a muscular foot and hard conical shell usually found under rocks and in crevices and tidepools during low tide. The shield limpet (*Collisella pelta*) and the plate limpet (*Notoacmea scutum*) inhabited Acadia Beach. The unstable limpet (*Collisella instabilis*) was discussed during the interviews.

Littoral. The beach area between the lowest and highest tide levels. For the purpose of this study littoral is equivalent to intertidal.

Log-table. A flat log or round of wood which the students used to display their beach finds. Post field trip discussions were held around the log-table.

Mariculture. The farming of the sea through the controlled cultivation of fish, oysters, clams, and other aquatic species.

Mollusc. (Phylum *Mollusca*) A soft bodied and usually hard shelled animal. Oysters, clams, and limpets were common molluscs of Acadia Beach.

Moss Animals. See Bryozoan.

Mussel, Edible Blue. (*Mytilus edulis*) An edible, dark blue bivalve which attaches itself to rocks, wharves, and other hard surfaces.

Oyster. (Phylum *Mollusca*) An edible bivalve found attached to rocks and other hard surfaces. The native oyster (*Ostrea lurida*) and the Pacific or Japanese oyster (*Crassostrea gigas*) were residents of Acadia Beach. The Pacific oyster was discussed during the interviews.
Oystercatcher, Black. (*Haematopus bachmani*) A crow-sized black bird with a vibrant red beak. Oystercatchers patrol the shore looking for molluscs.

Nudibranch. (Phylum *Mollusca*, Class *Gastropoda*) An ocean going slug. The brown nudibranch (*Acanthodoris brunnea*) along with its egg ribbons were common under rocks during early spring at Acadia Beach.

Oyster drill. (*Ocenebra japonica*) A predatory whelk snail that bores through the shell of other molluscs using its radula and shell dissolving secretions.

Periwinkle. (Phylum *Mollusca*, Class *Gastropoda*) A small, dark coloured snail common in the high tide and spray zones. The checkered periwinkle (*Littorina scutulata*) and the sitka periwinkle (*Littorina sitkana*) were common inhabitants of Acadia Beach.

Pileated Woodpecker. (*Dryocopus pileatus*) A black, crow-sized woodpecker with a flaming red crest. A resident pair of pileated woodpeckers inhabited the woods adjacent to Acadia Beach.

Plankton. A group of organisms, both plant (phytoplankton) and animal (zooplankton), carried by water currents usually found in the upper layers of the ocean.

Radula. A rasp-like tongue structure used by snails to bore through shells and scrape food from the substrate.

Rockweed. (*Fucus sp.*) A common kelp found attached by a small holdfast to rocks and barnacles. The tips of fucus are filled with gas.

Sandworm. (*Nereis vexillosa*) A large colourful worm (Phylum *Annelida*) found under beach debris. Sandworms have powerful jaws which can produce a painful pinch.

Sea Gooseberry. (*Pleurobrachia bachei*) A harmless, grape-sized jellyfish often found stranded on sandbars at low tide.

Sea Star. (Phylum *Echinodermata*) Starfish are also known as sea stars. Sea stars have a central disc, arms, and tube feet which enable them to move and stick to surfaces. Sea Stars were not common on Acadia Beach.

Shipworm. (*Bankia setacea*) A clam which burrows into wood using its foot. The burrows are pencil sized and follow the grain of the wood.

Siphon. The structure used by the bivalve to take in and expel water for feeding and respiration.

Spat. The immature oyster or the young of any other bivalve mollusc. Oyster spat use chemoreceptors to help locate a permanent home.
**Stipe.** The stem-like structure of seaweeds and marine algae which is attached to a holdfast.

**Subtidal.** The area below the low tide water level.

**Tellen clam.** (*Tellina bodegensis*) A small clam found in sandy environments. Tellen clams were common on Acadia Beach.

**Umbo.** The bump on a bivalve’s hinge. The oldest part of the shell.

**Wave Shock.** The affect of wave action during storms and tidal flow.

**Velcro Bug.** See isopod.

**Univalve.** A one shelled mollusc. Limpets and snails are univalves.

**“Wow!” Discovery.** The *voyageurs* called “Wow!” when they wished to share an exciting beach find with their peers.
Chapter 2: Review of Literature

2.1 Introduction

"An Intertidal Voyage" is a case study which examines six students' developing understanding of the physical adaptations and survival behaviours of six intertidal organisms. The voyage consists of a series of field trips and interviews designed to encourage exploration and analysis of student knowledge. To set my study within the context of the current research literature I selected studies which represented my research focus and chose literature which investigates students' prior ideas, situated learning, language, marine education, and interview techniques.

The literature review begins with a description of constructivism and its role in defining how children use their previous knowledge to construct new ideas. As Elliot Eisner (1991) suggests, "human knowledge is a constructed form of experiences and therefore a reflection of the mind and nature. Knowledge is made not simply discovered" (p. 7).

I found the theory of situated learning a natural progression from constructivism as it focuses on the creation of knowledge in a social context. In this study the children assumed the role of the cognitive apprentice, and I became the guide, the facilitator, who introduced the voyageurs to the situated learning activity, exploring the seashore (Hennessy, 1993).

I discovered that the children's use of analogies and metaphor represented their understanding of intertidal organisms. Dewey (1934) believed that "science states
meaning. Art expresses them”. I perceive the children’s language to be an artistic interpretation of their scientific knowledge.

The literature on marine education by Snively (1988, 1989a, 1989b) and Fortner and Mayer (1989) reflected the need for studies like “An Intertidal Voyage” in the educational curriculum as they provide insight into marine related issues such as water pollution and habitat conservation.

I studied Osborne and Freyberg’s (1985) and Bell’s (1993) research on interview techniques to help establish my role in the student interviews. My interview questions explored student understanding and language and were based on the students’ orientations of aesthete, scientist, and utilitarian (Snively, 1986).

2.2 Constructivism

“World making as we know it always starts from worlds already on hand. The making is remaking” (Schwandt, 1994, p. 126). During my course work in Science Education I became acquainted with constructivism. I wished to incorporate constructivist theory in my study as I believe that learners create knowledge by building upon their previous experiences. My own experiences as a student, educator, and beachcomber confirms the choice of constructivist research as a theoretical basis for “An Intertidal Voyage”. As the study evolved it was evident the children brought their personal seashore knowledge to the learning. They created new concepts and ideas by using their existing knowledge as “building blocks” or “bridges” to new ideas (Driver and Erickson, 1983, Hennessy, 1993).
As in many qualitative studies “An Intertidal Voyage” seeks “to understand participants’ viewpoints, not to predict student behaviour” (Shapiro, 1994, p. 22). In her book “What Children Bring to Light”, Shapiro (1994) states that “knowledge is a construction of the human mind” (p. 3). Her ideographic research philosophy advocates using childrens’ existing beliefs and ideas as a framework to interpret their understandings of newly acquired experiences. Through “An Intertidal Voyage” I explored the childrens’ previous seashore knowledge during interviews, personal observations, and conversations. The observations and experiences which the children selected to discuss had personal meaning to them and were not “a mere collection of fact upon fact” (p. 5).

During the study I examined the influence of the children’s backgrounds upon their learning which was evident in their seashore knowledge and related language. Constructivist philosophy states that children’s backgrounds and personal experiences affect their interpretation of natural phenomena (Driver, Guesne, & Tiberghian, 1985). Snively (1986) also claims that children’s ideas concerning natural phenomena are intuitive in the sense that children create their own interpretation of the natural world. Driver and Erickson (1983) discuss children’s science learning in relation to “their interpretations and sensory impressions” and state that childrens’ personal experiences and cultural background affect their response and understanding of science knowledge. Shapiro (1994) concludes that “we learn not from experiences but from the reconstruing of experience ... from the way in which we reflect upon the experience” (p. 35).
2.3 Situated Cognition and Cognitive Apprenticeship

During my research I found that the theory of situated cognition was a natural progression from constructivism as constructivist theory incorporates the concept of situated learning. Hennessy (1993) defines situated cognition as a theoretical framework which recognizes "the critical role of the social and physical circumstances in which actions are situated" (p. 2). Learning becomes a "culturally organized activity ... a process of enculturation or individual participation in socially organized practises, through which specialized local knowledge, rituals, practises, and vocabulary are developed" (p. 2). Student knowledge develops as a result of shared experiences which Brown, Collins, and Duguid (1989) define as knowledge that "is situated, being a product of the activity, context, and culture in which it is developed and used" (p. 32). In "An Intertidal Voyage" exploring the seashore was the "culturally organized activity", and the students' experiences, observations, and related language comprised the knowledge, rituals, and practises of the situated learning activity.

Situated cognition encompasses the concept of cognitive apprenticeship in which the learner shares the cognitive process with a guide or facilitator. Through modelling and coaching the facilitator helps the learner "to develop an appropriate notation and conceptual framework for a new or complex domain" (Hennessy, 1993, p. 11). I assumed the facilitator or tutor role during the study as I introduced the children to the various intertidal organisms and guided group discussions on adaptations and survival strategies, organism life histories, and other "neat" intertidal facts. I modelled appropriate
beach etiquette which included returning all rocks and organisms to their “home spot” and practising the no-collecting rule.

Scribner and Cole (1973) state that modelling is an integral component of informal learning. Schön (1989) emphasizes the important role of the teacher or facilitator in encouraging students “to build on what they already know” (p. 19). Through reflective teaching students are guided through the creation and articulation of their knowledge. The teacher’s “expertise is in knowing not to be an expert” (Horton and Freire, 1990, p. 128).

As the field trips progressed and the childrens’ knowledge developed I withdrew my help gradually allowing the students to make their own discoveries and have “control over their own learning process and the confidence to engage in critical analysis” (Hennessy, 1993, p. 12). My role became that of the “guide by the side” (Baron, 1993).

2.4 Student Language

“Our conceptions of reality are linguistic.” (Eisner, 1978).

Gregory Bateson (1991) wrote that language is “the most beautiful and elegant tool we are provided with” (p. 284). Throughout this study I documented and analyzed the students’ language in order to investigate the construction and progression of their seashore knowledge.

Lave and Wenger (1991) state that language is central to both constructivist and situated learning theories. They perceive language analysis as a method of interpreting human understanding. Ortony (1993) agrees that “the constructivist approach seems to
entail an important role for metaphor in both language and thought” (p. 2). A similar link between constructivism and language is forged by Sticht (1993) who describes the role of metaphor in “providing a meaningful and functional context for acquiring new knowledge by means of old knowledge” (p. 622). Snively (1995) also acknowledges the relationship between constructivism and language by observing that “we link new knowledge with prior knowledge through language” (p. 59). She states that all humans think metaphorically and “their metaphorical constructs are built up over time as part of a collective way of making sense of experience” (p. 59).

Lave and Wenger (1991) claim that students form a community of learners during situated learning experiences. Initially the students prefer to explore on their own but eventually communicate their knowledge to others by assuming a teaching role (Carlisle, 1985). During “An Intertidal Voyage” this exchange of knowledge occurred during conversations generated by group exploration and discussion. As the study progressed the students became educational connoisseurs which Eisner (1995) defines as learners who “not only watch and see, they talk, they listen” (p. 81). In their work on student understanding White and Gunstone (1992) also confirm the importance of conversation in the formulation of student ideas.

Lave and Wenger (1991) discuss the role of language in situated learning. They define language as “learning to talk” not learning “from talk” as it consists of stories, lore, and an exchange of ideas. In their work on language Lave and Wenger refer to the social community of learners as a “community of practise” (p. 3). In “An Intertidal Voyage” student involvement in group exploration, conversation, and the log-table discussions
formed a community of practise. As the students exchanged ideas they employed storying, "constructing stories in the mind" (Wells, 1986, p. 194), as a method of conveying their knowledge.

"The way we think. What we experience and what we do every day is very much a matter of metaphor" (Lakoff and Johnson, 1980, p. 3). Lakoff and Johnson (1980) define metaphor as using one "kind of thing" as a guide to understand and interpret another. They label the viewing of new knowledge through the lens of past experiences as metaphorical projection. In their study on metaphor Lakoff and Johnson expand the traditional linguistic interpretation of metaphor by moving it beyond words and into the "very concept of an argument" (p. 42). They believe that through language and metaphor analysis researchers can determine the extent of students' prior knowledge and experiences. Lakoff and Johnson define metaphors that interpret, comprehend, and describe experience as a sixth sense that enables students to perceive and experience the world. I interpreted Lakoff and Johnson's view of metaphor as a window into student thought as it highlights the importance of language in the creation of knowledge.

Schön (1993) agrees that metaphor is integral to learning as it "is central to how we think about things, make sense of reality, set the problems we later try to solve" (p. 640). Mayer (1993) believes that metaphor is integral to student understanding and learning as "metaphor improves conceptual recall and problem solving transfer" (p. 572). He concludes that a student's chosen metaphor influences the outcome of their learning. Gallas (1994) contends that through metaphorical language students progress to a more sophisticated level of understanding.
The students' metaphorical language enabled me to gain a greater understanding and interpretation of their seashore knowledge. I observed that the students used metaphor to "unite reason and imagination" (Lakoff and Johnson, 1980) which helped them to create and express their seashore knowledge.

During the study I observed that the students often used metaphor rather than scientific language and theories to express their seashore knowledge. In his study of the relationship between science and metaphor Lakoff (1993) states that as metaphor is more conceptual than linguistic it can be used in both science teaching and learning. Boyd (1993) believes that metaphors are a fundamental part of science as they often provide "an irreplaceable part of the linguistic machinery of scientific theory" (p. 483). Kuhn (1993) agrees that metaphor is integral to science learning as it connects "scientific language with the world" (p. 539). Students use metaphors in the form of analogies to understand science as scientific language is often "a source of confusion" (p. 540).

Mayer (1993) agrees that through metaphor students will better understand scientific descriptions and explanations. He states that the qualitative reasoning of metaphor precedes the quantitative in "successful scientific problem solving" (p. 570), and that the students' chosen metaphors influenced their learning outcomes. The incomplete role of quantitative reasoning in science is described by Bateson (1979) who believed that "logic and quantity turn out to be inappropriate devices for describing organisms and their interactions and internal organization" (p. 20). He concluded that "logic and linguistics should work on a common mass of data" (1991, p. 231).
Gentner and Jeziorski (1993) also observe that “analogy and metaphor are central to scientific thought” (p. 447). They believe that by transferring or “mapping” their knowledge through metaphor students use their previous or “base” knowledge to reach their “target” knowledge. Snively (1995) also acknowledges the relationship between metaphor and science as she states that “all scientific systems build knowledge on a framework of metaphor” (p. 59).

During the study the students used their previous seashore knowledge as a foundation for their choice of metaphor. Oshlag and Petrie (1993) state that for students to be able to employ metaphor in their explanations there must be some basic knowledge of the subject matter. Metaphor involves both the learner and educator as it “draws from the shared experiences of teacher and student” (p. 603). The link between metaphor and instruction is acknowledged by Oshlag and Petrie as they observed that students are more capable of comprehending difficult concepts when teachers use metaphor and analogy to convey meaning. In their study of language, Oshlag and Petrie conclude that metaphor makes learning more memorable as it uses the familiar as a guide to the new.

I was elated to discover the work of Gloria Snively (1986, 1995) as her research on metaphor emphasizes the importance of language in student learning. She believes that metaphor can “highlight specific concepts associated with beach ecology” (1986, p. 31) and “give new meaning to the students’ understanding of seashore life” (p. 79). She claims that students use everyday experiences and their social and cultural knowledge in their metaphors. As metaphor is a part of every day reality, it will effect how the students “think, perceive, and act” (1986, p. 24).
In her study “Sea of Images” (1986), Snively identified five specific orientations which the students used in their description and explanation of seashore knowledge. Within each orientation or “interpretive framework” is a set of beliefs and values specific to the individual. She designed “instructional metaphors that would be consistent with the students’ orientations toward the seashore” and investigated the students’ use of metaphor in their descriptions of seashore life” (p. 31). During “An Intertidal Voyage” the students’ language revealed orientations which directed their interpretation and expression of their seashore knowledge. For the purpose of this study orientations are defined as styles of knowing and are patterned after Snively’s aesthete, scientist, and utilitarian.1

2.5 Marine Education

During my search for marine education literature I discovered a plethora of informative field guides and engaging marine biology units. From the publications which outlined the vital role of marine education in the classroom I chose to examine the literature which I thought best represented the marine education component of “An Intertidal Voyage”. Fortner and Mayer (1989) define marine education as an educational process which enables people to develop understanding and sensitivity to the important role of aquatic environments in their world and creates awareness of the human impact on seas and oceans. Melear (1995) agrees that marine education fulfills an important goal of science teaching as it illustrates how science and societal issues overlap

1 I changed Snively’s utilitarian orientation to the warrior as the practical voyageurs of this study saw the seashore as a battlefield.
Fortner and Teates (1980) describe marine education as an important issue that is given either a perfunctory study or completely ignored in the classroom. Their work outlines a marine education programme that incorporates all “facets of the oceanic environment and its influence on human affairs” (p. 12). Their ideal curriculum includes an interdisciplinary investigation of the marine environment including history, the arts, literature, and language. Fortner and Teats conclude that a marine educational experience would provide the learners with a sense of environmental stewardship and an overall appreciation of the marine environment resulting in an enlightened and “informed citizenry” (p. 19).

Additional studies state the importance of environmental education programmes in the schools. Walter and Lien (1985) report that students garner an appreciation for the marine environment through direct experience. They conclude that beach field trips foster a positive student attitude toward the marine environment. McLaren (1995) adds that environmental education programmes demonstrate the affect of the students’ personal actions on their environment. One method of ensuring the success of an environmental education programme is through the training of pre-service teachers (Robertson, 1995) and graduate courses for in-service teachers (Melear, 1995).

Snively’s (1988, 1989a, 1989b) findings support those of Fortner and Teates (1980). Snively states that “the goals of any marine and aquatic education program must, at bottom, be a better understanding of fundamental value issues and how to deal with them.” (1989a, p. 99). She believes that marine education is a harbinger of human awareness of the world’s connection with water. Snively recommends that marine
education become an integral part of the school curriculum as the ocean and its coastlines are important to the well-being of British Columbians. The study of marine related issues is relevant and meaningful to Canadian students as many live near some of the world's most fascinating and varied coastlines. Snively envisions a school curriculum which involves a variety of topical issues including acid rain, fisheries and resource management, stewardship, and also investigates the advances in the science and technologies involved in aquatic exploration.

2.6 The Interview

"The ultimate aim of the interviewer is to put the person at ease." (Eisner, 1991, p. 183). Eisner (1991) describes the interview as "a powerful resource for learning how people perceive situations in which they work." (p. 81). Interviews played an extensive role in "An Intertidal Voyage" as they were a vehicle for the representation of student knowledge and their metaphorical language. The following interview literature comprises the theoretical foundation I selected for "The Intertidal Voyage".

Osborne and Freyberg (1985) point out that interviews are not designed to illicit the extent of the students' acceptable scientific knowledge. They are rather a reflection of all aspects of student thought. Osborne and Freyberg (1985) describe two types of interviews which encourage student response. The "interview about instances" (p. 6) explores the children's interpretation of a specific object. As the children's ideas unfold, the interviewer "attempts to establish reasons for the response" (p. 6). Osborne and Freyberg also describe the "interview about events" which explores the "children's views
of everyday phenomena" (p. 8). This event interview is more “flexible” as it enables the children to discuss their personal experiences.

The work of Brenda Beck introduced the concept of the metaphor interview (cited by Snively, 1986). Beck advocates interview questions which expand upon and define metaphor. During the interviews in “An Intertidal Voyage” I identified the students’ orientations through their language. Using Beck’s metaphor interview as a guide I modified my questions to encourage the students to extend their preferred orientation of either scientist, aesthete, or warrior.

Though Beck’s work with children concentrates primarily on the child-family relationship, Snively indicates that the metaphor interview can examine “student-seashore relationships” and “student-science relationships” (1986). In her work on metaphor Snively designed an interview which charts the students’ relationship with the seashore in terms of their beliefs, values, and orientations.

Bell (1993) outlines a comprehensive list of interview questions designed to encourage student thought and participation. These open-ended questions or “viewfinders” probe student understanding rather than elicit objective yes or no answers. Bell, Osborne, and Tasker (1985) advise that the interviewer know what to ask and when to ask it. During the interviews I asked questions which were easy, neutral, and penetrating to ensure success in determining the students’ seashore knowledge.
2.7 Summary

"Seeing rather than looking requires an enlightened eye" (Eisner, 1991, p. 1). The literature cited in this review acted as my guide as I experienced "An Intertidal Voyage" alongside the students. I focused my research using literature which delved into constructivism, situated cognition, cognitive apprenticeship, metaphor, marine education, and interview techniques.
Chapter 3: Study Design and Methodology

3.1 The Research Questions

This study examines six children's understanding of the physical adaptations and survival behaviours of six intertidal animals. Three research questions guided the study.

1. How does student knowledge change as they proceed through the three sets of field trips and the three interview sessions?

2. How do students use language to construct and explain their seashore knowledge?

3. What implications for classroom teaching can be drawn from the understandings gained in this study?

3.2 Introduction

I completed this study while attending the University of British Columbia as a full time graduate student in Curriculum and Instructional Studies. As part of my course work I accompanied a class of grade 4/5 students on their weekly excursions to the beach. I was introduced to the students as a fellow seashore enthusiast. The children were aware of my background as a marine educator and initially regarded me as an intertidal tour guide. Eventually I lost the expert label and became a regular member of the crew. Our exploration of the seashore, the resultant experiences, and the students' developing knowledge of the intertidal zone evolved to form the basis of "An Intertidal Voyage".

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1 For the purpose of this study the word How is defined as In what ways.
3.3 The School: Oceanview Elementary

Oceanview Elementary provided an interesting crew for "An Intertidal Voyage". The school is located on the outskirts of the campus of the University of British Columbia, and as a result many of the students' parents are studying at or employed by the university. As in most Vancouver schools, a variety of ethnic backgrounds are represented within the student body, and the school's location also results in socio-economic diversity. It is officially designated an inner-city school, yet it is located in one of Vancouver's more affluent neighbourhoods.

3.4 The Researcher's Role as Participant Observer

During the field trips I was considered a member of the "crew". My role as a participant observer allowed me to experience the "Wow!" discoveries alongside the students. I was able to convey to the children that I was not the "expert", and that everyone's observation was valid. The establishment of this non-hierarchical relationship was important to the outcome of the field trips and interviews. The children were encouraged to make their own discoveries and conclusions without the aid of an authoritative individual who held all the answers. My role was that of the "guide by the side" rather than the "sage on the stage" (Baron, 1993).

I was able to design and implement this beach study due to a lifelong passion for the marine environment. My experience as an informal educator with British Columbia Parks and the Vancouver Aquarium was also a factor in my judgement of the quality and quantity of knowledge available to the children. Prior to the study I joined the children on
their weekly beach trips, participated in seashore-related discussions, and introduced class projects related to the marine environment. The children augmented their seashore knowledge during family excursions to the Vancouver Aquarium and local beaches. The participants began the study with a burgeoning interest and some basic knowledge of the marine environment and its inhabitants.

Snively (1986) discussed the influence of observer bias in studies involving participant observation and interview techniques. I found similar limitations in my study during the field trips and interviews. It was not always possible to ask the same questions in each interview as each child’s unique set of responses influenced the course of further questioning. Also as an avid beachcomber and experienced marine educator I was enthusiastic about the study. My behaviour can be interpreted as a form of modelling as described by Hennessy (1993) in her work on cognitive apprenticeship. I assumed the role of "the competent other person, the tutor" (p. 12) which Hennessy stated as being vital to the process of cognitive apprenticeship. I "modelled" the behaviour which I wished the children to emulate. During the beach trips I became the investigator, the observer, the "guide by the side" (Baron, 1993). The field trips were the "authentic activity" and our investigation of the intertidal organisms’ adaptation and survival strategies became the "problem solving activity" (Hennessy, 1993, p. 15). Eisner (1991) also believed that it is imperative that the researcher have a thorough understanding and keen interest in the study and that personal involvement on the part of the qualitative researcher places a unique signature on the work.
3.5  The Classroom Teacher: Claire

I was introduced to Claire, a teacher at the research school, by my thesis advisor. Claire had a keen interest in marine education and invited me to accompany her class on their trips to the local seashore. These weekly jaunts began by my joining the class as a resource person and became a regular addition to the Friday morning routine. Throughout the year we experienced and discussed the natural changes in the local beach and forest ecosystems. Our discussion topics covered a variety of themes ranging from terrestrial slugs to sea squirts. Claire and I met periodically to discuss the science curriculum and possible links to our “Beach Days”. Due to Claire’s expertise as an educator and her enthusiasm and willingness to incorporate new ideas into her science programme, the concept of documenting our beach study evolved naturally through our work together. As an experienced educator Claire was dedicated to the promotion of science education both within and outside the classroom. Her co-operation and enthusiasm facilitated the progress of the study.

3.6  Selection of Students

The research school’s proximity to the campus of a large, urban university ensured a particularly knowledgeable and articulate student body, and many of the parents were students and educators. The research site (Acadia Beach) was a twenty minute walk from the school grounds making it a popular destination for school field trips and class picnics. As a result the students were familiar with the seashore and its inhabitants. The children were also richly experienced in their exposure to literature, computer studies, family
excursions to the Vancouver Aquarium and local beaches, and marine biology related videos and television programmes.

Claire's grade 4/5 class was comprised of an energetic, thoughtful, and knowledgeable group of students. It was an arduous task selecting only six children from this articulate and knowledgeable class. During the course of our shared beach experiences, I was able to personally observe each child and selected the following students as the intertidal voyageurs of this study.

I became well acquainted with Dan as he was often my partner for the walk to the beach. I was impressed with his extensive knowledge of natural history which he acquired from books, the Internet, television programmes, and trips to the Vancouver Aquarium and local beaches. I knew that Dan enjoyed discussing his seashore knowledge, and he would be an enthusiastic and articulate voyageur.

I selected Cathy as a study participant as she combined scientific knowledge with practical information. When I chatted with her during the beach walks she expressed an interest in the physiology and life histories of the organisms as well as their "edibility factor".

Nancy displayed an interest in the creative aspects of the intertidal zone. She always selected the most colourful and interestingly shaped organisms for her log-table discussion. I chose Nancy as a study participant for her artistic interpretation of the seashore.
Rod's boisterous behaviour during the beach walks often obscured his interest in the intertidal organisms. I selected Rod as a *voyageur* as I wished to give him the opportunity to express his developing seashore knowledge.

Andy's quiet interest in the seashore made him an interesting study participant. He was a great intertidal detective and had a talent for discovering the most secretive organisms. Rather than being a vocal participant in the log-table discussions Andy preferred to simply observe. I selected Andy as a *voyageur* as his participation in the study would give him the opportunity to voice his seashore knowledge.

I selected Hannah as a study participant for her gift of story telling. Her description of seashore life contained wonderful analogies comparing the intertidal inhabitants to her own world. Hannah's sense of humour and gregarious nature made her an engaging study participant.

All the students exhibited a keen interest in the marine environment and were eager to discuss their experiences and observations. In addition to the above mentioned qualities the participants were also chosen through collaboration with their classroom teacher based on the following criteria; the students:

- were articulate,
- displayed an enthusiastic interest in the marine environment,
- were native speakers of English,
- were representative of both the creative and the scientific mind,
- enjoyed expressing their ideas to others, and
- demonstrated collaborative behaviour.
As the data collected in this study was a verbal representation of knowing it was important for Claire and myself to select children who were articulate, had an extensive vocabulary, and were comfortable conversing with both adults and children. We decided that as boys and girls have different knowledge and interpretations of organisms it was important to select three boys and three girls as study participants.

The children knew me well as we had embarked upon our "Intertidal Voyage" together at the beginning of the school year. Some of the students had worked with me during the previous year in Claire's grade 3/4 class. This familiarity may have influenced the childrens' responses during the interviews, but it was not seen as a limiting factor.

3.7 Overview of the Research Methodology

I gathered data from three interviews and nine field trips which comprise the events of this study. The study began with the first interview. Four field trips followed the first interview, two more field trips followed the second interview, and three field trips took place after the third interview. The first interview assessed the students' pre-field trip seashore knowledge. The second and third interviews recorded changes in student knowledge.

During the field trips I acted as a participant observer recording data through field notes. The field notes were comprised of student conversations and behaviours and my own personal observations and reflections. The forest walk, "Wow!" discoveries, and the log-table discussions were an important source of field trip data. The forest walk took place as the students walked a wooded trail to Acadia Beach. The "Wow!" discovery was
an exciting or unusual organism discovered by one of the students. To encourage classmates to investigate their find the student yelled “Wow!”. The log-table discussion was the group talk which followed the beach walk. The students gathered at a beach log to discuss their findings and to ask and answer questions.

The interviews took place in a vacant classroom at the students’ school. During the interview session I placed myself beside the student at a small round table and presented examples of the six intertidal organisms outlined in this chapter. The data were recorded through a video tape of the interview which was later transcribed on my computer data base. A colleague was present during the interviews to help with the videotaping, provide feedback and act as a form of member checking.

3.8 Overview of the Case Study

"An Intertidal Voyage" is a qualitative case study based on the work of Lincoln and Guba (1985), Snively (1986), and Eisner (1991). Snively investigated students’ use of metaphor in describing their understanding of the seashore. She defined five orientations or “frameworks” through which the students interpreted their seashore knowledge. I adapted Snively’s scientific orientation to represent Dan’s and Cathy’s scientific style of knowing and Snively’s aesthetic orientation to represent Nancy’s and Hannah’s aesthetic style of knowing. I modified Snively’s utilitarian orientation to represent Rod and Andy’s warrior style of knowing. I documented the students’ language and their styles of knowing through personal communication, group conversations generated during field trips, and interviews.
Eisner's (1991) concept of “productive serendipity” (p. 241) defines the nature of this case study. The study’s emergent data were comprised of the students’ changing knowledge and their descriptive language. The study’s findings could not be predicted as the data emerged as the study unfolded.

My goal was to create a field focused and non-manipulative study (Eisner, 1991). I participated in and developed work which was ongoing with the class. The students’ knowledge was acquired while exploring the seashore, and their language was expressed during informal group discussions, in the classroom, and personal interviews.

Geertz (1973) refers to the “thick description” which is characteristic of the qualitative study. Rather than investigating the superficial aspects or the biological description and classification of the six intertidal organisms I penetrated the surface to discover the “interpretive character” (Eisner, 1991, p. 32) of the students’ understanding.

I felt compelled to write “An Intertidal Voyage” in my own voice as I wish to weave a sense of humanity and empathy into the study. Eisner (1991) refers to the use of descriptive language and the presence of voice in a qualitative study as the researcher’s signature. My goal was to create a signature which reflects a great love of the seashore and a desire to guide others to an appreciation of its beauty, diversity, and importance.

3.9 The Interview Setting

A portable classroom at Oceanview Elementary was selected as the interview room. This site was chosen for the three sets of interviews as it:

- was located next door to the students’ classroom allowing for safe and convenient access,
was vacant in the afternoons enabling the interviews to proceed without interruption and allowing time for set up of audio visual equipment, and

- was located in an area which was separate from other students and teachers providing non-disruptive interview sessions.

3.10 The Beach Setting

The field trips were conducted at Acadia Beach, located in Point Grey, Vancouver, British Columbia, which is easily accessed by a forest path which originates from the school grounds. Acadia Beach is a mecca for local beachcombers, dog walkers, and wind surfers. The students are familiar with this beach as it has been a convenient location for end of the school year picnics and field trips. Acadia beach was selected for the research site as it:

- was in close proximity to the school,

- provided on site washroom facilities,

- included an intertidal area which was located a distance away from the road providing a safe environment for investigation and observation,

- was home to intertidal species as well as a number of birds and marine mammals which created a diverse ecosystem for the children to observe and experience (e.g.: loons, sandpipers, eagles, seals),

- was accessed by a beach/forest trail which introduced the children to a local forest ecosystem which exhibited a variety of plants and animals to observe and investigate,

- had a rocky seashore habitat as well as a sandy beach area providing a rich environment for plant and animal life (e.g.: marine algae, oysters, barnacles, limpets, shore crabs, etc.),

- had resident purple and green shore crabs which increased the opportunity for the children to observe the adaptation and survival strategies of these animals,

- had Dungeness crab cast-offs which enabled the children to examine a larger crab species not usually encountered intertidally,
- encompassed a shoreline which bordered Vancouver Harbour presenting the children with possible threats to the intertidal community (e.g.: freighters, pleasure craft, industrial use of the harbour, pollution), and

- was used by fishers which resulted in interesting beach finds (e.g.: dead fish).

Acadia Beach is an ideal location for the research site as the diverse intertidal area is representative of local marine environments. The setting was familiar to the students, and they were comfortable exploring and investigating its living and non-living treasures. This natural learning environment encouraged the children to bring their own interests and prior beach experiences to the study.

3.11 The Six Intertidal Organisms

Wherever land and sea meet, along a sandy beach, against a rocky shore, across a mud flat or at the edge of a coral reef, a weird and wondrous array of plants and animals exists in a turbulent world that can be breathtakingly beautiful and at the same time, unyieldingly harsh (Carson, 1955).

The following intertidal organisms were chosen for interview discussion.

3.11.1 The Dungeness Crab (Cancer magister)

This animal was chosen due to its familiar presence and its unique adaptation and survival strategies. I selected the Dungeness crab species as it was larger than the purple and green shore crabs. The crab selected for interview discussion was a cast-off skeleton.
During the molt the crab sheds its entire exoskeleton, eye sockets and all. The children were familiar with these cast-offs as they were a common sight on our beach. Dungeness cast-offs were readily accessible during the early spring.

I hoped the sight and touch of the Dungeness crab would trigger the children's interest in the crustacean's fascinating adaptation and survival strategies. During our field trips we discussed the crab's:

- cast-off phenomenon,
- ability to regenerate lost limbs,
- sexual dimorphism,
- mating and breeding behaviour,
- protective devices (e.g.: exoskeleton, pincers, camouflage, aggression, locomotion),
- life cycle,
- habitat,
- enemies, and
- feeding strategies and prey.

3.11.2 Sugar Kelp (*Laminaria saccharina*)

As marine algae was a mainstay of our beach finds it was a natural choice for interview discussions. We encountered a variety of alga species including bull kelp, sea lettuce, and fucus. The sugar kelp was chosen as the algal representative in the interviews as it was a mini version of the larger bull kelp which had fascinated the children. We had examined this seasonal brown algae with its long stipe and glossy floating bulb during the kelp die-off in the fall. The sugar kelp sports a rippled fan-like blade with a sinewy holdfast which anchors the entire structure to a small rock. We discussed this common brown alga in terms of:

- camouflage,
- the holdfast's role as an anchor in wave-washed environments,
- survival needs (e.g.: light),
- growth rate,
• the lack of a root structure,
• the comparison between alga and animal,
• reproduction,
• ability to avoid dehydration,
• life cycle,
• habitat, and
• enemies (e.g.: sea urchins).

3.11.3 The Pacific Oyster (Crassostreas gigas)

During the bleak winter months the steadfast Pacific oyster (Crassostrea gigas) was often our only beach find. The children had christened it “old faithful”. The oyster’s availability and its aesthetic and scientific qualities made it a natural beach find for interview discussion. I selected two examples for interview discussion. The first oyster had molded its lower shell onto a small rock. The other was a partially opened specimen exhibiting the pearlized colours and qualities of this lustrous bivalve. Adaptation and survival strategies which we discussed included:

• camouflage,
• oyster “glue” which enables the shell to adhere permanently to surfaces,
• the oyster shell’s role as protection against predators and dehydration,
• indigenous and non-indigenous species,
• life cycle,
• habitat, and
• enemies (e.g.: oyster drill, man).

3.11.4 The Unstable Limpet (Collisella instabilis)

The limpet was a common sight on Acadia Beach. The children soon learned they had to be good detectives to discover this crevice dwelling gastropod. I chose the unstable limpet for the interviews as it was a different shape than the Acadia Beach native, the shield limpet (Acmaea pelta). I was interested in seeing if children would detect the
strange “squished” appearance of this limpet as being a field mark of a different species rather than a freak of nature. We discussed the following list of limpet survival and adaptation strategies:

- camouflage,
- the animal’s ability to adhere to surfaces using its foot as a suction cup,
- the shell’s role as a protective device,
- life cycle,
- habitat,
- enemies (e.g.: oyster catcher), and
- feeding strategies and prey.

3.11.5 The Giant Acorn Barnacle (*Balanus nubilus*)

Few beachcombers are cognizant of the fascinating animals which inhabit these sharp peaked mini-mountains, yet Acadia Beach is home to hundreds of small acorn barnacles. The giant acorn barnacle, a stunning representative of the phylum arthropoda, was selected for the interviews. Its large size and obvious barnacle characteristics allowed for extensive discussion of this crustacean’s adaptation and survival strategies. Field trip observations of the acorn barnacle highlighted the animal’s:

- camouflage,
- shell as a protective device,
- ability to “glue” itself to its home,
- relationship to crabs,
- life cycle,
- habitat,
- enemies, and
- feeding strategies and prey.
3.11.6 The Flat Fish (*Lepidopsetta bilineata*)

Few fish are encountered in the intertidal area, yet their unique adaptations make them an intriguing study. One crisp and sunny beach day we were fortunate to discover half a starry flounder among the tide line detritus. Though the fish was missing some body parts it was possible to examine the animal's unique "sideways" mouth and flattened body. The children were fascinated by this strange looking fish and christened the starry flounder the "catch of the day". A similar species, the rock sole, was our interview fish as the starry flounder is not a commercially viable species and cannot be easily located in stores.

Topics for discussion included:

- habitat, camouflage,
- the migrating eye,
- the flounder’s transformation from "normal" fish to flat,
- habitat,
- enemies, and
- feeding strategies and prey.

3.12 Sequence of Events

The qualitative data for "An Intertidal Voyage" were gathered during a series of events which took place over the months of February through June of 1996. The information was collected during three sets of interviews and nine field trips. Each of the interviews was audio/video taped. The children became intertidal *voyageurs* as they experienced the following events.
3.12.1 Event 1: The Three Interviews

The first set of individual interviews was scheduled prior to the introductory beach field trips. A portable classroom adjoining the student’s home room was the interview site. Each child was seated at a small table while I explained the interview process and videotaping procedure. The interview commenced with a casual chat about our beach trips. As I presented the student with the first organism, the Dungeness crab (*Cancer magister*), I urged them to “just talk” and say what they knew about this animal. A series of open ended questions designed to probe the student’s prior knowledge followed the crab’s introduction. The students were then asked to comment on the sugar kelp (*Laminaria saccharina*), the Pacific oyster (*Crassostreas gigas*), the unstable limpet (*Collisella instabilis*), the giant acorn barnacle (*Balanus nubilus*), and the rock sole (*Lepidopsetta bilineata*). A colleague was also present during the interviews to help with the video equipment, to provide feedback for later discussion, and as a form of member checking.

The purpose of the initial interviews was to determine the students’ prior knowledge concerning the six intertidal organisms. Their observations and explanations provided a base from which to document the progress of the learning as the voyageurs continued upon their intertidal voyage.

For the second interview, each student returned to the neighbouring school portable. The questions and probes focused on the topic of new learning during the recent field trips. The same organisms from the first interview session were the topic of discussion.
The third interview took place during the final month of the school year. The interview questions were designed to assess the students’ cumulative knowledge and any changes which may have occurred since the first and second interview. I also encouraged the students to express their personal ideas of the intertidal organisms including their favourite inhabitant and who they would “most like to be”. The same six organisms examined in the first two interviews were discussed in the final interview.

3.12.2 Event 2: The Nine Field Trips

The children participated in nine field trips during the study. Field trips one through four followed the first interview. Field trips five and six occurred after the second interview. Field trips seven, eight, and nine took place after the third interview.

The purpose of the field trips was to introduce the students to the intertidal zone. Each trip was unique as the changing tides and seasons revealed a diverse group of organisms. The final field trip enabled the students to apply their newly acquired beach knowledge by acting as facilitators for a kindergarten class who accompanied them. The field trips took place on Friday mornings from 9:00 a.m. to 10:30 a.m. over a four month period.

Each of the field trips was given a title which describes the beach discoveries of that particular day. I wrote a detailed account of each of the nine field trips and then summarized the events as follows. The first field trip was referred to by the children as the Tiny Day as the tiny organisms encountered included immature shore crabs, limpets, and clams. The highlight of the second beach trip, Oyster Day, was an abundance of Pacific
oysters. The third field trip was christened Petrified Day as the “Wow!” discoveries included mountains of crab exoskeletons and a “petrified” duck skeleton complete with razor edged bill and webbed feet. On the fourth field trip, Blustery Day, the students were fascinated by colourful boardsailors riding the waves. During the fifth field trip, Crabby Day, a low tide revealed an abundance of purple and green shore crabs. The sixth field trip, Spring Day, included egg-carrying shore crabs. During the seventh field trip, Exploding Isopod Day, the “Wow!” discovery was a female isopod or “velcro bug” carrying a brood of miniature isopods under her abdominal flaps. The eighth field trip, Pileated Day, was named after the large red crested pileated woodpecker which was glimpsed during the walk to the beach. During the ninth and final field trip, Teaching Day, the voyageurs buddied with a kindergarten class acting as intertidal zone tour guides. A complete description of the nine field trips is presented in Appendix D.

The Latin names of the organisms encountered during the field trips are recorded in Table 1.

3.13 Data Analysis

Data were recorded during the study’s two events, the interviews and the field trips. Each interview was recorded with a video camera and an extension microphone which improved the audio portion of the video tape. At the end of each interview I recorded in a notebook my personal observations and reflections concerning the students’ knowledge and behaviour and included examples of their descriptive language. From each video tape I transcribed the verbatim talk of the student interviews using my computer
data base and a video cassette player. One complete interview transcript is presented in Appendix C.

During the field trips I recorded the students’ behaviour, conversations, and examples of their descriptive language in my field notes. I also included my personal observations and reflections concerning the students, the organisms encountered, the forest walk, the “Wow!” discoveries, and the log-table discussions. The students’ names are replaced with short pseudonyms in both the interview transcripts and the field trip notes.

To analyze the interview data I reviewed the transcripts and categorized the students’ knowledge of the physical adaptations and survival behaviours of the six intertidal organisms as either scientific, incomplete, or confused according to Webber’s (1996) three levels of conceptual understanding. A transcript showing scientific and confused knowledge is presented in Appendix C.

A student’s response was designated scientific if it contained at least three relevant facts concerning the physical adaptation or survival behaviour of the selected intertidal organism. For example a scientific response regarding the physical adaptation of the crab’s shell included the shell’s role in defense, camouflage, and in avoiding desiccation during low tide. I chose three as the number of facts characterizing scientific understanding as I believe three examples convey a thorough understanding and safeguards against accidental or “guess” responses. Examples of the students’ scientific knowledge appears in Appendix B.
An interview response categorized as incomplete contained some correct facts but lacked information important to the organism's survival behaviour or physical adaptation. An example of incomplete knowledge was a student response which mentioned the defensive capabilities and camouflage of the crab's shell but did not include the shell's role in avoiding desiccation during low tide.

Confused knowledge occurred when the student included erroneous information in the description of the physical adaptation or survival behaviour. An example of a confused response concerning the crab's shell was that the shell was light in weight which enabled the organism to float to the surface and catch food. Examples of the students' confused knowledge appears in Appendix B.

The students' existing seashore knowledge and the changes in their knowledge were transcribed from the interview video recordings using my computer data base. Student knowledge was then recorded on the Changes in Student Knowledge charts which list the six intertidal organisms and the selected physical adaptations and survival behaviours. Three symbols representing a scientific (circle), an incomplete (square), and a confused (triangle) understanding are recorded on the charts to indicate the students' knowledge of the selected physical adaptations and survival behaviours of the six intertidal organisms. A dash indicates survival behaviours and physical adaptations which were not mentioned by the student during the interview.

I used the interview data, field trip notes, and personal observations and reflections to compose an interpretive commentary on each student. This commentary accompanies
the Changes in Student Knowledge charts and discusses each student in terms of their 
learning styles, behaviour, knowledge, and descriptive language.

I reviewed the interview video tapes, transcripts, and field notes to record the 
students’ descriptive language and their use of metaphor and analogy. I was able to 
categorize each student as either an aesthete, scientist, or warrior by analyzing their 
language recorded during the field trip and interviews. I refer to these three categories or 
orientations (aesthete, scientist, warrior) as the student’s style of knowing. The student 
orientations of aesthete and scientist are based on Snively’s (1986) work on metaphor. 
Snively’s utilitarian orientation is modified to fit the warrior style of knowing.

A student was designated a scientist if they used scientific language and theories in 
their explanations of seashore life. Dan and Cathy, the scientists, described the crab’s 
outer shell as an “exoskeleton” and “carapace”. They referred to the physical differences 
between the male and female as sexual dimorphism, and they understood the crustacean’s 
planktonic larval phase.

The student as aesthete appreciated the beauty of the seashore. Nancy and 
Hannah, the aesthetes, concentrated on the designs, colours, and shapes of the intertidal 
zone and used analogies to describe the inhabitants’ physical adaptations and survival 
behaviours. The aesthetes remarked that a group of limpets resembled “little checkered 
hats”, and they distinguished one crab species from another by the patterns and colours of 
the carapace.

The warrior student concentrated on the dangers of the intertidal zone. Rod and 
Andy, the warriors, viewed the seashore as a battleground. They appreciated organisms
for their weaponry of pincers, jaws, and spines. The crab was described in terms of its “armoured” exoskeleton and “crushing pincers”. Rather than discussing an organisms’ life cycle or physiology the warriors preferred to highlight its defensive and offensive capabilities.

3.14 Limitations of the Methodology:

Every voyage will encounter stormy weather. The elements are an integral part of any beach study, and they may influence the duration of the study, the quantity and diversity of organisms present, as well as the comfort level of the participants. Fortunately the children were so enthusiastic about their role as intertidal voyageurs that the wind, rain, and often chilly days of a typical Vancouver spring did not hamper their discoveries and experiences. Various unforeseen circumstances were more intrusive. Specific interventions and phenomena may have influenced the outcome of the data collection.

The following is a list of such impediments.

- Often during our study the children found the resident windsurfers, dogs, and fishers more compelling than the intertidal treasures. It was necessary to include these discoveries in our discussions. As a result the childrens’ focus on these days was not solely on the survival and adaptation strategies of intertidal organisms.

- The research site, Acadia Beach, was situated near a clothing optional beach. On occasion patrons of the neighbouring shores would stroll alongside our group of children. In such cases it was necessary to terminate our study for that day.

- Acadia Beach is representative of a particular marine habitat resulting in the availability of specific intertidal organisms which were indicative of a rocky beach area. The intertidal organisms highlighted in the study would not be common to all West Coast seashores.

- The proximity of Acadia Beach to Vancouver Harbour affected the quality and the diversity of the resident intertidal organisms. The harbour’s role as an important recreation area as well as its high industrial and commercial use affected the
surrounding seashores and their inhabitants. There was a preponderance of organisms tolerant of human encroachment and pollution. The more susceptible and less adaptive organisms were absent.

- Seasonal changes affected the diversity of organisms investigated in the study. During the study period we experienced an extremely cold winter which preceded an unseasonably chilly spring. The result was a lack of “old standbys” such as crabs, limpets, and marine algae. Shore crabs were late in breeding during the study period.

- It was not possible for me to interact and converse with each participant during every beach trip as my presence was in constant demand for all “Wow!” discoveries. My field notes were composed of conversations in which I was personally involved. As a consequence, some of the childrens’ language and their knowledge of the survival strategies and adaptations of intertidal organisms was not recorded during this portion of the data collection.

3.15 Impediments During The Interviews

The following impediments were present during the interviews:

- As the interview classroom was vacant in the afternoons, it was also used by school staff. The interviews were often interrupted by teachers who were unaware that the room was booked. The interview flow was halted as the necessary explanations and subsequent apologies were made.

- The video recorder and microphone were borrowed from the University Audiovisual Services Department. The equipment was occasionally unavailable and often in poor repair which resulted in delays in the interview process and difficulty during the transcription of interview data.

- Due to the illness of some of the participants, interviews were rescheduled which resulted in the delay of the subsequent beach field trips.

- One participant had an extremely quiet speaking voice. A constant reminder to speak more loudly was necessary throughout the duration of the interviews. These interruptions affected the flow of the conversation, and some of the inaudible sections of the interview made verbatim transcription difficult.

- During one week of the study period a Teacher-On-Call was present as the classroom teacher was ill. I arrived for interviews only to discover the class had disappeared. After searching the school I was informed that the class had left for a programme at the local high school. On another occasion a fire-drill interrupted an interview. In both instances the subsequent interviews and field trips were delayed.
3.16 Trustworthiness

“An Intertidal Voyage” is a qualitative study which requires unique criteria to establish trustworthiness. Lincoln and Guba (1985) recommended establishing trustworthiness by placing the emphasis on “the characteristics of the data” rather than on “the characteristics of the researcher” (p. 290). The conventional questions of validity, reliability, and objectivity are replaced with the “naturalist’s” definitions of credibility, transferability, dependability, and confirmability.

3.17 Credibility

To establish credibility Lincoln and Guba (1985) employed triangulation, examining the data from various viewpoints. Eisner (1991) referred to this process as structural corroboration which he described as the compilation of "bits and pieces of evidence that substantiate the conclusions one wants to draw” (p. 55). My bits and pieces were derived from a variety of sources. Through the analysis of personal field-note recordings, audio/video taped interviews, and student interactions I was able to collect and analyze the data from multiple sources.

Verbatim transcriptions of the audio/video taped portions of the interviews and group presentations enabled me to record the childrens’ seashore knowledge in their own language. Feedback during the field trips was provided through informal discussions regarding “Wow!” discoveries and on-site group work. Prior to the second and final interviews I asked the children to comment on their beach knowledge recorded in previous
interviews and during informal discussions which acted as a form of member checking which increased the credibility of the data.

Lincoln and Guba (1985) stated that the process of prolonged engagement will “increase the probability that credible findings and interpretations will be produced” (p. 301). I worked with the study group over the period of two school years which enabled me to establish a positive long-term relationship with the children. I was called upon for advice and invited to attend class parties and performances. I knew the students by their first names and became acquainted with their friends, parents, and siblings. My role as an active participant observer in the study was integral to the building of a trusting relationship between researcher and participant.

3.18 Transferability

“The purpose of the case study is not to represent the world but to represent the case.” (Stake, 1994, p. 245). “An Intertidal Voyage” investigates the unique aspects of the case, the participants, the researcher, and their learning. As the researcher my prime concern was to determine the importance of the study “within its own world” (p. 242) not in establishing generalizations, uniformity, or standardization to other research. Due to the unique nature of the study, transferability was not integral to the establishment of trustworthiness. Instead the findings provide a data base from which further research may evolve (Lincoln and Guba, 1985). However, some of the findings of this study may provide an understanding of student interactions and student learning in the informal environment.
3.19 Dependability and Confirmability

I used various methods of data collection to create an "audit trail" (Lincoln and Guba, 1985, p. 319) to achieve dependability and confirmability. Raw data were recorded through hand written field notes and the audio/video taping of the interviews and presentations. My personal observations and reflections during the course of the study were also included in the data collection. Additional notes summarizing possible findings, conclusions, interview questions, and the processes (methodology) involved in the study completed the audit trail. I was fortunate to have a colleague join me in the interviews and during the field trips to provide feedback and verification of the collected data.
Chapter 4: Data Presentation and Interpretation of Changes in the Students’ Knowledge of Physical Adaptations and Survival Behaviours of the Six Intertidal Organisms

4.1 Introduction

The data are presented in the following two chapters. Chapter four presents the changes in student knowledge through a series of charts and interpretive commentaries on each student. Chapter five shows how the students use language (defined through their styles of knowing) to interpret and articulate their seashore knowledge. The data are presented in two chapters to differentiate between these two distinct interpretations.

This chapter begins with an introduction to two intertidal organisms, the Dungeness crab and the kelp, investigated in this study. Each organism is described through a vignette which illustrates two of the voyageurs’ field trip experiences. These vignettes create a picture of the seashore and describe the richness and diversity of the beach explorations and student investigations which formed the basis of their knowledge and descriptive language.

The chapter also presents the changes in student knowledge. This section begins with a review of each of the six students and a summary of the changes in their seashore knowledge as recorded in the interviews. To capture the essence of the students’ intertidal voyage I provide a detailed description of their field trip and interview experiences. Each student’s journey is given a title to portray the uniquely individual ways they experienced the seashore.
A series of charts accompanies each voyageur’s intertidal voyage on which four symbols represent the level of student understanding (Webber, 1996). The charts show the changes in the students’ knowledge of the physical adaptations and survival behaviours of six intertidal animals. Student knowledge is represented over three interviews so that comparison can be made over time. The symbols used in each chart are circle, square, triangle, and dash:

A circle (o) indicates a scientific understanding. Student knowledge includes appropriate terminology and a correct description/explanation of the physical adaptation or survival behaviour.

A square (•) indicates an incomplete understanding. Student knowledge includes the appropriate description/explanation but lacks an integral component of the physical adaptation or survival behaviour.

A triangle (△) indicates a confused understanding. Student knowledge includes an awareness of the physical adaptation or survival behaviour but includes erroneous information. A dash (-) indicates that the student did not mention either physical adaptation or survival behaviour. Examples of the three levels of understanding are presented in Appendix A. A glossary of the survival behaviours and physical adaptations which appear on the Changes in Student Knowledge Charts is presented in Appendix B.

4.2 Intertidal Vignettes

I composed a detailed vignette for each interview plant and animal and chose the following two as representative of all six intertidal organisms.
4.2.1 The Crab

Rod, one of the *voyageurs* who participated in the study, created the term Crabzilla as a testament to the crab's aggressive behaviour and well armoured body. The well adapted crustacean reminded him of the imaginary lizard Godzilla of Japanese cinema fame.

4.2.1.1 Crabzilla Day

Everyone was excited as we began the now familiar trek to Acadia Beach. Not only was it a wonderfully vernal morning, but the prospect of a low tide promised a wealth of fascinating beach finds. The fact that this was the Friday before the week long spring break was also partly responsible for our joyous mood.

As we followed the winding path through cottonwood and alder we were accompanied by the bubbling aria of an enthusiastic winter wren. Kinglets flitted over head as we examined the pink tipped branches of salmonberry bushes. We whispered in anticipation about a possible hummingbird sighting. It would be our first of the season. The sharp trill of a northern flicker echoed through the greening canopy as we glimpsed a bald eagle soaring overhead. The presence of this majestic bird signalled the end of our forest journey. The seashore lay ahead!

Earlier in the morning we discussed possible changes in seashore life since our previous beach visit three weeks earlier. The students were unanimous in their hope of finding crabs. These pugnacious crustaceans had been scarce over the winter months, and we were ready for some close encounters! We were not to be disappointed. As soon as
we hit the sand the “Wow!” discoveries began. Almost everyone discovered a colony of purple shore crabs hiding under the myriad of barnacle encrusted rocks. There were cries of “This one’s a female. You can tell by her round stomach.”, and “Look at this guy’s polka-dot pincers!” Many of the students wondered about the “baby” crabs. Why did they sport such wonderfully diverse black and white patterns on their backs? How old were they, and why weren’t they crushed under the weight of the rocks? As we traversed the beach, a different kind of “Wow!” sighting occurred. The Dungeness crabs were in the midst of their spring molt. Wave washed mounds of pincers, legs, and the tell-tale orange-brown carapaces of this large edible crab were strewn across the beach. Immediately many of the students picked up the various body parts and sniffed. “Yup, cast-offs all right. They don’t stink like a dead crab!” “Not only that, you can see right through the elbows.” “Look, even the eye balls are left behind!” One student interpreted the crab’s thoughts during the molt as “I’m out’a here!”. The process was compared to a snake shedding its skin. Perfectly intact cast-offs were christened “petrified crabs”. The hair-like structures on the underside of the crab’s shell reminded the students of fur, and the moveable mouthparts were crustacean “fangs”.

The students exhibited various methods of interacting with the crabs. One group decided to observe a colony of purple shore crabs. A large male was christened “crabzilla” as a testament to his impressive size and dexterity when employing his large pincers. Other students practised picking up the skittish crustaceans. They were impressed by the crab’s ability to escape by “running” sideways, and also by the animal’s quick recovery after finding itself upside down. Many students, after learning that crabs
and spiders were related, decided they no longer wished to experience a living encounter and were content to examine the cast-offs. Pincers were activated, and legs were prodded and bent in every direction. Lifting the back of the carapace, the students marvelled at the silvery transparent gills which reminded them of "feathers".

The sandy section of the beach exhibited a different environment as the well adapted inhabitants indicated. The *voyageurs* noticed that green shore crabs with their hairy appendages replaced their rock-loving purple cousins. Pincer waving individuals were just as "crabby" as their rock dwelling counterparts. Males were compared to females, and the "babies" were examined. One *voyageur* interpreted bubble blowing behaviour as a dry crab. That was our signal to return all specimens to the tide pool.

Throughout the morning students had placed interesting beach items on our discussion table. This was usually a large flat log or evenly cut log round. To conclude our morning we held a quick meeting to discuss the finds. The students were fascinated by the crab's ability to molt its old shell. They were intrigued by the circumstances involved and wondered about the crab's ability to protect itself after molting. The crustacean's soft shell rendered it vulnerable to predators such as gulls and other crabs. We discussed the male Dungeness crab's method of protecting the soft shelled female by holding her underneath him until her shell hardened. The pair would mate during this time taking advantage of the female's pliable shell and abdomen. The life cycle of the crab was examined beginning with the larval stage in the plankton stream and the eventual evolution to terrestrial form. As a final farewell to crabzilla and his cohorts our beach finds were
ceremoniously returned to the shoreline. We began our trek homeward. The students conversed excitedly about crabs and holidays!

4.2.2 The Bull Kelp

The stipe or stem of the bull kelp is often called a sea pickle as its colour and shape resemble a pickle. The stipe can be pickled and is considered to be quite edible.

4.2.2.1 Sea Pickle Day

We were always eager to examine the colourful array of marine algae which decorated our beach after a high tide. The children enjoyed feeling the rubbery texture of bull kelp and examining the organisms’ intricate holdfasts. The children found the sight of a five foot kelp blade and stipe attached to a tiny rock or single barnacle amusing as they remarked “the kelp made a bad choice!” for its anchor.

After one particularly blustery day we had the opportunity to study a variety of wave deposited algal species. The children were able to identify the various types of seaweed using the different colours as their guide. Their favourite green alga was sea lettuce as “it looked so tasty!” Despite its edible appearance they decided to leave the bright green fronds to the local seaducks. The children observed that rockweed or fucus, sugar, and bull kelp were the most common representatives of brown algae on our beach.

During our algae days we studied the organism’s unique survival adaptations. The children observed that many species were anchored to rocks or barnacles by a tenacious structure called a holdfast. The bull kelp’s holdfast was compared to the “gnarly and
woody root” of an ancient tree. We discussed the term seaweed as a misnomer as “weed” generally refers to a rooted plant that propagates through seed dispersal. The children surmised that algae are similar to plants as they both absorb nutrients from the sun. Algae reproduction involves a gamete-producing phase alternating with a spore-producing stage. The voyageurs were fascinated by the great kelp die-off which occurs when over-mature kelp dies during the fall and winter months. Storms deposit huge twisted mounds of rotting kelp on local beaches. The voyageurs were amazed to learn that bull kelp grows quickly and can reach a length of thirty metres in one season and some individual organisms may live up to two years. Stipes, bulbs, and fronds that are lost or damaged to sea urchin predation and storms are regenerated.

A favourite past time during our algae day was to pop the gas filled tips of the rockweed and bull kelp. The voyageurs were mystified as to the purpose of these air pockets. After we discussed the nutritional requirements of algae the children concluded that the gas-filled sacs acted as floatation devices or “life jackets” which lifted the kelp fronds closer to the sun. The children preferred the rockweed’s common name, popping wrack, as it aptly described the lovely sound produced when the gas-filled sacs were stepped upon or squeezed.

The main focus of one log-table discussion was the kelp forest. We discussed this unique environment’s role as a home to numerous marine organisms such as kelp fish, sea otters, and sea urchins. The kelp stipes and fronds support a myriad of life including encrusting bryozoans or moss animals, cruising nudibranchs and snails, and hitchhiking limpets. We examined the gray maze-like pattern of a moss animal colony. The children
commented on its “moldy” appearance and “unanimal-like” qualities. We decided to investigate the colony under a microscope when we returned to the classroom.

We talked about marine algae’s commercial uses in toothpaste and foods such as ice cream. Some of our voyageurs had sampled seaweed directly as sushi and nori. We decided to christen the long thick stipes of the bull kelp “sea pickles” as a tribute to their length, brown-green colour, and edibility.

Another favourite kelp related discovery was the plethora of marine organisms that used the mountains of stranded marine algae as an edible home. The voyageurs enjoyed observing the acrobatic amphipods living under the mountains of rotting bull kelp. Rockweed isopods, usually discovered on their namesake alga, were nicknamed “velcro bugs” as a testament to their ability to cling to rockweed fronds and human fingers. During low tides we were fortunate to glimpse tiny green shrimp scooting around the vibrant sea lettuce and subtidal olive-brown kelp crabs riding the swaying fronds of bull kelp.

Marine algae became one of our favourite beach finds as it was a multipurpose organism which appealed to every sense. It came in a variety of marine hues. It was edible. It was wonderfully smooth to the touch, had a great smell, produced wonderful sounds, and housed a multitude of fascinating sea treasures.

4.3 The Students’ Journeys

The voyageurs’ interview and field trip experiences are described in the following intertidal journeys. Accompanying each student’s journey is a summary which details
changes in their knowledge and a chart which shows their scientific, incomplete, confused,
and not mentioned knowledge of the survival behaviours and physical adaptations of the
six intertidal organisms as recorded during the interviews.

4.4 Dan’s Intertidal Journey: A Teaching Experience

Dan was the teacher. In his interviews he demonstrated an extensive scientific
background and keen interest in marine biology. In addition to enthusiastically
experiencing the seashore during the field trips, Dan was an avid independent researcher
of the marine environment. He studied the seashore through books, the Internet, and
weekly trips to the Vancouver Aquarium and local beaches. He was a vocal participant in
the “Wow!” experiences and the log-table discussions.

On the walks to Acadia beach Dan often provided a running commentary on the
particular marine species he was studying at the time. During one fifteen minute stroll,
Dan extolled the virtues of the Pacific Giant Octopus. He reported data on the mollusc’s
complex brain and acute eyesight as well as including the animal’s Latin name and
biological classification.

During the interviews Dan’s knowledge was primarily scientific, but he included
interesting analogies to illustrate his explanations. He used scientific terms such as
arthropod, crustacean, and carapace to describe the Dungeness crab. He was aware that
kelp was an alga which sustained itself through photosynthesis. To explain the kelp life
cycle Dan described the process as “spore, zygote, immature plant, adult”. Dan exhibited
an extensive knowledge of the intertidal organisms’ feeding strategies. He understood the
role of plankton as an important food source for filter feeders such as the oyster and barnacle. He described the limpet as a “gastropod which rasped algae from the substrate using its radula.” When describing the flounder’s migrating eye he added that there were also “left eye flounders” called sandabs.

4.4.1 Summary of Changes in Dan’s Knowledge

Dan demonstrated a preponderance of scientific knowledge in his three interviews. In the second interview some of Dan’s scientific knowledge changed to incomplete but returned to scientific in the third interview. This change in knowledge can be described as a state of flux which occurs when the student combines new knowledge with prior ideas. During the interviews Dan had three areas of confused knowledge and omitted three survival behaviours and three physical adaptations. He conveyed comparable knowledge in survival behaviours and physical adaptations and used knowledge acquired during the field trips in his responses.

During the three interviews Dan’s understanding of the physical adaptations and survival behaviours can be detailed as follows:

- demonstrated a scientific understanding in his first interview of: crab molting (sheds exoskeleton to grow, sheds entire shell, new shell is soft), shell (hard, strong, prevents desiccation, armour in battle), regeneration (lost and damaged appendages regenerate, occurs during molt, new appendage small in size), feeding strategies (scavenge, attack, filter feed), locomotion (crawl, swim, bury), hiding (under sand, algae, rocks), pincers (large, colourful, ridged claws), and speed (swim, crawl, bury): kelp size (large and small kelp species, bull kelp longest, need length to reach sunlight), food source (an algae, needs sunlight, converts sunlight to energy), holdfast (not a root, acts as an anchor, adheres to hard surfaces using glue) moisture retention (outer layer holds moisture, can survive desiccation, recover at high tide) and holes in blade (allows water to pass through, not in all species, protection during storms): oyster feeding strategies (filter feeder, feeds on plankton, feeds during high tide) and glue (secretes glue to adhere to homebase, adheres to hard surface even other oyster, does not move
from homebase): barnacle habitat (rocky areas, with other barnacles, inhabit different zones depending on species), feeding strategies (filter feeder, feeds during high tide, uses appendages to strain food from water), shell (hard, sharp, protects from predators and desiccation), trap door (closes during high tide, opens to feed, protection and prevents desiccation), glue (secretes glue to adhere to hard surfaces, does not move, protection from predators and wave shock), and life cycle (egg stage, planktonic larval stage, familiar adult stage): limpet shell (conical, hard, protection from predators and desiccation), suction-cup foot (sticks on, protection from predators, wave shock, desiccation), feeding strategies (grazer, feeds on algae, leaves a trail), hiding (found in crevices and under rocks at low tide), and clamping down (sticks to avoid predators and desiccation): sole camouflage (colour, shape/mimicry can change colour and pattern), migrating eye (eye moves to other side of head, flounders are either right eye or left eye, becomes a bottom dweller and eyes gaze upward), body shape (flat, streamlined, undulating swim), and life cycle (egg, larvae, upright fish becomes a flat fish),

- showed a progression in his knowledge of: crab camouflage (colour, design, mimicry), feeding strategies (ambush, attack, scavenge), hair (sensory system, keeps mouth area clear, on legs and shell), hiding (under rocks, sand, and algae), and life cycle (egg, larval, adult stage, larval stage planktonic): kelp die-off (occurs during winter storms, piles up on beaches, short life span) and forest (forms large, dense forests, protection from predators and wave shock, creates home for other organisms): oyster habitat selection (spat choose homebase, near other oysters, nutrient rich, clean area) and clamping down (adductor muscles closes shell, protection from predators and desiccation): barnacle grouping (form dense patches, select nutrient rich and silt free environments) and hitchhiking (attaches to limpets, crabs, and whales for protection and food source): sole feeding strategies (ambushes from hiding spot, sharp teeth, eats smaller fish and crabs),

- showed a change in his knowledge in the second and third interview of: crab feeding, hair, and hiding: sole feeding strategies. His knowledge returned to its initial scientific designation in the third interview,

- showed a confused understanding of: crab hair (all crabs have it) kelp camouflage (they don’t need camouflage) and limpet camouflage (they don’t need camouflage). Comments in parentheses are examples of Dan’s confused knowledge,

- revealed a steady state of knowledge in: crab molting, pincers, regeneration, shell (scientific): kelp food source, holdfast, moisture retention (scientific): barnacle glue, life cycle, shell, trap door (scientific): limpet clamping down, feeding, hiding (scientific): sole body shape, camouflage, life cycle, migrating eye (scientific),
• included additional information in the second and third interviews on: crab camouflage (colour, shape, design) and aggression (pincers, sharp legs, strength): kelp camouflage: oyster life cycle (egg, planktonic larva, adult), shell (hard, camouflage, prevents desiccation and predation), grouping (safety in numbers), and camouflage (colour, mimicry, resembles rocks): barnacle hitchhiking (attaches to whales, crabs for protection and food source), grouping (safety in numbers, form dense patches, larger species are more solitary and sub-tidal), and camouflage (colour, shape): limpet hiding (under rocks, in crevices), habitat (rocky, algae-rich environments, intertidal), suction-cup foot (located on the underside, attaches to substrate, protection from desiccation, wave shock, and predators), homebase (area where limpet returns after feeding, often a small depression), habitat (rocky, algae-rich, hiding places), and camouflage (mimicry resembles rocks and barnacles, colour, shell patterns): sole migrating eye (both eyes on one side of body, occurs as juvenile fish), hiding (uses undulating motion with fins and body to bury itself in sand), habitat (depends on species, sandy or rocky environments, bottom dweller), and scales (protection),

• did not mention: crab: gender change, male protecting female, and blowing bubbles: oyster gender change: limpet grouping: sole slime,

• demonstrated comparable understanding of physical adaptations and survival behaviours,

• showed an equal understanding of both plant and animal physical adaptations, and

• mentioned the field trips and log-table discussions in his interviews.
Table 2.
Changes in Student Knowledge - Dan

<table>
<thead>
<tr>
<th>Survival Behaviours</th>
<th>First Interview</th>
<th>Second Interview</th>
<th>Third Interview</th>
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<tbody>
<tr>
<td>Aggression</td>
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<td>Blowing Bubbles</td>
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<tr>
<td>Feeding</td>
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<td>Pairing Waving</td>
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<th>Physical Adaptations</th>
<th>First Interview</th>
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<tbody>
<tr>
<td>Camouflage</td>
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<th>Giant Acorn Barnacle (Balanus nubilus)</th>
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<td>Survival Behaviours</td>
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<td>Colonization/Grouping</td>
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<td>Hitch-Hiking</td>
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</table>

| Physical Adaptations                  |                 | O                | O               |
| Camouflage                            | O               | O                | O               |
| Glue                                  | O               | O                | O               |
| Life Cycle                            | O               | O                | O               |
| Shell                                 | O               | O                | O               |
| Trap Door                             | O               | O                | O               |

<table>
<thead>
<tr>
<th>Sugar Kelp (Laminaria saccharina)</th>
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<th>Third Interview</th>
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<td>O</td>
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<tr>
<td>Holes in Blade</td>
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<td>Kelp Forest</td>
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<td>Moisture Retention</td>
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<td>Rapid Growth Rate</td>
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<td>Seasonal Die-off</td>
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<td>Size/Length</td>
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<table>
<thead>
<tr>
<th>Pacific Oyster (Crassostrea gigas)</th>
<th>First Interview</th>
<th>Second Interview</th>
<th>Third Interview</th>
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</thead>
<tbody>
<tr>
<td>Survival Behaviours</td>
<td></td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Colonization/Grouping</td>
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<tr>
<td>Clamping Down</td>
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<tr>
<td>Feeding</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Habitat Selection</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>

| Physical Adaptations               |                 | O                | O               |
| Camouflage                         | O               | O                | O               |
| Gender Change                      | O               | O                | O               |
| Habitat                            | O               | O                | O               |
| Glue                               | O               | O                | O               |
| Life Cycle                         | O               | O                | O               |
| Shell                              | O               | O                | O               |

<table>
<thead>
<tr>
<th>Unstable Limpet (Pella instabilis)</th>
<th>First Interview</th>
<th>Second Interview</th>
<th>Third Interview</th>
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<tbody>
<tr>
<td>Survival Behaviours</td>
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<td>Clamping Down</td>
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<td>Feeding</td>
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<td>Habitat</td>
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</tr>
<tr>
<td>Grouping</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>

| Physical Adaptations               |                 | O                | O               |
| Camouflage                         | O               | O                | O               |
| Shell                              | O               | O                | O               |
| Slime                              | O               | O                | O               |
| Suction-Cup Foot                   | O               | O                | O               |

Note. Scientific (O), Incomplete (D), Confused (Δ), Not Mentioned (-)
4.5 Cathy’s Intertidal Voyage: A Gourmet Experience

Cathy’s extensive scientific knowledge was evident during the field trips and log-table discussions. She often visited the seashore and Vancouver Aquarium with her family and enjoyed books and television programmes on marine life. An aquarist at heart Cathy kept a home aquarium and was well versed in the art of maintaining a community of fish.

During the walks to Acadia Beach Cathy cheerfully reported on the food preferences of her aquatic charges usually referring to who was eating whom. Cathy was also the gourmet of the group. She was well informed on the “edibility” of the plants and berries which grew along the path to the beach. As she patrolled the intertidal zone Cathy often spoke of her Grandmother’s expertise in preparing seafood. The entire group became rather hungry as Cathy reminisced about steaming clam chowder and cracked crab smothered in butter.

During her first interview Cathy conveyed scientific knowledge which was peppered with a pragmatic perspective of intertidal organisms. She particularly enjoyed discussing the Dungeness crab as she had observed and tasted many individuals. She was the only student who described the crab’s bubble blowing strategy. “He’s saying, ‘Put me back!’ ”. She added that the crab must be at least six and one half inches across to be “legally eaten”. Cathy mentioned that empty oyster shells must be left on beaches to encourage the spat to take up residence. She noticed that barnacles were a good indicator of the high tide line on wharf pilings and believed that the limpet’s shape and colour mimicked a “giant eye to scare off predators”. Cathy concluded that flat fish, especially halibut, were “very tasty in fish and chips”.
In the final interview Cathy’s responses included a range of knowledge. There was progression in her understanding of both survival behaviours and physical adaptations, but in some areas her scientific knowledge changed to incomplete and confused. The shift in her second interview was possibly due to a bout with the flu. She was also moving to another school district at the end of term and spoke of her sadness at leaving her friends and teacher. It is possible these factors were responsible for the decline in Cathy’s scientific knowledge.

4.5.1 Summary of Changes in Cathy’s Knowledge

Cathy began her interviews with a scientific understanding of many of the survival behaviours and physical adaptations. During her second and third interview there was a significant change in her scientific knowledge to incomplete and confused. Cathy was ill with the flu at this time which may have influenced the outcome of these two interviews. Over the course of the interviews Cathy omitted five physical adaptations and one survival behaviour. She demonstrated a comparable understanding of both physical adaptations and survival behaviours and showed a greater scientific understanding of animal adaptations than plant. Cathy employed her field trip knowledge to illustrate her interview responses.

During the three interviews Cathy’s knowledge of the physical adaptations and survival behaviours of intertidal organisms can be detailed as follows:

- demonstrated a scientific understanding in her first interview of: crab camouflage (colour, shape, carapace design), molting (sheds exoskeleton to grow, entire shell is shed, new shell is soft, mating occurs), pincers (large, powerful, colourful), feeding strategies (scavenger, predator, filter feeder), hiding (buries in sand, in eelgrass, immature hide under rocks), and speed (swimming, crawling, burying): kelp holdfast
(anchor, protection from storms and predators), and moisture retention (feels slimy, dries out at low tide, recovers at high tide): oyster grouping (live in groups, for protection, indicates good feeding ground), habitat (rocky areas, nutrient rich areas, intertidal), habitat selection (chooses site near other oysters, uses chemoreceptors, native oyster habitat taken over by Pacific oyster), shell (hard, colour/shape, protection from predators and desiccation), feeding strategies (filter feeder, siphon, eats plankton), and gender change (seasonal change from male to female and reverse): barnacle trap door (two plates shut at the top, protection from predators and desiccation, opens to feed), glue (sticks to homebase, adheres permanently, leaves a barnacle scar), feeding strategies (uses feet to strain food, filter feeder, eats plankton), and hitchhiking (attaches to crabs, limpets, whales): limpet camouflage (shape, colour, design), clamping down (muscle attaches limpet to surface, protection from wave shock, predators, and desiccation), habitat (on rocks, under rocks, in crevices), and suction-cup foot (muscle on foot, small oval cup on foot, protection from predators, wave shock, and desiccation): sole camouflage (colour, shape, changes design and colour), life cycle (egg, larva, adult, normal fish, flat, bottom dwelling fish) and hiding (burying in the sand),

• showed a progression in her knowledge of: crab hair/ cilia (hair is found on legs and under carapace, acts as a filter and sensory device): oyster grouping (group together, for protection, indicates good feeding area), habitat (rocky areas, clean areas, with other oysters and intertidal): barnacle grouping (small intertidal species group together, for protection and camouflage): limpet hiding (intertidal so hide at low tide, under rocks, in crevices),

• showed a change in her knowledge of: crab male protecting female (scientific to incomplete), feeding strategies (scientific to confused), hiding (scientific to confused), speed (incomplete to confused), and habitat (incomplete to confused): kelp forest (scientific to incomplete): oyster gender change (scientific to confused), glue (incomplete to confused), and life cycle (incomplete to confused): barnacle trap door (scientific to incomplete), and feeding strategies (scientific to confused): limpet suction-cup foot (scientific to incomplete), clamping down (scientific to incomplete), and feeding strategies (incomplete to confused): sole migrating eye (scientific to incomplete), body shape (scientific to incomplete), and habitat (scientific to incomplete),

• demonstrated a confused understanding of: crab life cycle (immature crabs resemble parents), feeding strategies (eat plankton), gender change (they are all born female), hiding (they don’t need to hide), speed (they just slowly crawl along), and habitat (rocky areas only): kelp food source (eat plankton) and moisture retention (die if they dry out): oyster glue (a muscle which sticks the oyster to rocks), gender change (they change gender only once), and life cycle (no planktonic larval stage): barnacle grouping (they live by themselves), life cycle (the young barnacles are small adults), and feeding strategies (they eat crabs and limpets): limpet feeding strategies (they eat plankton). Comments in parentheses are examples of Cathy’s confused knowledge;
• revealed a steady state of knowledge in crab aggression (scientific), molting (scientific), pincers (scientific), barnacle hitch-hiking (scientific), oyster shell (scientific), limpet camouflage (scientific) and sole hiding (scientific),

• did not mention: kelp holes in the blade, rapid growth rate, and size: barnacle camouflage: limpet home base: sole scales and slime,

• included in the second and third interviews additional information on: crab pincer waving (attract female, warning, communication), blowing bubbles (from mouth, indicates a dry crab, prevents desiccation), locomotion (crawls, swims) and life cycle: kelp camouflage (colour, shape), holdfast (anchor, stationary, protection from storms), food source (confused), and moisture retention (confused): oyster camouflage colour, shape), shell (hard, strong, colour), life cycle (spat), and grouping (protection from predators, oysters grow on oysters, mimicry resemble rocks): barnacle shell (strong, sharp, protection from predators and desiccation) grouping (safety in numbers, intertidal species and subtidal species), and habitat (rocky areas, all intertidal zones, clean areas): limpet grouping (protection from predators and desiccation) and slime (visible slime trail when feeding): sole camouflage (colour, shape, can change pattern and colour to reflect habitat),

• demonstrated comparable understanding of physical adaptations and survival behaviours,

• demonstrated greater scientific understanding of animal adaptations, and

• mentioned the field trips and log-table discussions in her interviews.
Table 3.
Changes in Student Knowledge - Cathy

**Dungeness Crab (Cancer Magistrate)**

<table>
<thead>
<tr>
<th>Survival Behaviours</th>
<th>First Interview</th>
<th>Second Interview</th>
<th>Third Interview</th>
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<tbody>
<tr>
<td>Aggression</td>
<td>O</td>
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<tr>
<td>Blowing Bubbles</td>
<td>-</td>
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<td>-</td>
</tr>
<tr>
<td>Feeding</td>
<td>-</td>
<td>0</td>
<td>Δ</td>
</tr>
<tr>
<td>Habitat</td>
<td>0</td>
<td>0</td>
<td>Δ</td>
</tr>
<tr>
<td>Hiding</td>
<td>O</td>
<td>-</td>
<td>Δ</td>
</tr>
<tr>
<td>Male Protecting Female</td>
<td>O</td>
<td>O</td>
<td>0</td>
</tr>
<tr>
<td>Pincer Waving</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Speed</td>
<td>-</td>
<td>0</td>
<td>Δ</td>
</tr>
</tbody>
</table>

**Physical Adaptations**

| Camouflage                     | O               | O                | O               |
| Gender Change                  | -               | -                | 0               |
| Hair                           | -               | -                | 0               |
| Life Cycle                     | -               | -                | Δ               |
| Locomotion                     | -               | -                | 0               |
| Molting                        | O               | O                | 0               |
| Pinchers                       | O               | O                | 0               |
| Regeneration                   | -               | -                | O               |
| Shell                          | -               | 0                | O               |

**Rock Sole (Lepidopsetta bilineata)**

<table>
<thead>
<tr>
<th>Survival Behaviours</th>
<th>First Interview</th>
<th>Second Interview</th>
<th>Third Interview</th>
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</thead>
<tbody>
<tr>
<td>Feeding</td>
<td>O</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Habitat</td>
<td>O</td>
<td>O</td>
<td>0</td>
</tr>
<tr>
<td>Hiding</td>
<td>O</td>
<td>O</td>
<td>0</td>
</tr>
</tbody>
</table>

**Physical Adaptations**

| Body Shape                     | O               | 0                | 0               |
| Camouflage                     | O               | O                | O               |
| Life Cycle                     | -               | O                | O               |
| Migrating Eye                  | O               | 0                | 0               |
| Scales/Fins                    | -               | -                | -               |
| Slime                          | -               | -                | -               |

**Giant Acorn Barnacle (Balanus nubilus)**

<table>
<thead>
<tr>
<th>Survival Behaviours</th>
<th>First Interview</th>
<th>Second Interview</th>
<th>Third Interview</th>
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</thead>
<tbody>
<tr>
<td>Colonization/Grouping</td>
<td>-</td>
<td>Δ</td>
<td>O</td>
</tr>
<tr>
<td>Feeding</td>
<td>O</td>
<td>-</td>
<td>Δ</td>
</tr>
<tr>
<td>Habitat</td>
<td>-</td>
<td>-</td>
<td>O</td>
</tr>
<tr>
<td>Hitch Hiking</td>
<td>0</td>
<td>0</td>
<td>O</td>
</tr>
</tbody>
</table>

**Physical Adaptations**

| Camouflage                     | -               | -                | -               |
| Glue                           | O               | -                | O               |
| Life Cycle                     | 0               | 0                | Δ               |
| Shell                          | O               | O                | O               |
| Trap Door                      | O               | 0                | O               |

**Sugar Kelp (Laminaria saccharina)**

<table>
<thead>
<tr>
<th>Physical Adaptations</th>
<th>First Interview</th>
<th>Second Interview</th>
<th>Third Interview</th>
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<tbody>
<tr>
<td>Camouflage</td>
<td>-</td>
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<td>O</td>
</tr>
<tr>
<td>Food Source</td>
<td>-</td>
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<td>Δ</td>
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<tr>
<td>Holdfast</td>
<td>O</td>
<td>-</td>
<td>O</td>
</tr>
<tr>
<td>Holes in Blade</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Kelp Forest</td>
<td>0</td>
<td>O</td>
<td>0</td>
</tr>
<tr>
<td>Moisture Retention</td>
<td>O</td>
<td>-</td>
<td>Δ</td>
</tr>
<tr>
<td>Rapid Growth Rate</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Seasonal Die-off</td>
<td>-</td>
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<td>-</td>
</tr>
<tr>
<td>Size/Length</td>
<td>-</td>
<td>-</td>
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**Pacific Oyster (Crassostrea gigas)**

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<th>First Interview</th>
<th>Second Interview</th>
<th>Third Interview</th>
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</thead>
<tbody>
<tr>
<td>Colonization/Grouping</td>
<td>-</td>
<td>Δ</td>
<td>O</td>
</tr>
<tr>
<td>Clamping Down</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Feeding</td>
<td>-</td>
<td>0</td>
<td>Δ</td>
</tr>
<tr>
<td>Habitat</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Habitat Selection</td>
<td>-</td>
<td>0</td>
<td>O</td>
</tr>
</tbody>
</table>

**Physical Adaptations**

| Camouflage                     | -               | -                | 0               |
| Gender Change                  | O               | -                | Δ               |
| Habitat                        | 0               | 0                | O               |
| Glue                           | 0               | 0                | Δ               |
| Life Cycle                     | -               | 0                | Δ               |
| Shell                          | O               | O                | O               |

**Unstable Limpet (Pelta instabilis)**

<table>
<thead>
<tr>
<th>Survival Behaviours</th>
<th>First Interview</th>
<th>Second Interview</th>
<th>Third Interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clamping Down</td>
<td>O</td>
<td>O</td>
<td>0</td>
</tr>
<tr>
<td>Feeding</td>
<td>Δ</td>
<td>0</td>
<td>Δ</td>
</tr>
<tr>
<td>Habitat</td>
<td>O</td>
<td>-</td>
<td>O</td>
</tr>
<tr>
<td>Hiding</td>
<td>Δ</td>
<td>O</td>
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<tr>
<td>Home Base</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Grouping</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
</tbody>
</table>

**Physical Adaptations**

| Camouflage                     | O               | O                | O               |
| Shell                          | 0               | -                | O               |
| Suction-Cup Foot               | O               | 0                | 0               |

**Note.** Scientific (O), Incomplete (I), Confused (Δ), Not Mentioned (-)
4.6  Nancy’s Intertidal Voyage: A Retail Experience

Nancy’s role was that of an observer demonstrated by a greater interest in the physical adaptations of the intertidal organisms. During the field trips Nancy organized an intertidal flea market. She collected a variety of crab and mollusc shells, rocks, and marine algae which were showcased at the beach on logs and rocks. “Customers” used rocks and shells to purchase the assorted intertidal wares. Nancy was very conscious of the “saleability” of intertidal organisms so she preferred to discuss the colourful hues and intriguing shapes of oysters, limpets, crabs, and marine algae.

During the interviews Nancy discussed the crab’s protective exoskeleton, the varied colours of marine algae, the oyster’s fluted shell, the limpet’s conical shell, the barnacle shell’s chalky colour, and the compressed body shape of the sole. She appreciated the pearl hued interior and undulating shape of the oyster shell and found the intricate pattern and soft “fur” of the Dungeness carapace intriguing. Her knowledge of survival behaviours was not as complete as her knowledge of physical adaptations, but both areas progressed over the interviews. Nancy’s responses advanced toward scientific understanding, and her knowledge changed in organisms she found aesthetically pleasing (oyster, barnacle, crab). As Nancy included more scientific knowledge in her responses she concentrated less on the organisms’ physical characteristics.

4.6.1 Summary of Changes in Nancy’s Knowledge

Nancy did not demonstrate a preponderance of scientific knowledge in her first interview but included additional survival behaviours and physical adaptations in her
second and third interviews. Her responses changed from not mentioned and confused to an incomplete or a scientific understanding as the interviews progressed. During her interviews Nancy did not mention eleven physical adaptations and six survival behaviours and omitted nineteen adaptations. Nancy initially concentrated on physical adaptations but by her third interview demonstrated comparable knowledge in survival behaviours. She had a greater understanding of animal adaptations than plant and used her field trip experiences in her interview responses. Nancy was the only student to pose questions during the interviews.

During the three interviews Nancy’s knowledge of the physical adaptations and survival behaviours of intertidal organisms can be detailed as follows:

- demonstrated a scientific understanding in her first interview of: crab gender change (all crabs began as males, some changed to males, females had rounder abdomen): sole migrating eye (born as “normal” upright fish, eye moved to other side, becomes a “flat” bottom fish),

- showed a progression in her knowledge of: crab camouflage (crabs look like seaweed), regeneration (lost or damaged appendages regenerate), and hiding (found under seaweed and sand): oyster camouflage (colour blends with barnacles) and habitat (prefers rocky areas with other oysters): barnacle shell (protection from predators and desiccation at low tide), grouping (live in groups), hitchhiking (some species attach to whales), and habitat (inhabit rocky areas): limpet shell (protects animal form predators): and sole body shape (flat shape helps it hide),

- showed a change in her knowledge of: crab life cycle (incomplete to confused): barnacle glue (incomplete to confused): sole habitat (incomplete to confused) and body shape (scientific to incomplete),

- demonstrated a confused understanding of: crab feeding strategies (crabs only eat algae), life cycle (larval stage crabs are smaller version of the adult), male protecting female (the male carries the female on his back), and aggression (crabs have teeth): kelp food source (ate plankton), and die-off (occurs all year): oyster glue (oysters attach with a suction cup foot) and life cycle (larval stage oysters are smaller versions of the adult): barnacle glue (barnacles attach with a suction cup foot) and life cycle (larval stage barnacles are just smaller versions of the adult): limpet feeding strategies (only eat plankton) and suction-cup foot (use glue to stick on): sole habitat (they only
live in rocky tidepools) and life cycle (the young hatch inside the female and stay with her until they are adults). Comments in parentheses are examples of Nancy’s confused knowledge,

- revealed a steady state of knowledge in: crab habitat (incomplete), pincers (incomplete): kelp food source (confused), holdfast (incomplete): barnacle trap door (incomplete): sole camouflage (incomplete),

- included in the second and third interviews additional information on: crab camouflage (colour, shape, shell design), molting (shed the exoskeleton to grow), life cycle (begins as an egg and enters plankton stream), hiding (under sand, algae, and rocks), regeneration (occurs during molting), feeding strategies, and aggression: kelp die-off (short life span) and food source: oyster glue, habitat (rocky areas with other oysters), habitat selection (choose their home base), camouflage (colour, shape), shell (protection form predators and desiccation), clamping down (uses a muscle to close shell for protection), and life cycle: barnacle glue (secretes a sticky glue), feeding strategies (feed during high tide), grouping (lives alongside other barnacles, safety in numbers), habitat (rocky areas, on rocks, clean areas), and shell (protection, prevents desiccation, sharp): limpet feeding strategies, clamping down (sticks to avoid predators and desiccation), camouflage (colour and shape), habitat (rocky areas, under rocks, in crevices), and shell (protection, prevents desiccation, hard): sole camouflage (shape and colour), feeding strategies (ambushes, bottom feeder), life cycle, and body shape (flat, mimicry, undulating swimmer),

- did not mention: crab locomotion, pincer waving, speed, and blowing bubbles: kelp camouflage, growth rate, size, forest, and holes in blade: oyster grouping and gender change: barnacle camouflage: limpet hiding, slime, home base, and grouping: sole hiding, slime, and scales,

- concentrated on physical adaptations in the first interview. Included survival behaviours in the second and third interviews,

- demonstrated a greater scientific understanding of animal adaptations than plant adaptations, and

- mentioned the field trips and log-table discussions in her interviews.
Table 4. Changes in Student Knowledge - Nancy

**Dungeness Crab (Cancer Magistrate)**

<table>
<thead>
<tr>
<th>Survival Behaviours</th>
<th>First Interview</th>
<th>Second Interview</th>
<th>Third Interview</th>
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<tbody>
<tr>
<td>Aggression</td>
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<tr>
<td>Blowing Bubbles</td>
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<tr>
<td>Feeding</td>
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</tr>
<tr>
<td>Habitat</td>
<td>∩</td>
<td>∩</td>
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<tr>
<td>Hiding</td>
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<tr>
<td>Male Protecting Female</td>
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<tr>
<td>Fins Waving</td>
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<td>Speed</td>
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<tr>
<td>Gender Change</td>
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<tr>
<td>Hair</td>
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<td>Regeneration</td>
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**Rock Sole (Lepidopsetta bilineata)**

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<td>Slime</td>
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**Giant Acom Barnacle (Balanus nubilus)**

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<td>Trap Door</td>
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**Sugar Kelp (Laminaria saccharina)**

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**Pacific Oyster (Crassostrea gigas)**

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<td>Life Cycle</td>
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<td>Shell</td>
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**Unstable Limpet (Pelta instabilis)**

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<th>Third Interview</th>
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<tr>
<td>Habitat</td>
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<td>Hiding</td>
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<td>Physical Adaptations</td>
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<td>Camouflage</td>
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<td>Shell</td>
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<tr>
<td>Suction-Cup Foot</td>
<td>∩</td>
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*Note. Scientific (O), Incomplete (□), Confused (A), Not Mentioned (-)
4.7 Rod's Intertidal Voyage: A Success Story

Rod was the success story of this study. He began as a student whose primary interest was in forcing crabs to attack everything from sticks, shells, other crabs, and fellow beachcombers’ fingers. During the study a transformation occurred. As the field trips unfolded Rod became an active participant in the intertidal investigations and log-table discussions. He included a variety of intertidal organisms in his explorations though crabs remained his favourite. Rod began to research intertidal organisms by frequenting the local library for books on marine life and visiting the Vancouver Aquarium “to get a closer look at the tough guys like crabs and sharks”. He applied his newly acquired knowledge to his beach experiences and interviews.

During the walk to Acadia beach instead of running ahead and roughhousing, Rod chatted enthusiastically about the marine organisms he encountered during fishing expeditions with his Dad. Once on the beach he had an excellent eye for discovering “Wow!” items such as fish skeletons, secretive limpets, and well camouflaged nudibranchs. Rod’s fascination with crabs continued as he became an expert at distinguishing male from female, locating the largest purple shore crabs, and female crabs “in berry”. Crabs were no longer opponents to be subjugated and controlled. Instead Rod viewed the crustaceans as fascinating “survivors of the intertidal zone”. He gently cradled tiny shore crabs in his cupped palms and carefully returned them to their home rock. He was a vehement proponent of beach etiquette chastising fellow beachcombers for leaving rocks overturned or handling crabs by their fragile appendages.
As one of the warriors of the group, Rod’s scientific knowledge of defensive strategies such as the crab’s aggressive behaviour and protective armour was well represented during the interviews. His first interview responses concentrated on each organism’s physical adaptations. He demonstrated a scientific understanding of the barnacle’s impenetrable shell and predator-proof trap door. His scientific knowledge of the crab’s powerful pincers, protective exoskeleton, and aggressive behaviour was enthusiastically reported. Rod’s knowledge changed in the second interview. He included new knowledge on both physical adaptations and survival behaviours of intertidal organisms. During the third interview many of Rod’s responses demonstrated scientific knowledge most notably in the physical adaptations of the barnacle and crab and in limpet behaviour.

Rod’s enthusiasm escalated alongside his scientific knowledge. He expressed regret when the Friday beach trips concluded, but Rod did have the opportunity to apply his new beach knowledge. His family was moving to the East coast, and he was excited at the prospect of investigating new seashores and different intertidal organisms.

4.7.1 Summary of Changes in Rod’s Knowledge

Rod changed from mentioning a small number to including most physical adaptations and survival behaviours in his final interview. In his first interview Rod had a scientific understanding of six adaptations and an incomplete understanding of eleven adaptations. In his second and third interviews he added a significant number of survival behaviours and physical adaptations. Rod had confused knowledge of fifteen adaptations
and omitted one survival behaviour and six physical adaptations during the interviews. He initially concentrated on physical adaptations but included more survival behaviours as the interviews progressed. Rod showed comparable knowledge in both plant and animals and included his field trip knowledge in his interview responses.

During the interviews Rod’s knowledge of the physical adaptations and survival behaviours of intertidal organisms can be summarized as follows:

- demonstrated a scientific understanding in his first interview of: crab hiding (under sand, under algae, immature found under rocks), aggression (use pincers, defense posture): oyster clamping down (muscle closes shell, protection from predators and desiccation): limpet shell (hard, colour, protection from predators) and suction-cup foot (sticks to substrate, small oval on foot, protection from predators): sole camouflage (colour, shape, mimicry),

- showed a progression in his knowledge of: crab camouflage (colour, shape, and antennae looks like algae), pincer waving (to attract mate, males are larger, warning sign), shell (hard, camouflage, strong), feeding strategies (scavenge, predatory, filter feeder): kelp holdfast (anchor, does not acquire food for algae, permanent anchor): oyster camouflage (colour, shape, design) and shell (hard, bivalve, protection from predators and desiccation): barnacle camouflage (colour, shape), shell (hard, sharp, protection from wave shock, predators, desiccation), and trap door (shuts at low tide, opens to feed, protection from predators): limpet clamping down (muscle attaches limpet to surface, protection from predators), camouflage (shape, pattern, colour), feeding strategies (grazer, eats algae, uses a radula): sole camouflage (changes colour and pattern to suit environment, shape),

- showed a change in his knowledge of: crab habitat (incomplete to confused): barnacle feeding strategies (incomplete to confused), glue (incomplete to confused): sole feeding strategies (incomplete to confused),

- demonstrated a confused understanding of: crab habitat (live only in rocky areas), hair (all crabs have it), life cycle (they stay under rocks until they are adults): kelp moisture retention (dies if dries out), kelp forest (kelp don’t live in groups), moisture retention (if they dry up they die): oyster habitat (they grow anywhere), habitat selection (they grow where they land), life cycle (they stay with their parents), and feeding strategies (they eat crabs): barnacle glue (they can un-stick), feeding strategies (they eat oysters) and life cycle (they always look like the grown ones): limpet hiding (you can find them anywhere), homebase (they don’t have any particular home spot): sole feeding strategies (they swim quickly after their prey). Comments in parentheses are examples of Rod’s confused knowledge,
• included in second and third interview additional information on: crab regeneration (regenerates lost or damaged appendage, occurs during molt, re-growth is smaller), molting (sheds shell to grow, entire exoskeleton shed), locomotion (swimming legs, crawling legs, burying legs), speed (swim, crawl, bury), male protecting female (holds female during mating and for protection during soft shell stage), shell (hard, strong, armour), pincer waving (attract mate, warning, communication): kelp camouflage (shape, colour, pattern), growth rate (fast growing, recovers from damage from storms and predators), seasonal die-off (occurs in winter), size (some species have long stems as they inhabit deeper water) moisture retention (see confused), kelp forest (see confused): oyster camouflage (colour, shape, mimicry resembles rock), glue (like cement, permanent), habitat (rocky areas with other oysters), feeding strategies (see confused): barnacle camouflage (colour, shape, mimicry), grouping (safety in numbers, protection from predators and wave shock), hitchhiking (attaches to whales and crabs, for protection and food source), habitat (intertidal, rocky areas), glue (made by animal), life cycle (see confused), feeding strategies (filter feeders): limpet hiding (under rocks), shell (hard, conical, protection from predators and desiccation), slime (creates slime trail), and feeding strategies (rasp algae from rocks): sole body shape (streamlined, indicates bottom dweller, changes as a juvenile), hiding (burying in the sand) life cycle (egg stage), feeding strategies (ambush),

• did not mention: crab blowing bubbles, gender change, life cycle: kelp holes in the blade: oyster gender change: sole slime, scales,

• concentrated on physical adaptations in the first interview. Included survival behaviours in the second and third interviews,

• demonstrated an equal understanding of both plant and animal adaptations, and

• mentioned the field trips and the log-table discussions in his interviews.
Table 5.
Changes in Student Knowledge - Rod

**Dungeness Crab (Cancer Magistrate)**

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<thead>
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<tr>
<td>Blowing Bubbles</td>
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<tr>
<td>Feeding</td>
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<tr>
<td>Habitat</td>
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<tr>
<td>Hiding</td>
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<tr>
<td>Male Protecting Female</td>
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<tr>
<td>Speed</td>
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</table>

**Physical Adaptations**

| Camouflage          | -               | -                | O               |
| Gender Change       | -               | -                | -               |
| Hair                | O               | -                | O               |
| Life Cycle          | -               | -                | O               |
| Locomotion          | -               | -                | O               |
| Molting             | -               | O                | O               |
| Pincers             | O               | O                | O               |
| Regeneration        | -               | -                | O               |
| Shell               | O               | O                | O               |

**Survival Behaviours**

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**Rock Sole (Lepidopsetta bilineata)**

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<tr>
<td>Hiding</td>
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</table>

**Physical Adaptations**

| Body Shape          | -               | O                | O               |
| Camouflage          | O               | O                | O               |
| Life Cycle          | -               | O                | O               |
| Migrating Eye       | O               | O                | O               |
| Scales/Fins         | -               | -                | -               |
| Slime               | -               | -                | -               |

**Giant Acom Barnacle (Balanus nubilus)**

<table>
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<tr>
<td>Hitch-Hiking</td>
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</table>

**Physical Adaptations**

| Camouflage          | O               | O                | O               |
| Glue                | O               | O                | O               |
| Life Cycle          | -               | -                | -               |
| Shell               | -               | -                | -               |
| Trap Door           | O               | O                | O               |

**Sugar Kelp (Laminaria saccharina)**

<table>
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**Pacific Oyster (Crassostrea gigas)**

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<th>First Interview</th>
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<th>Third Interview</th>
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<td>Colonization/Grouping</td>
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<td>Habitat Selection</td>
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**Physical Adaptations**

| Camouflage          | O               | O                | O               |
| Gender Change       | O               | O                | O               |
| Life Cycle          | -               | O                | O               |
| Shell               | O               | O                | O               |

**Rock Sole (Lepidopsetta bilineata)**

<table>
<thead>
<tr>
<th>Physical Adaptations</th>
<th>First Interview</th>
<th>Second Interview</th>
<th>Third Interview</th>
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<tbody>
<tr>
<td>Body Shape</td>
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**Unstable Limpet (Pelta instabilis)**

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<th>Third Interview</th>
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<td>Grouping</td>
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**Physical Adaptations**

| Camouflage          | -               | O                | O               |
| Shell               | O               | O                | O               |
| Suction-Cup Foot    | O               | O                | O               |

Note: Scientific (O), Incomplete (I), Confused (Δ), Not Mentioned (-)
Andy was a quiet participant in both the field trips and interviews. During the field trips he assumed the role of observer. He was intrigued by the aggressive behaviour of the shore crabs. Rather than actively participate in the staged "crab wars" Andy was content to watch. He had a wonderful ability to discover interesting beach finds as he cruised the high tide line searching for flotsam and jetsam. Andy's quest for intertidal knowledge was an individual experience. During the log-table discussions he offered numerous finds for discussion but rarely included his voice in the ensuing conversations.

During the interviews Andy physically examined the organisms which resulted in many of his responses focussing on the organisms' physical adaptations. As the interviews progressed he included more survival behaviours and demonstrated a significant amount of scientific knowledge in the crab, oyster, kelp, sole, and barnacle. A review of the interview data revealed that the majority of Andy's knowledge indicated a scientific or incomplete understanding. He began with his prior seashore knowledge and added new ideas as the interviews progressed. Andy was a "just the facts" student. He learned through individual observation and exploration. Andy initially did not articulate his knowledge but became more expressive as the study progressed.

### 4.8.1 Summary of Changes in Andy's Knowledge

Andy demonstrated either incomplete or scientific knowledge in his first interview. As the interviews progressed Andy included additional survival behaviours and physical adaptations and by his third interview included a majority of the categories in his
responses. During his interviews Andy demonstrated confused knowledge in two survival
behaviours and three physical adaptations and omitted five survival behaviours and seven
physical adaptations. Andy concentrated primarily on animal adaptations during his
interviews and used his field trip knowledge as examples in his interview responses.

During the three interviews Andy’s understanding of the physical adaptations and
survival behaviours of intertidal organisms can be summarized as follows:

- showed scientific understanding in his first interview of: crab camouflage (colour,
  shape, mimicry), speed (swims, crawls, buries): kelp holdfast (anchor, not a root,
  stationary): oyster feeding strategies (filter feeder, bivalve, eats plankton) and habitat
  selection (spat chooses habitat): barnacle trap door (opens for feeding, closes at low
  tide, protection from predators and desiccation), glue (made by animal, permanent,
  leaves a scar when barnacle is removed) feeding strategies (filter feeder, uses
  appendages as strainer, eats plankton): limpet slime (creates slime trail), suction-cup
  foot (protects from predators and desiccation, strong), habitat (algae rich area, rocky
  area, under rocks): sole camouflage (changes colour and pattern to reflect
  environment, flat shape), scales (protection from injury and predators), body shape
  (streamlined, changes as it matures),

- showed a progression in his knowledge of: crab aggression (uses pincers, defense
  posture, sharp legs), camouflage (colour, shape, design), molting (entire exoskeleton,
  new shell is soft, mating occurs), shell (hard, strong, curves), regeneration (of
  damaged appendages, occurs during molt, new growth smaller), pincers (strong,
  ridged), speed (swim, crawl, burying), aggression (pincers, defense posture, inflict
  pain): kelp camouflage (colour, shape, size), food source (algae, needs sunlight, not
  from holdfast), holdfast (not a root, stationary, glues on to hard surfaces), die-off
  (occurs in winter, during storms), size (bull kelp longest): oyster camouflage (colour,
  shape, design), shell (hard, glued on, adductor muscle to close), glue (like cement,
  secreted by animal, permanent), habitat (rocky areas, likes fresh water, sometimes on
  other oysters): barnacle camouflage (colour, conical shape, mimicry), shell (hard,
  sharp, secreted by animal), trap door (closes during low tide, opens to feed, protects
  from desiccation): limpet camouflage (colour, design, shape), suction-cup foot (oval
  disc on underside, sticks on, not permanent): sole scales (sharp, armour, slimy),
  camouflage (shape, mimicry, changes colour to suit habitat), body shape (compressed,
  indicates ground-fish, bottom dweller),

- showed a change in his knowledge of: crab habitat (incomplete to confused) oyster
  feeding strategies (scientific to incomplete),
demonstrated a confused understanding in: crab habitat (they only live in rocky areas), life cycle (they are born alive): oyster life cycle (young resemble adult): barnacle glue (they suck on), life cycle (young resemble adult): limpet feeding strategies (they eat plankton). Comments in parentheses are examples of Andy’s confused knowledge,

included in the second and third interviews additional information on: crab camouflage (colour, mimicry, shape), molting (sheds shell to grow, entire exoskeleton is shed, an invertebrate), regeneration (lost and damaged limbs replaced, occurs during molt, new appendage smaller), aggression (defense posture, raises pincers), and life cycle (egg stage): kelp camouflage (colour, design, shape), food source (an algae, requires sunlight for energy), die-off (occurs in winter), and size (bull kelp the longest): oyster camouflage (mimicry, colour, shape), glue (made by animal, permanent, like cement), habitat (with other oysters, intertidal, on and under rocks), life cycle (see confused), feeding strategies (filter feeder, eats plankton, uses siphon), and clamping down (uses muscle to close shells, protection from desiccation and predators): barnacle grouping (safety in numbers, small intertidal species group together), habitat (intertidal and subtidal, with other barnacles, rocky areas), hitchhiking (attaches to whales), camouflage (shape, colour, mimicry), life cycle (see confused), and feeding strategies (filter feeder, uses appendages to strain, feeds during high tide on plankton): limpet clamping down (uses muscle on foot, protection from predators and desiccation), slime (creates slime trail, visible, aids in locomotion). suction-cup foot (adheres animal to surfaces, protection from predators and wave shock), camouflage (colour, shell pattern, shape), shell (strong, hard, conical), and feeding strategies (see confused): sole migrating eye (eye moves to one side of head, becomes a groundfish, becomes flat), habitat (depends on species, hides under sand, bottom dweller), feeding strategies (ambushes), and hiding (burying in the sand),

did not mention: crab blowing bubbles, locomotion, male protecting female, gender change: kelp growth rate, moisture retention, and holes in the blade,: oyster gender change and grouping: limpet homebase and grouping: sole slime,

concentrated on the physical adaptations of intertidal organisms in the first interview. Included survival behaviours in the second and third interviews,

demonstrated comparable understanding of both plant and animal adaptations, and

mentioned the field trips and the log-table discussions in his interviews.
Table 6.
Changes in Student Knowledge - Andy

<table>
<thead>
<tr>
<th>Dungeness Crab (Cancer Magistrate)</th>
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<td>Suction-Cup Foot</td>
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Note: Scientific (O), Incomplete (D), Confused (Δ), Not Mentioned (-)
4.9  Hannah's Intertidal Voyage: An Anthropomorphic Experience

Hannah preferred to focus on one intertidal organism per field trip. She
concentrated on familiarizing herself with that animal using her own life experiences as a
guide. Each organism experienced life as Hannah did. Every animal had a family home
whether it be an overturned clam shell, a barnacle rock, or an empty bottle. Hannah
compared the crab molt to herself outgrowing a favourite outfit. The kelp “wore a little
coat to protect it from toxic waste”. The oyster’s protective shell was “like a ring with a
jewel”. The limpet’s shell “looks like a lampshade”, and the rock sole protected itself
from hungry gulls by “slapping them in the face with its tail”.

Hannah was an enthusiastic and willing participant of the beach walks and log-
table discussions. During one field trip she became acquainted with “Bob” a diminutive
hermit crab discovered living under a rock “with his extended family”. Hannah compared
his borrowed shell to wearing a garbage can on her behind. When Bob “jumped” out of
Hannah’s hand, she was devastated as she “didn’t get to say good-bye to him”.

During the interviews she revealed a significant amount of scientific knowledge.
Areas of scientific understanding included the crab molt, male protecting female, and
camouflage. She also accurately described the kelp holdfast as being able to withstand “a
water earthquake of waves and storms”. To describe the oyster’s feeding strategies
Hannah explained that “the oyster filters plankton from the water to eat”. Other areas of
scientific knowledge included Hannah’s discussion of the rock sole’s life cycle, mimicry,
and ability to breathe through gills.
4.9.1 Summary of Changes in Hannah’s Knowledge

Hannah demonstrated a scientific understanding of many of the physical adaptations and survival behaviours in her first interviews. Hannah demonstrated confused knowledge in seven survival behaviours and eight physical adaptations and omitted five behaviours and ten adaptations in her responses. Hannah’s plant and animal knowledge was comparable, and she used examples of her field trip experiences in her interview responses. Overall Hannah’s knowledge did not show a significant change over the three interviews.

During the interviews Hannah’s knowledge of the physical adaptations and survival behaviours of the intertidal organisms can be detailed as follows:

- demonstrated a scientific understanding in her first interview of: crab camouflage (colour and design of carapace, mimicry), molting (sheds shell to grow, occurs throughout life, new shell is soft), pincers (male has large colourful pincers, for defense and offense), shell (strong, hard, and domed), hiding (under rocks when young, under sand, in eelgrass), and aggression (attacks with pincers, body goes rigid, sharp appendages): kelp size (grows to reach sunlight, bull kelp longest, intertidal species smaller), holdfast (anchor, permanent, not a root), and moisture retention (holds moisture in, dries out at low tide, recovers at high tide): oyster habitat selection (spat chooses clean area with food and near other oysters): barnacle shell (hard, peaked, sharp): sole camouflage (changes colour and pattern to reflect habitat, flat shape) and body shape (streamlined, compressed, flat),

- showed progression in her knowledge of: crab male protecting female (occurs during molt, female has soft shell, male carries female): barnacle habitat (rocky areas, intertidal species are smaller, found with other barnacles): limpet habitat (algae rich, rocky, intertidal): sole migrating eye (occurs as a juvenile, eye moves to right or left side, fish can look above as bottom dweller),

- showed a change in her knowledge of: crab life cycle (incomplete to confused): kelp moisture retention (scientific to confused) and holdfast (scientific to incomplete to scientific): barnacle trap door (incomplete to confused), grouping (incomplete to confused), and feeding strategies (incomplete to confused): limpet feeding strategies (incomplete to confused), clamping down (incomplete to confused), and suction-cup foot (incomplete to confused),
• demonstrated confused understanding in: crab aggression (they bite), feeding (they eat algae only), hair (keeps crab warm) and life cycle (larva resembles adult), male protecting female (the male carries the female around): kelp die-off (dies all year), food source (eats plankton), growth rate (grows slowly), and moisture retention (if it dries out it dies): oyster life cycle (no larval stage), shell (it has to borrow a shell): barnacle trap door (stays shut at all times), grouping (barnacles live alone), feeding strategies (eat crabs), and life cycle (no egg or larval stage): limpet feeding strategies (they eat plankton), clamping down (they hold on with glue), and suction-cup foot (they glue on): sole feeding, (they eat plankton), life cycle (no egg or larval stage). Comments in parentheses are examples of Hannah's confused knowledge,

• revealed a steady state of knowledge in: crab camouflage (scientific), habitat (incomplete), molting (scientific): oyster shell (incomplete): sole habitat (incomplete),

• included in the second and third interview additional information on: crab regeneration (replaces damaged limbs, occurs during molt, re-growth is smaller), life cycle (egg stage), and speed (swim, crawl, bury): kelp food source (needs sunlight for growth), die-off (see confused), and rapid growth rate (see confused): oyster camouflage (colour, shape, mimicry) and life cycle (see confused): barnacle glue (made by animal), feeding strategies (uses appendages to feed), grouping (for protection), hitchhiking (attaches to whales), and life cycle (see confused): limpet hiding (under rocks and marine algae, in crevices) and shell (hard, strong, conical): sole migrating eye (eye moves to other side of head, fish becomes bottom dweller, can see above),

• did not mention: crab blowing bubbles, pincer waving, or gender change: kelp camouflage, holes in blade, and forest: oyster gender change: limpet homebase, grouping, and slime: sole scales and slime

• concentrated on both survival behaviours and physical adaptations,

• demonstrated comparable understanding of both plant and animal adaptations, and

• mentioned the field trips and log-table discussions in her interviews.
Table 7.
Changes in Student Knowledge - Hannah

<table>
<thead>
<tr>
<th>Dungeness Crab (Cancer Magistrate)</th>
<th>Rock Sole (Lepidopsetta bilineata)</th>
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<tbody>
<tr>
<td><strong>Survival Behaviours</strong></td>
<td><strong>Survival Behaviours</strong></td>
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<td>Blowing Bubbles</td>
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<td>Male Protecting Female</td>
<td>Physical Adaptations</td>
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<td>Body Shape</td>
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<td>Camouflage</td>
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<td>Life Cycle</td>
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<td>Migrating Eye</td>
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<td>Scale/Fins</td>
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<td>Slime</td>
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<td>Locomotion</td>
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<tr>
<th>Giant Acorn Barnacle (Balanus nubilus)</th>
<th>Sugar Kelp (Laminaria saccharina)</th>
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<tbody>
<tr>
<td><strong>Survival Behaviours</strong></td>
<td><strong>Physical Adaptations</strong></td>
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<td>Colonization/Grouping</td>
<td>Camouflage</td>
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<td>Feeding</td>
<td>Food Source</td>
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<td>Habit</td>
<td>Holdfast</td>
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<td>Hitch-Hiking</td>
<td>Holes in Blade</td>
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<tr>
<td>Physical Adaptations</td>
<td>Kelp Forest</td>
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<td>Camouflage</td>
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<td>Moisture Retention</td>
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<td>Life Cycle</td>
<td>Rapid Growth Rate</td>
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<td>Shell</td>
<td>Seasonal Die-off</td>
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<td>Trap Door</td>
<td>Size/Length</td>
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<th>Pacific Oyster (Crassostrea gigas)</th>
<th>Unstable Limpet (Pelta instabilis)</th>
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<td><strong>Survival Behaviours</strong></td>
<td><strong>Physical Adaptations</strong></td>
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<td>Colonization/Grouping</td>
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<td>Clamping Down</td>
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<td>Feeding</td>
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<td>Habitat Selection</td>
<td>Hiding</td>
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<td>Physical Adaptations</td>
<td>Home Base</td>
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<td>Camouflage</td>
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<td>Gender Change</td>
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<td>Shell</td>
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Note: Scientific (O), Incomplete (□), Confused (Δ), Not Mentioned (-)
4.10 Summary of Changes in Student Knowledge

Five of the six voyageurs showed a progression in their seashore knowledge (Hannah was the exception). I observed that the students' understanding of the physical adaptations and survival behaviours of intertidal organisms became more scientific, and they included new seashore knowledge in their interview responses as they progressed through the study. In some areas the students' knowledge changed from scientific to incomplete. I designated a student's knowledge scientific if they included three correct facts concerning the survival behaviour or physical adaptation. Student knowledge was categorized incomplete if an important fact was "missing" in the student's response. Therefore, I interpreted a change in student knowledge from scientific to incomplete as an omission of knowledge rather than a decrease in the students' overall understanding.

The students showed some change from incomplete to confused knowledge during the interviews, and in two instances there was a change from scientific to a confused understanding (Dan was the exception). It is difficult to say why these changes occurred. It is possible that as the students tried to make sense of new information they became confused due to "information overload" or to the perceived challenge of their previously held ideas. Changes in student knowledge may also be attributed to the student's physical or emotional well being during the interviews or the state of flux which can arise with the introduction of new knowledge.
Chapter 5: Styles of Knowing
An Analysis Of Student Language

5.1 Introduction

As each student experienced their intertidal voyage a distinct style of knowing emerged. For the purpose of this study a style of knowing is defined as the expressive role a student assumes to articulate their knowledge of the physical adaptations and survival behaviours of selected intertidal organisms. The style of knowing acts as a conceptual framework which enables the student to make sense of their seashore knowledge. During the field trips and interviews the students expressed their distinct styles of knowing through descriptive language.

The students’ styles of knowing are similar to the orientations Snively (1986) explored in her study on metaphor. She defined an orientation as “an interpretive framework” which is constructed by an individual to understand and experience their world. Snively stated that children create meaning and develop understanding when describing their experiences through language and make sense of experience through metaphor. During “An Intertidal Voyage” the voyageurs held specific orientations or styles of knowing which directed the manner in which they created meaning and interpreted knowledge. In reading the interview transcripts these styles became evident and were given descriptive titles as follows: Dan and Cathy assumed the roles of The Scientists. Hannah and Nancy became the Aesthetes. Rod and Andy were The Warriors.
In this chapter the students' language is presented as a verbal portrait of their style of knowing. Their language is represented using data from all events to show examples of metaphor and the styles of knowing.

5.2 The Aesthetes: Hannah and Nancy

"Humans are the admirers, reflectors, imitators, lovers, protectors. Humans are aware of beauty or ugliness in nature. Pertaining to, an artistic interpretation of nature: art, music, poetry, drama, dance, etc. (Snively, 1986, p. 57).

Nancy and Hannah expressed an aesthetic appreciation and interpretation of the seashore. Hannah, the analogist, compared the intertidal organisms' survival strategies to her own life experiences using descriptive language and creative analogies. Nancy, the visual artist, described her beach thoughts and experiences through each organism's shape, design, pattern, and colour.

5.2.1 Hannah: The Analogist

Through colourful and personal analogies Hannah described the survival and adaptation strategies of the intertidal organisms. Hannah's responses were placed into three categories. Her responses included analogies pertaining to her personal life experiences, detailed descriptions of each organism's colours and shapes, and engaging stories concerning the inhabitants of the intertidal zone.

Hannah compared her own life experiences to those of the organisms' investigated in the study and used them to make sense of the organisms' adaptation and survival
strategies. During one of the field trips Hannah encountered a hermit crab which she christened "Bob". When asked how a hermit crab's borrowed shell differed from that of our interview subject the Dungeness crab, Hannah explained that the hermit crab chose a shell in the same way we would "sit on a garbage can and then get up with the can still stuck on our behind!". When detailing the Dungeness crab's plight of outgrowing its old shell Hannah used her own experience of "outgrowing a space" to explain the molting phenomenon. "It's like when you're about four years old and you're playing inside a box. A few years later when you're about seven you don't fit in the box anymore!" Not yet recognizing the crab's planktonic larval stage, Hannah described "baby" crabs as living on their own "buried in the sand until they grow a shell, and they don't live with their Mom and Dad."

The slime of the bull kelp reminded Hannah of her vinyl raincoat, and when she touched the alga it felt like "noodles overcooked by twenty minutes". Hannah suggested that the kelp could be tested for "doneness by throwing it on somebody's back who was wearing a swimsuit". If it stuck, the kelp was done! Hannah compared the kelp stipe (stem) to the tasty cheese strings from her lunch. The blades were like the fronds of a palm tree or "just like the big feather pen in the movie 'The Pursuit of Happiness' ". Hannah compared the intricate "microhands" of the holdfast to a candle holder and described the structure's "multiarmed" form as "the holdfast is like when your body is stiff and trying to stretch out, like an octopus you have eight arms. A holdfast is like a decapod, no, a centapod". Hannah believed that kelp had the ability to migrate to new growth sites "like a football team that has given up". If the kelp became stranded on a
beach the eventual desiccation was "like going a day without food or having chocolate milk for a week".

The white conical patches of barnacles reminded Hannah of the "mountains on the Coquihalla highway". When describing the affects of the changing tides on the barnacle Hannah reported that at high tide the crustacean is covered and protected so it "must feel like it's wearing winter clothing". Low tide was "like a T-shirt" as the barnacle was exposed to the elements and predators. When asked to expand on the shell's protective properties Hannah compared barnacle's outer structure as "a toilet paper roll capped on one end with construction paper". The shell's trap door was "like a ziplock baggie" which kept the barnacle safe from predators. Hannah chatted about the varying sizes of barnacles and remarked that "their diet makes them small ... if you gave them a hamburger a week, just like people they would grow". Hannah concluded that the barnacle's family life consisted of the "babies moving into their grandparents' house, and they can pass the shell down from generation to generation".

The luminescent mother of pearl inside the oyster shell reminded Hannah of the hologram image she saw on a credit card. She described the oyster shell as a well appointed home complete with fluted "ceiling", "chalk-white floors", and "polished walls". According to Hannah the shell's glistening interior was "tidied" by the bivalve during "spring cleaning". The predatory oyster drill which consumes the oyster after drilling through the bivalve's shell was compared to a "multi million dollar company who wants to demolish your house and build a warehouse".
Hannah's observations compared the domed shell of the limpet as a "jewelled ring shaped like a pyramid". She knew that the shell was integral to the limpet's survival as it helped the animal avoid desiccation. "Limpets have sensitive skin. It's like too much tanning is bad for your skin." A dried out limpet was "like the gum you find stuck under tables in restaurants".

According to Hannah the starry flounder at the Vancouver Aquarium was "extremely lazy as it lies around all day taking naps and waiting for food". She compared the fish's spiky dorsal fin to "little paintbrushes standing on end". The flounder's unkempt appearance was explained as "a bad hair day". Hannah's interpretation of the function of the small pectoral fin located on the animal's underside was unique. "It's a booster just like on an old car" and it enabled the fish to travel from rock to rock. When explaining why most intertidal organisms feed during high tide Hannah remarked that is was "like going shopping on sale". There was "lots of food available at a low price".

"I know it's a Dungeness because of its shape and colour." Hannah made her intertidal species identification through each organism's camouflaging colours, decorative hues, and distinctive shape. Her aesthetic observations enabled her to classify organisms into distinct species. When discussing the Dungeness crab, Hannah was able to distinguish male from female and identify immature individuals by employing her observation skills. Hannah's language expressed her knowledge of sexual dimorphism in crabs. "The female has a pointy triangle, a lighthouse, underneath. That's where the eggs come out." When I asked Hannah how she knew our crab was a Dungeness she used the distinctive colours and shape of the crab's carapace to identify the species. "The orangey-brown top shell has
a turkey leg pattern on it." Hannah added that the red rock crab's shell sported a different shape and was dark red in colour.

During the interviews Hannah expressed a wonderful ability to play with words. Through rich, illustrative comparisons Hannah described the inhabitants of the intertidal zone. A predatory gull was referred to as a "bay-gull which people may mistake for a little bread food and call it a bagel!" A female shore crab carrying her multitude of glistening black eggs was like "crabiar".

5.2.2 Nancy: The Visual Artist

Nancy was the visual artist. Her identifications and explanations of survival and adaptation strategies were made through the examination of each organisms' patterns, colours, and shapes. "Each crab has its own design. This one looks like a happy face." The camouflaging characteristics of the crab's shell and appendages were described in terms of the colours. The crabs "arms" appeared to be "wrapped in saran wrap." Nancy easily distinguished the Dungeness from the red rock crab. "The pincers of the Dungeness are trimmed in white. Red rock crabs have black tipped pincers, and the rest of the Dungeness crab is orangey white and chalky white." The cilia or hair which covers the legs and front of the Dungeness crab was compared to a "grizzly bear" or "goat fur". Nancy easily identified immature crabs as "baby crabs" were not as "colourful, bumpy" or as "hard as old crabs". Nancy was eager to explain the symmetrical characteristics of the crab's shell. "On a crab if it still has all its legs and stuff you could cut it right down the middle and you would have perfect sides."
Nancy enthusiastically described the myriad of colours exhibited by the various species of marine algae she encountered. "Sea lettuce is a frilly parsley green." Brown algae was "cow coloured kelp". The holdfast was the "tentacle ball" which held the "tissue paper" fronds in place. She was able to differentiate the indigenous native oyster from the imported Giant Pacific oyster by analysing the shape, colour, and design of the bivalve's shell. The "flat, wide, and bumpy" Giant Pacific oyster shell was unlike the "purple-white tall, thin shell" of the indigenous species. Nancy expressed an interest in examining the luminescent layers of mother of pearl under a microscope when she returned to the classroom. The soft bodied oyster animal reminded Nancy of "two jelly beans mashed together".

Nancy categorized limpet species by their shape, either oval or round, and by their "zig zag" or "checkered patterns". The inside of the shell was "ringed with swirly purple, white and silver like the oyster shell". Nancy identified old limpets by their "thick and dull" shells. Young limpets were decorated with "bands of fresh and lively colours". The delicate blue grey limpet shells reminded Nancy of her Dad's teacups.

Nancy christened barnacles the consummate "shape shifters". She described the familiar crustaceans as "either tall like miniature ribbed columns or flat and squashed looking, depending on where they live". Their ribbed outer shells reminded her of "spaghetti strands all stuck together". The animal's chalky outer shells would "make great sidewalk chalk". Nancy surmised that barnacles attach themselves to rocks by "using sharp toothpick-like feet which stick in".
Nancy's aesthetic description of the starry flounder included a "sideways mouth", "thick lipped jaws", "spiky teeth", and "octagonal patterned skin". The fish's translucent tail was "just like sushi grass". Nancy was intrigued with the flounder's ability to change its skin colour to match the surrounding habitat and was well versed in the art of countershading. She described the camouflaging benefits of a darker dorsal surface contrasting with a lighter underside. Nancy's favourite characteristic of the starry founder was the design.

5.3 The Scientists

"Humans are the observers, identifiers, quantifiers, predictors, theoreticians, experimenter, controllers. Humans and nature are interconnected and dependent on one another for survival." (Snively, 1986, p. 57)

As Snively illustrated in the above lines, all individuals interact with nature. The scientist interprets the seashore through knowledge of the relationships among its living inhabitants. Two of the voyageurs, Cathy and Dan, viewed the intertidal zone from a scientific orientation.

Cathy and Dan described their beach experiences and the survival behaviours and adaptations of the organisms through descriptions of the interdependency and interconnectedness between humankind and nature. Much of their seashore knowledge was gleaned from books, trips to the Vancouver Aquarium, class field trips, and personal experience. Cathy and Dan viewed the seashore from a scientific orientation which was
reflected in their language as they discussed the organisms' physical adaptations and survival behaviours.

Cathy was the practical or "utilitarian" scientist as she enjoyed investigating, researching, and sometimes eating the inhabitants of the intertidal zone. Her knowledge was derived from reading books and visiting the Vancouver Aquarium, beaches, and restaurants. Cathy was an avid field trip participant and particularly enjoyed asking questions and relating her own beach experiences. Her language concentrated on the interactions between organisms. Dan was the research scientist. His information was derived from books, the Internet, television documentaries, and family trips to the Vancouver Aquarium and city beaches. Dan was well versed in biological classification as he often referred to the phylum and class of the intertidal organisms.

5.3.1 Cathy: The Practical Scientist

During the interviews I determined that much of Cathy's beach knowledge originated from books, trips to the Vancouver Aquarium, and personal experience. Cathy was the practical scientist as her descriptions and explanations were biologically based but influenced by her personal experiences involving the fishing and eating of seafood. Her explanation of the cast-off phenomenon was accurately described during the interviews. "The shell is lightweight and it doesn't smell. That's how I know it's a cast-off." During her detailed explanation of the crab's molt Cathy compared the shedding of the crustacean's shell to a snake shedding its skin. She described the male crab's protective behaviour during mating. "The male, the one with the pointed abdomen, holds the female
until her shell hardens. They mate when the shell is soft." She discussed the crab's other adaptation strategies including the shell's ability to protect the animal from predators and desiccation. "When a crab starts blowing bubbles at you it's saying, 'Time to put me back in the tidepool!'"

Cathy quickly determined that kelp was an algae which needed sunlight and proper water conditions to grow. The kelp blade which Cathy referred to as "a rubbery lasagna noodle" avoided desiccation during low tide by "holding moisture in". She realized the holdfast acted as an anchor to stabilize wave tossed kelp. "It hooks onto rocks so it won't be carried away." Cathy remembered seeing the bryozoans or moss animals which lived on the kelp. "They are small grey spots which get food and protection from the kelp" During our beach trips the moss animals were a common sight on the rotting blades of kelp.

The highlight of Cathy's oyster discussion was the animal's ability to change gender. Cathy had read about this fascinating phenomenon and eagerly discussed the hermaphroditic oyster. During the field trips she discovered the adhesive qualities of oyster glue. "You need a crowbar to get them off the rocks because they have sticky tabs which hold them on." She observed gulls dropping the bivalves on the rocks to break open the protective shells. Cathy knew that oysters fed on plankton by "using their tongues to get them out of the water". Our oyster discussion concluded with Cathy mentioning that they make great bait for fishing.

"This must be a giant acorn barnacle. It's so big!" Cathy quickly identified the interview barnacle as an unfamiliar species. The barnacles encountered during the field
trips were the smaller acorn and thatched barnacles. Cathy added that barnacles "stay put forever". She had observed a barnacle feeding at the Vancouver Aquarium and enthusiastically described the process. They feed by "opening their trap door and sticking out their tongue a few times to catch plankton". Cathy discussed the barnacle's ability to "hook onto whales for protection and a free meal". She also mentioned the circular scars the barnacle shell leaves on rocks, marine algae, and whales.

During our beach trips Cathy exhibited a particular interest in limpets and acquired a rich knowledge of the small gastropod through independent research. She delighted in discovering limpets hidden under rocks and secreted within crevices. She examined the small body inside the conical shell and discovered that it was similar to a land slug as it had "one big foot". Cathy mentioned that limpets were difficult to remove from their home rock, but she had observed crows and gulls plucking them from their homebase using their bills as a "lever". Cathy discussed the limpet's feeding strategy during high tide. "They cruise the rocks snacking on algae and leaving small trails along their rock highway."

The migrating eye of the starry flounder was the highlight of Cathy's flatfish discussion. She explained that the "sideways eye" enabled the fish to hunt and watch for predators while lying buried in the sand. "My Dad caught one once and it looked like it was drunk!" When she discussed camouflage Cathy mentioned that the flounder's "checkerboard and gravel pattern" enabled the fish to blend in with its surrounding environment. It "perfectly matched its living space". Cathy's summary of the flounder's appearance was "it looks like it's been in a accident". During her interviews Cathy's also
mentioned fishing expeditions with her Dad, and encounters with sandlances and sculpins during excursions to the Vancouver Aquarium and local beaches.

5.3.2 Dan: The Research Scientist

Dan's descriptions of the intertidal zone and its inhabitants were also based on a scientific orientation. His interview responses contained biological terms but were flavoured with descriptive language and metaphor. Dan emphasized the interconnectedness and interdependency of organisms. Dan spent a large amount of time on the Internet "looking up seashore stuff". He also enjoyed reading books and watching television programmes on marine life and was a frequent visitor to the Vancouver Aquarium and neighbourhood beaches.

Dan's penchant for scientific language was evident in his description of the Dungeness crab. The crustacean was the "decapod" which used its "chilepeds" to defend itself in battle. His explanation included a detailed explanation of sexual dimorphism in crabs. "Females are all feathery inside the abdomen. Those feathers hold the eggs in." During the interviews Dan delighted in providing information on the crab's scientific classification. "They are very distantly related to arachnids and insects in the fact that they are all arthropods, and they are part of the crustacean family." Dan compared the crab's molt to our own growth patterns. "They molt because their skin gets too tight. It's like our skeleton because it doesn't grow. It adds on. It's like that feeling you get when your sneakers are too tight." Dan also mentioned the role of the crab's shell in moisture
retention, the regeneration of lost or damaged limbs, and the crustacean's speed swimming ability.

Dan immediately recognized the kelp as an algae. "They look like plants, but they're not quite. They're algae and their cells need light to survive. They don't have seeds." Dan's knowledge of kelp survival strategies included the role of the hold fast. "It acts like a boat anchor, another adaptation for living in a wave torn environment." Dan also mentioned the giant bull kelp and compared the perforated blade of the silk eyelet kelp to "a block of holey Swiss cheese".

During the interviews Dan explained the detailed relationship between marine algae and other marine organisms. He recognized the importance of the sea otter in the survival of a kelp forest. "A lot of kelp have developed really thick stipes so it would take the sea urchins a long time to go through it. By that time the sea otters go down and have a beautiful breakfast of sea urchins." Dan was aware that limpets and nudibranchs grazed on the kelp. He added that these organisms were not a real threat as the kelp grew very rapidly like "yeast in a loaf of bread".

Dan quickly identified the interview oyster as a Giant Pacific oyster. He pointed out the umbo near the shell's hinge and "the smooth pearly area where the adductor muscle was located". Dan enthusiastically related the saga of the deadly oyster drill. "They have no defense against those guys because even burrowing won't get them off." Dan also described how gulls and crows smash the oyster by dropping them from the air and how the oystercatcher "sits and waits for the oyster and then stick their beaks in and go yum yum!". Aware that the oyster is a filter feeder Dan compared the bivalve's
method of straining food from the water to the feeding strategies of baleen whales. "Filters it out like baleen, sorts out the water and keeps the animals inside."

During his interview Dan identified the barnacle by its "overlapping plates", and discussed the barnacle's planktonic larval stage. "They will go around in the plankton stream until they find a nice place to stay and then attach their front appendages and just stick there." The animal then glues its hard shell to the substrate with "it’s cement thing". Dan recognized that the barnacle’s shape was partially influenced by its habitat. "Too many barnacles or overcrowding causes the barnacles to have an unusual shape. This shape (long and thin) is unnatural. It is the cause of too many spat coming into an area.” Dan added that barnacles also select plankton feeding whales as a home base. “It’s a great way of getting a free meal, protection, and a ride at the same time.”

"Limpets are a type of sea snail with a radula. They are molluscs and gastropods." Through independent research Dan learned that limpets inhabit both the low and high tide zones. "They make little fox holes so when low tide comes they just go into the foxhole." Clamping down into their foxhole also protects the limpet from "predatory snails", gulls, "water loss, and exposure". Dan was able to determine the limpet's age by counting the "growth rings" on its shell. They move about using their foot "unlike their cousins the oyster and clams who also have a foot but it’s for digging".

Dan's flounder knowledge was extensive. He was aware that there were both right eye and left eye species of flounder. The sandab, "a fish you never hear much about", was a left eye flounder, and the interview specimen was a "right eye flounder". At the Vancouver Aquarium Dan observed that a flat fish easily disappears into its surroundings
due to its "colour pigments". He added that they used "electroreceptors" in their lateral line to "feel" the presence of both predators and prey. These "little pores" were similar to those of sharks, but the flounder “only needed them on one side of its body”. Dan concluded his flat fish discussion by stating that the interview fish was a true flounder. "Not like the one in (the movie) 'The Little Mermaid'. That thing was no flounder. It was too fat!"

5.4 The Warriors

Life is a battleground. Every limb is a weapon. Every shell is a shield. The warrior’s motto of the intertidal zone: Attack or be eaten!

Two of the voyageurs, Rod and Andy, were intrigued by the aggressive nature of many intertidal animals. They understood the dangers of living in the intertidal zone and discussed the organisms in terms of their ability to protect themselves. Crabs were their favourite seashore inhabitant. During the field trips the two students constructed crab war zones by placing rocks in a circle. Male shorecrabs, chosen for their "big pincers", were then placed in the "arena". "Let the games begin!" Andy and Rod were disappointed with the outcome as their troops of shore crabs retreated under the rocks preferring concealment to battle.

The warriors were aware of the dangers of an outgoing tide. They discussed how intertidal organisms actively defended and protected themselves from heat, cold, desiccation, predators, pollution, and man. Rod and Andy viewed the beach as a battleground where the inhabitants were designed to protect themselves from the many dangers.
Both students chose language which reflected their warrior interpretation of the intertidal zone. The morphology of each organism was described in terms of size, strength, and armament, and the animals' behaviour was explained in terms of aggression.

5.4.1 Rod: The Strategist

Rod was fascinated by the survival strategies of the intertidal organisms and combined his knowledge of defense strategies with biological information. The interview crab reminded Rod of captive crabs he encountered at a local shopping mall. "They had rubber bands on their claws so they couldn't snap at you." Rod suggested that crabs attacked their predators and prey by using their claws to "break its back or shell by pinching it". He was aware that "pincers could be used to hold food or for defense" and added that claws acted as "a warning signal" to prospective challengers. Rod stated that larger crabs were "meaner" than smaller individuals, but he preferred smaller crabs as he could "play with them". Rod correctly identified the crab's hard carapace as an exoskeleton. "Crabs have an outer skeleton, an exoskeleton, like ants have." He added that crabs used their tough carapace as a defensive shield against predators such as gulls and man.

While discussing kelp Rod mentioned that living kelp felt like rubber. He added that the holdfast prevented the algae from floating to the surface "where predators could get them". He knew that kelp "absorbs stuff like plants do" and needed "sun and water to help it grow". The moss animals which covered the kelp blades reminded Ross of "fossils that look like Egyptian writing". After observing a kelp tank at The Vancouver
Aquarium Rod was fascinated by the numerous organisms which relied on the kelp forest for survival, food, and protection. Rod surmised that kelp grew in great forests “so they could protect each other and maybe wrap their stems around predators and strangle them”.

During the interviews Rod incorporated his personal experiences into his responses. He had observed gulls carrying shellfish high into the air and then "smashing them on the rocks". He knew that the “deadly” oyster drill "drilled into the shell and sucked out" the living bivalve. Rod believed the oyster's best method of defense was "clamping the two shells together so no one could get in without drilling or breaking the shell".

"Blistering barnacles" was a quote Rod remembered from pirate movies. He believed the barnacle's best method of defense was "its little door which shuts out the predators". That same door allowed the barnacle to "open up, wave around, and get something to eat and then come back in". During a field trip Rod observed barnacles living in a rock indentation which he referred to as a village. He stated that living in a group was good protection for them and kept the barnacles from getting "too hot and bored". Rod was fascinated by the large size of the giant acorn barnacle. "It would have been neat if a big one like this was in the middle, and then the little ones were on the outside, and this one was like the leader." He added that he would not live near such a large barnacle as it would "take all the food and there wouldn't be much left over".

Rod was impressed by the tenacity of limpets. He noted that they were extremely difficult to remove from their home rock. During the field trips Rod observed that the
animal's suction cup foot acted "like a plunger". "It sticks, and I was too afraid to put it on my finger because it might stay there." He stated that the inside of the animal contained "guts of some kind like a slug" and added that the limpet was well equipped against predators and only the "oysterdrill" could attack it successfully. Rod believed the limpet "probably sucked out barnacles" from their shells or "they might eat algae". During the field trips Rod often found barnacles grouped together. He surmised that they were "probably like sheep. They stay together so the wolf can't get them".

While on fishing trips with his Dad, Rod encountered many fish species including flatfish. He remarked that the flounder with its "funny eyes" was a good eating fish. Rod identified the nostrils, gills, and sideways mouth of the interview fish as being similar to the flat fish he encountered during a field trip. He predicted that the flounder's flattened body and skyward gaze would help the fish hide and then "ambush its prey". The fish's swimming style reminded Rod of a hovercraft as it "glides across the bottom". Rod's favourite aspect of the flounder was the eyes as they "looked neat and were designed for hiding".

5.4.2 Andy: The Survivalist

Andy was keenly aware of the physical characteristics which enabled organisms to protect and defend themselves. During the interviews he thoroughly examined each organism before offering his views on its survival adaptations and strategies. Andy believed that each intertidal organism both plant and animal made a conscious decision
concerning its survival. Barnacles and limpets “chose” a home base, and kelp “picked” a growth site “far away from enemies”.

The crab was Andy’s favourite animal as it was built for battle and survival. Andy carefully examined the interview crab while he discussed the animal’s adaptations and survival strategies. He stroked the “fur” on the underside of the carapace and commented on its ability to “catch things” for the crab to eat. The animal’s armoured pincers were built for “fighting other animals and for catching food”. Andy added that the crustacean’s tough shell was “just like a warrior’s shield” and its colour enabled the animal to conceal itself in the sand and under rocks and algae. As Andy peered inside the crab’s mouth he remarked on the animal’s “fangs” or mouthparts. He added that the “spikes” along the outside of the animal’s back shell helped to protect the crab in battle. Andy particularly liked the Dungeness crab as the adults were “big, fast, and powerful”.

Andy explained the kelp in terms of its survival strategies. He realized that the kelp’s holdfast functionned as an anchor. When an enemy attacked the kelp Andy predicted that the alga would be able to pull itself out of danger using the holdfast as a weight. He added that the kelp also protected itself from predators through camouflage and its ability to grow in large, protective groups or forests.

Andy observed that the “hard, thick, and bumpy” barnacle was well designed to withstand enemy attacks. He commented that during low tide the barnacle’s trap door remained closed to avoid predators, and it opened up at high tide to trap its food. It chose to “stay close to other barnacles for protection”.

When he discussed the oyster and limpet Andy’s favourite topic was the notorious oyster drill. He delighted in describing the predatory mollusc’s ability to bore through the shell of its prey and consume the hapless animal inside. Andy commented that if the oyster cemented itself between two rocks or “lived in a small space” it would be difficult for the drill to attack. The limpet had the ability to “suck onto anything” making it “impossible to get off”. He concluded that the hard, thick shells and camouflaging colours of the oyster and limpet enabled them to elude other predators including birds and fish.

Andy enthusiastically discussed the flounder. He observed the fish was well armoured and pointed out the animal’s rough skin and dorsal spines. Andy explained that the fish’s eyes migrated to one side as it was “easier to see enemies and attack when you live on the bottom of the ocean”. He mentioned that the fish’s flattened body shape and camouflaging colour were perfect for “hiding out” or “waiting to ambush”.
6.1 Discussion

This study provides an understanding of six childrens’ developing knowledge of the physical adaptations and survival behaviours of selected intertidal organisms. As the students experienced “An Intertidal Voyage” their changing knowledge of the physical adaptations and survival behaviours of intertidal organisms was developed and interpreted through a variety of ways.

The field trips gave the students the opportunity to experience the life of intertidal organisms. They handled an acrobatic purple shore crab and observed the glistening egg mass of a female “in berry”. Tidepool investigations enabled the students to watch the feathery appendages of a feeding barnacle and the antics of the personable hermit cruising in his mobile home. During high tide the students were able to explore the flotsam and jetsam of the spray zone. Many fascinating beach finds were discovered hidden among the tangled mounds of bull kelp and barnacle scarred beach logs. Energetic amphipods exploded from their subterranean abodes, and on one occasion, the disembodied head of a starry flounder peered from beneath a blanket of sand, shells, and driftwood.

The log-table discussions provided the students with the opportunity to display their beach finds and share their experiences and knowledge. A significant exchange of knowledge occurred as the children reported on their “Wow!” discoveries. They detailed the events leading to the find, their knowledge of the organism, and personal reflections. The discussions also prompted interest in further intertidal investigation through in-class
discussion, experimentation, as well as individual and group research via books and the Internet.

The interviews provided insight into the students' scientific knowledge and styles of knowing. An analysis of the interviews indicated the extent of the students' knowledge before, during, and after the field trips. The interview data documented the changes in the students' knowledge of the physical adaptations and survival behaviours of the six intertidal organisms and showed that the students showed an increase in some or all of their intertidal knowledge.

The interviews also opened a window into the students' orientations or styles of knowing. By examining the students' metaphorical language it was possible to identify the aesthete, the scientist, and the warrior. The students' styles of knowing directed the manner in which they understood the physical adaptations and survival behaviours of the six intertidal organisms.

6.2 The Findings

The data suggest that the field trips enhance student understanding of the physical adaptations and survival behaviours of intertidal organisms. In a majority of areas the students' seashore knowledge became more scientific, and they included additional survival behaviours and physical adaptations as they progressed through the interviews. Snively (1986) documented similar changes in student understanding in her study "Sea of Images". From a constructivist viewpoint the study revealed that the students used their prior seashore knowledge as a basis for the creation and interpretation of new knowledge
acquired during the field trips. The variability among the students’ seashore knowledge may be due in part to the complexity and richness of the learning environment.

Though the students’ scientific knowledge progressed during the study their styles of knowing did not change. The aesthetes, Nancy and Hannah, retained their aesthetic appreciation and interpretation of the intertidal organisms. The warriors, Rod and Andy, continued to perceive the intertidal organisms in terms of their defensive and offensive capabilities. The scientists, Cathy and Dan, maintained their scientific interest in and understanding of the physical adaptations and survival behaviours of intertidal organisms throughout the study. “An Intertidal Voyage” supports Snively’s findings that changes in student knowledge did not affect their orientation. Both studies revealed that student knowledge became more scientific, but their orientation or style of knowing remained constant.

During their intertidal voyage the students expressed their developing seashore knowledge through descriptive language. Snively (1986, 1995) and Lakoff and Johnson (1980) found that students used descriptive language and metaphor to explain and interpret their knowledge. In her analysis of student language Snively (1986) found that students held orientations which helped them create meaning and develop an understanding of seashore phenomena. In this study the voyageurs held similar orientations which I defined as styles of knowing.

“An Intertidal Voyage” supports Lave and Wenger’s (1980) conclusion that children learn in social situations. The field trips and log-table discussions exemplify a group learning situation which occurred in the field. The students used their prior
experiences and ideas to construct knowledge of new phenomena and employed conversation and discussion as a method of conveying that knowledge. Student learning was situated in the authentic activity of exploring the seashore. In the language of situated cognition my role could be seen as the facilitator, and the voyageurs’ role was that of the cognitive apprentice.

The field trip data also support Carlisle’s (1985) observation that children will begin exploration as an individual process and then assume a teaching role to share their experiences with others. The voyageurs became intertidal tour guides as they introduced a group of younger beachcombers to the seashore during the final field trip, A Teaching Day.

The field trips also provided an opportunity for the students to develop an environmental stewardship for the seashore. Students who originally viewed the beach as a playground began to see the seashore and its inhabitants as an intertidal community which must be preserved and protected. Within their hearts and minds the voyageurs held a unique “keepsake” of their personal intertidal voyage (Jolie Mayer-Smith, personal communication, August 28, 1997).

6.3 Implications For Teaching

“An Intertidal Voyage” provides evidence that students learn through direct experience. Students learn during field trips as they explore, observe, and share their knowledge through discussion and conversation. One way students interpret and express their knowledge is through their styles of knowing. Educators may benefit from this
finding by implementing environmental studies programmes and encouraging group learning and discussion. Teachers may find that by acknowledging a student’s style of knowing they support the student’s ability to express knowledge in their own language.

This study may help educators design and implement beach field trips and pre and post field trip activities as it provides ideas on how to assess student learning during a field trip. Students link their prior knowledge to new learning through various methods, and educators may wish to encourage students to express their ideas through art, drama, and creative writing. Students and teachers can collaborate on a field guide featuring local flora and fauna with the students’ language and illustrations included in the descriptions of the various species. Educators may discover that the incorporation of field work in the school curriculum can instill an environmental ethic within their students.

The presence of a guide or facilitator was an important part of “An Intertidal Voyage”. Educators may wish to adopt the tutor role as an additional teaching style, and use questioning and discussion techniques designed to probe student understanding and guide discovery learning.

6.4 Future Research

Exploring the seashore yields a wealth of information. Not only does it provide a glimpse into the world of the intertidal zone it also introduces areas for further investigation. After the final interviews I pondered many questions. I wondered if the voyageurs would continue to visit the seashore after our beach days ended. Would they continue to develop a sense of stewardship for the environment? Would their interest
extend to other areas of the environment? Would their new found knowledge encourage them to visit the beach with their family and study the marine environment through books and audio-visual materials? All these questions comprise ideas for future research.

"An Intertidal Voyage" investigated a small number of students. A larger study of children’s seashore knowledge could incorporate gender, cultural, global, and indigenous peoples’ issues as additional research areas.

Researchers may also investigate how situated learning through field trips can be integrated into other areas of the curriculum such as mathematics, social studies, and language arts. Further research could involve the creation and implementation of an interdisciplinary curriculum involving the seashore and other subject areas. The topic of marine education could be extended to include water pollution, the overharvesting of marine organisms, and habitat destruction.

6.5 Epilogue

6.5.1 Personal Reflections

Exploring the seashore is a unique and rewarding experience. Through my own beach experiences I have gained a lifelong interest, understanding, and appreciation of the natural world. My quest for knowledge did not end at the shoreline as my childhood interest in natural history flourished to incorporate marine mammals, fish, birds, plants, trees, and a myriad of other natural wonders.

Through activities such as those outlined in "An Intertidal Voyage" children are introduced to the wonders of the natural environment. Beach field trips enable students to
experience the seashore *in situ*. Students become aware of the fragile yet resilient intertidal community that exists beneath the waves, rocks, and sand during a low tide. Once that seed of awareness is planted the benefits to the students, their teachers, and to the environment are rich and rewarding. As an educator one of my goals is to create a sense of stewardship for the natural world and inspire students to become environmental caretakers.

6.5.2 The Voyage Ends

The month of June brought an end to the school year and “An Intertidal Voyage”. The students celebrated their year with a class party at Acadia Beach. Of course an intertidal walk was on the agenda as well as bubble blowing, swimming, and eating!

The six *voyageurs* observed the end of the school year in uniquely individual ways. Rod and Andy staged their crab wars, organizing their troops with less intensity and more compassion than at the beginning of the year. Dan chatted enthusiastically about his current research topic, the whale shark, and Cathy conversed excitedly about her latest fishing expedition and the delicious meal which followed. Nancy was busy buying and selling her intertidal wares, and Hannah was content to create a sand castle village with the intention that the resident shore crabs would find it “comfortable and warm”.

Many parents accompanied the class to the beach. During a conversation with Nancy’s parents I learned that the beach walks were the highlight of Nancy’s year. When the family travelled to Morocco they were amazed that Nancy identified many species of marine life at the local aquarium by using her Acadia Beach knowledge as a field guide.
She remarked to her mother that the marine organisms "look a little different, but I can tell who these sea creatures are because I met their cousins during our beach study". Nancy's extended intertidal voyage represents the foundations, goals, and epilogue of this study.
References


Appendix A

A Glossary of the Physical Adaptations and Survival Behaviours of the Six Intertidal Animals in the Changes in Student Knowledge Charts

To explain the physical adaptations and survival behaviours of the six intertidal organisms, I compiled a glossary of the descriptors used in the interview charts. Richard Boyd (1993) defined the term “catechresis” as the use of metaphor to remedy gaps in vocabulary. I included examples the children’s language as a form of catechresis to extend the following definitions.

The following descriptors are presented in the first, second, and third interview charts.

**Dungeness Crab (Cancer magister)**

**Survival Behaviours**

**Aggression**
The organism uses its legs and pincers to fend off predators and protect itself in battle.

“Crabzilla!” (Rod)

**Blowing Bubbles**
A dry or annoyed crab will produce bubbles which froth from the mouth area. Bubble production enables the crab to keep the gill area moist to avoid desiccation during low tide.

“The bubbles are saying, Put me back in the water!” (Cathy)

**Feeding Strategies**
As a feeding strategy crabs use their pincers to tear apart and place food into the mouth. Their sensory system locates food through touch and smell. They can also ambush prey by hiding in the sand or marine algae.

“They just hide and wait. Sometimes they are scavengers and eat dead things using their pincers.” (Andy)
Habitat
Certain species prefer specific habitats. The Dungeness crab frequents a sandy environment containing eel grass beds.

“Crabland” (Nancy)

Hiding
Crabs avoid their enemies by burrowing in the sand or hiding under rocks and marine algae.

“Hanging out.” (Dan)

Male Protects Female
The male holds the female underneath his abdomen before, during, and after her molt. Mating occurs during this time.

“The male carries the female around. He needs to stretch afterward.” (Hannah)

Pincer Waving
Crabs will wave their pincers as a warning and as a mating ritual.

“Hey, I’m here, and I’m deadly.” (Dan)

Speed
The animal employs speed swimming/crawling to chase prey and escape from predators.

“Speedy legs” (Nancy)

Physical Adaptations

Camouflage
The crab’s shell pigments blend with the marine environment.

“The shell has a turkey leg pattern on it.” (Nancy)

Gender Change
Immature crabs exhibit male characteristics, but some will eventually acquire the broader abdomen and reproductive organs of the female.

“One day you’re female the next, you’re a male.” (Dan)
Hair/Cilia
The Dungeness crab has hair-like structures on the underside of the shell and on the legs. The hair acts as a sensory system and also filters the water entering the mouth area. The presence of hair usually indicates a sand dwelling crab.

“Crab fur” (Nancy)

Life Cycle
After hatching crab larvae join the plankton stream. They undergo a series of larval stages until they are large enough to become land dwellers.

“The kids don’t live with their parents like we do.” (Hannah)

Locomotion
A pair of specially adapted swimming legs enable the crab to speed crawl or, in some species, swim, to escape predators or chase prey.

“Speedswimming” (Cathy)

Molting
In order to grow, crabs shed their shells. The new shell which is soft and spacious is more accommodating to the crab’s growing body. Some crabs will eat their old shell for the calcium content.

“They kind of shed their skin like snakes do.” (Andy)

Pincers
Pincers are designed for defense, ripping apart prey, and, during mating, attracting and holding the female. The male crab usually has larger pincers than the female.

“Claws with teeth on the inside” (Andy)

Regeneration
A lost or damaged limb will be completely replaced after a series of molts.

“They kind of shed their skin like snakes do.” (Andy) “A few molts later and voila, a new leg!” (Dan)

Shell
The crab’s hard, sharp carapace is an excellent defense against predators and desiccation. The crab is most vulnerable during the soft shell period after molting.

“The hardtop” (Cathy)
Sugar Kelp (*Laminaria saccharina*)

Physical Adaptations

**Camouflage**
The varied colours of marine algae enable them to blend in with the environment.

"It comes in every colour." (Nancy)

**Food Source**
Kelp is an algae which needs sunlight for growth.

"They need light for their cells to grow." (Dan)

**Holdfast**
The holdfast is a root-like structure which glues the kelp onto a hard, stable surface. It acts as an anchor for the kelp during storms and tidal movement.

"Microhands" (Nancy)

**Holes In Blade**
The small holes found in the blade of some kelp species enable water to pass through the structure minimizing wave shock.

"It feels bubbly, like Swiss cheese." (Andy)

**Moisture Retention**
Some marine algae can withstand the heat and dryness of the low tide zone.

"It kind of feels like noodles over-cooked by twenty minutes." (Hannah)

**Rapid Growth Rate**
Marine algae grows quickly in order to counteract the damaging affects of predators and storms.

"It grows like the yeast in bread." (Dan)

**Seasonal Die-Off**
During the winter months, over-mature kelp forests die back due to winter storms. Some kelp species may live for up to two years.

"The great kelp die-off." (Rod)
Size/length
The massive size of the kelp bed protects individual kelp organisms. A single bull kelp may attain a length of twenty metres allowing it to reach the surface where sunlight is more accessible.

“They live under the water, but they need light.” (Cathy)

Pacific Oyster (*Crassostrea gigas*)

Survival Behaviours

Colonization
Oysters often live en masse sometimes using the shell of another oyster as a base. The cramped living arrangements aid in protection from enemies, wave shock, and moisture-loss during low tide.

“They all stick on to themselves.” (Hannah)

Clamping Down
The oyster’s strong adductor muscle keeps the shell tightly shut protecting it from predators and desiccation during low tide.

“There’s a ceiling around the oyster so it stays shut.” (Hannah)

Feeding Strategies
The oyster is a filter feeder. It prefers areas where fresh water enters the ocean.

“They open their shell and suck in stuff” (Andy)

Habitat Selection
Oysters usually adhere to hard, stable surfaces such as rocks, ledges, and other oyster shells. They prefer rocky, protected shores and bays.

“They grow between rocks so you can’t catch them.” (Rod)

Physical Adaptations

Camouflage
The creamy white colour of the oyster’s fluted shell blends well with neighbouring limpets, barnacles, discarded shells, and rock.

“They look like they’ve been in the sun too long.” (Hannah)
Gender Change
Some oysters change sex either every season or every year depending on the individual organism. They do not exhibit both sexual characteristics simultaneously.

“They can decide to be either a male or female. It’s up to them.” (Cathy)

Habitat
The shape of the oyster shell is determined by the organism’s habitat. A long thin shell denotes a narrow cramped living space. Our local waters are too cold for the spat of the Japanese oyster and most of the commercial spat is brought from Japan.

“Skinny oysters live in skinny places.” (Nancy)

Oyster Glue
The oyster cements itself to its home using a glue-like substance.

“Oysters have sticky glue.” (Cathy)

Shell
The hard outer shell protects the organism from predators and water loss. The oyster shell will mold itself to the shape of the growth site.

“The mighty shell! It’s all bumpy with layers.” (Nancy)

Giant Acorn Barnacle *(Balanus nubilus)*

Survival Behaviours

Feeding Strategies
The barnacle is a filter feeder using its feathery appendages to strain plankton from the water.

“They stick out their feet and catch plankton.” (Dan)

Grouping
Safety in number is the barnacle’s motto. A colony of barnacles denotes a good food supply and a rocky, protected environment.

“A carpet of barnacles.” (Nancy)
Hitchhiking

Slow moving whales such as the gray and humpback are used by some barnacle species as mobile homes. Barnacles will also attach themselves to crabs and marine algae. Hitchhiking offers the crab protection and a more varied food supply.

"The crab or whale can get them 'outa' there!" (Dan)

Habitat:

The preferred barnacle habitat is a protected, rocky shore. The giant acorn barnacle is a subtidal species.

"Barnacle rocks." (Cathy)

Physical Adaptations

Barnacle Glue

The barnacle secretes a substance which glues the bottom of the outer shell to a suitable living surface. The glue enables the organism to protect itself from wave action and predators.

"It’s a cement thing." (Rod)

Camouflage:

The white colour and jagged structure of the barnacle enables it to blend with the environment.

"They look like mini-mountains." (Hannah)

Life Cycle

The larval form of the barnacle lives in the plankton stream until it becomes large enough to settle and join a colony.

"They don’t always look like barnacles." (Rod)

Shell

The barnacle’s sharp, hard outer shell protects it from predators and water loss. The giant acorn barnacle also broods its eggs inside the shell cavity.

"It’s like a zip-lock baggie." (Hannah)
Trap Door
The barnacle animal can open the top of its shell to allow for feeding, fertilization, and water flow. When shut, this trap door protects the animal from predators, water loss, and wave action.

“It locks in the water.” (Andy)

Unstable Limpet (*Pelta instabilis*)

Survival Behaviours

Clamping Down
Using its suction cup-like foot the limpet is able to adhere to rocks and other hard surfaces. Clamping down helps the organism to stay put during storms and strong tides as well as keeping the inside cavity to moist. Predators find removing a limpet an arduous task.

“It’s like a plunger. You try to pull it up and it’s hard.” (Rod)

Feeding Strategies
Limpets are grazers cruising the marine environment for algae. They are gastropods which means “stomach foot”. The strong rasping foot cleans algae from the substrate. During low tide the immobile limpet hunkers down into a narrow crevice or underneath a rock.

“Limpets feed at high tide. It’s like when you go shopping when the sale is on. There’s more stuff and it’s cheaper.” (Hannah)

Habitat
The limpet chooses a habitat rich in algae and rocky hiding places. Some species inhabit the spray zone. Others prefer the mid and low tide zones.

“Limpets inhabit the first floor of the intertidal zone.” (Hannah)

Home Base
Some limpets will return to the same home spot after each feeding session.

“A limpet foxhole.” (Dan)
Grouping
Limpets can often be found grouped together during low tide. The safety in numbers theory applies here as well as moisture retention.

“A cosy nest of limpets.” (Nancy)

Physical Adaptations

Camouflage
Limpets are well camouflaged as their shells sport a myriad of marine hues and patterns.

“They look like mini-volcanoes.” (Nancy)

Outer Shell
The limpet’s hard outer shell protect the organism from desiccation, predators, and wave shock.

“They look like triangular sun hats or rock hats.” (Hannah)

Slime
Slime is produced by the limpet enabling smooth travel over the substrate.

“The limpet trail.” (Rod)

Suction-Cup Foot
The suction force of the limpet’s foot is extremely powerful making it difficult for anyone or anything to remove the limpet.

“It has a dent on the bottom.” (Andy)

Rock Sole (Lepidopsetta bilineata)

Survival Behaviours

Feeding Strategies
The bottom dwelling sole buries itself in the sand waiting for unsuspecting prey to come within range.

“He ambushes.” (Rod)
Habitat
Sole will hide in the sand changing their colour and pattern to mimic the environment. Some species prefer rocky environments.

“They turn into their home.” (Nancy)

Hiding
Flatfish can easily hide from both predator and prey by using their flat shape, camouflage, and ability to bury themselves in the sand.

“They live where it’s really dark, and they can take naps, and no one will bug them.” (Hannah)

Physical Adaptations

Body Shape
The flattened body of the flounder enables it to hide on the bottom and slip through narrow cracks and crevices.

“A fish pancake.” (Hannah)

Camouflage
The sole has the ability to mimic the colours and patterns of the surrounding environment.

“They’re like chameleons.” (Andy)

Life Cycle
The transformation of the normal upright fish into the flat, bottom dwelling flounder is a unique adaptation.

“They’re born as eggs.” (Dan)

Migrating Eye
When first born all flat fish appear as “normal” upright fish. As the organism matures one eye moves or migrates to the opposite side of the fish. The bottom dwelling flatfish is able to gaze skyward using both eyes.

“He decides, ‘I’m tired of looking this way!’ ” (Hannah)
Scales/ Fins
Scales and spiny fins protect the fish’s soft underside.

“He’s got prickles!” (Andy)

Slime
A substantial amount of slime oozes from the skin of flounders. The slime protects the organism’s scales and skin and may aid in respiration.

“Fish are slippery!” (Cathy)
Appendix B

Examples Scientific and Confused Understanding for Dungeness Crab and Kelp

Examples of a Scientific Understanding for Dungeness Crab

Scientific: the student includes at least three correct features of the survival behaviour or physical adaptation. I chose three examples to indicate scientific understanding as the number three excludes accidental and “guess” responses.

Survival Behaviours

Aggression
1. pincers-“The crab crushes things with its pincers when its mad or hungry.” (Dan)

2. defense posture- “They flatten their body and raise their pincers.” (Cathy)

3. strength/force- “They can push things around because they’re strong.” (Rod)

Blowing Bubbles
1. froth from mouth- “The bubbles come out of their mouth.” (Cathy)

2. aggression- “The bubbles mean they’re mad.” (Cathy)

3. desiccation- “The crab’s drying out when it has bubbles.” (Cathy)

Feeding
1. strain- “The crab strains stuff out of the water like plankton.” (Andy)

2. scavenge- “Crabs pick at dead stuff and eat it.” (Rod)

3. attack- “I’ve seen crabs ambush fish and clams and attack them with their claws.” (Rod)

Habitat
1. sand - “They live on sandy beaches.” (Hannah)

2. immature are intertidal - “Sometimes you find the little baby crabs when the tide goes out. They like to be under rocks.” (Dan)

3. eelgrass - “You can find them in eelgrass.” (Nancy)
Hiding
1. sand - “They bury themselves in the sand.” (Andy)

2. eelgrass/marine algae - “I’ve found them hiding under seaweed.” (Nancy)

3. under rocks - “The babies hide under rocks because they’re scared.” (Rod)

Male Protecting Female
1. male carries female - “The male holds the female against his stomach.” (Cathy)

2. female has soft shell - “He holds her because her shell is soft and she needs protection.” (Nancy)

3. mating occurs - “The crabs mate when they’re walking together.” (Hannah)

Pincer Waving
1. warning - “When I try to pick them up they lift up their pincers to scare me. It works.” (Dan)

2. attract mate - “I’ve seen crabs on TV waving their pincers around to get a female.” (Rod)

3. aggression - “Crabs lift up their pincers to pinch you.” (Cathy)

Speed
1. attack or retreat - “Crabs move fast when they want to get away or when they get mad.” (Andy)

2. feeding or migration - “When they are hungry crabs can really move.” “Crabs like to move around.” (Hannah)

3. sideways motion - “They do a crab walk and go sideways.” (Nancy)

Physical Adaptations

Camouflage
1. colour - “Their orange colour helps them blend in.” (Hannah)

2. shape/mimicry - “Sometimes I think a crab is a rock.” (Rod)

3. design - They have wavy patterns on their back.” (Nancy)

Gender Change
1. immature - “All crabs are born females.” (Nancy)
2. change to female - "After they molt a few times some change to females." (Nancy)

3. pointed abdomen - "You can tell the male. He had a pointed abdomen." (Nancy)

Hair
1. on legs and under carapace - "Dungeness crabs have hairy legs." (Andy)

2. filter - "The hair keeps sand from getting in their mouth." (Dan)

3. sensory - "Crabs can feel things like waves and vibrations through their hair." (Cathy)

Life Cycle
1. egg - "I know that crabs are born as eggs." (Andy)

2. larval stage - "New crabs float around in the water. They’re plankton." (Hannah)

3. final stage - "After lots of molts it looks like a crab and walks around." (Rod)

Locomotion
1. swimming - "Some crabs have paddle-like swimming legs." (Dan)

2. crawling - "Their pointed legs help them move along sand and stuff." (Rod)

3. burying legs - "They use their legs to push up the sand and then they hide under it." (Hannah)

Molting
1. sheds shell - "When their shell gets to small they get rid of it like a snake shedding its skin." (Cathy)

2. entire exoskeleton - "Everything is left behind. Even the eye skeleton." (Nancy)

3. soft shell - "The crab’s new shell is very soft. It takes a while for it to get hard." (Cathy)

Pincers
1. strong - "I’ve heard that a big Dungeness crab can break your finger." (Rod)

2. large and colourful - "The pincers can be bright red with white tips. The male has the biggest pincers." (Cathy)

3. ridges - "Their pincers are kind of bumpy inside." (Hannah)

Regeneration
1. lost limbs grow back - "If a crab loses an arm, it grows back." (Andy)
2. during molt - "It takes a few molts for the claw to grow back to a good size."  (Dan)

3. size - "I've seen a crab with one large pincer and one tiny one. The tiny one is growing back."  (Nancy)

Shell
1. camouflage/colour/design - "The shell helps the crab hide in sand and look like a log."  (Rod)

2. hard/shape - "Its back is sort of curved to make it strong if you step on it."  (Dan)

3. moisture - "The shell helps the crab during low tide because it keeps him wet."  (Cathy)

Examples of Scientific Understanding of Kelp

Scientific: the student includes at least three correct features of the physical adaptation or survival behaviour in their explanation.

Physical Adaptations

Camouflage
1. colour - "Seaweed comes in different colours."  (Cathy)

2. mottled - "I call the brown and white kelp cow kelp."  (Andy)

3. shape - "Sometimes it looks like rocks and barnacles."  (Rod)

Food Source
1. sunlight - "Their cells need sunlight to grow."  (Dan)

2. photosynthesis - "Seaweed is like a plant. They turn the sun's energy into food."  (Rod)

3. algae - "Kelp is like a plant. It's not an animal. It's an algae."  (Hannah)

Holdfast
1. anchor - "The holdfast keeps the kelp from floating away."  (Cathy)

2. not a root - "It doesn't get food for the seaweed."  (Hannah)

3. attaches to hard surfaces - "I've seen kelp growing on rocks, logs, and even crabs."  (Andy)
Holes in Blade
1. some species - “Not all seaweeds have holes in them.” (Dan)
2. water passes through - “During storms the waves go right through the kelp.” (Dan)
3. natural - “I can tell when the holes are supposed to be there.” (Dan)

Kelp Forest
1. protection - “It's a good idea to live in a group with other kelps. It’s safer.” (Cathy)
2. nursery - “Lots of animals live on the kelp like moss animals.” (Cathy)
3. size - “The kelp forest can go for miles.” (Dan)

Moisture Retention
1. dry - “Seaweed gets crispy in the sun.” (Nancy)
2. recovery - “When the tide comes in the seaweed plumps up again.” (Dan)
3. outer layer - “It has a thick skin that keeps the wet in.” (Cathy)

Rapid Growth Rate
1. rate - “Seaweed grows fast.” (Rod)
2. recovery - “Kelp get ripped apart by waves and sea urchins eat it, but it grows again.” (Rod)
3. kelp harvest - “Some people mow it like grass. We eat it in ice cream and toothpaste.” (Rod)

Seasonal Die-Off
1. season - “It piles up on the beaches in the winter.” (Andy)
2. storms - “There are more storms and waves in winter, and the kelp is ripped up.” (Dan)
3. life-span - “Bull kelp can live for two years sometimes.” (Rod)

Size/Length
1. forest - “Even in deep water you can see the tops of the kelp.” (Dan)
2. length - “I have seen really long stems on the beach. They must live far out.” (Rod)
3. species - “Bull kelp get the longest.” (Andy)
Examples of Confused Understanding for Dungeness Crab

Confused: the student mentions the survival behaviour or physical adaptation but includes incorrect information in their explanation

**Survival Behaviours**

**Aggression**  
"Crabs get mad, and they bite with their sharp teeth."  (Nancy)

**Blowing Bubbles**  
"Bubbles come out when the crab eats. It's like our saliva."  (voyageur)

**Feeding**  
"They only eat plankton."  (Nancy)

**Habitat**  
"They (Dungeness) live under rocks."  (Cathy)

**Male Protecting Female**  
"The male carries her around on his back."  (Nancy)

**Speed**  
"Crabs don't move very fast."  (Cathy)

**Physical Adaptations**

**Gender Change**  
"They can change back and forth from male to female depending."  (Cathy)

**Hair**  
"The hair keeps them warm."  (Dan)

**Life Cycle**  
"Baby crabs are very small and stay with their mom for a while."  (Hannah)
Examples of Confused Understanding of Kelp

Confused: the student mentions the physical adaptation or survival behaviour but includes incorrect information in their explanation.

Camouflage
   "It doesn't need any camouflage. No one eats it." (Dan)

Food Source
   "Kelp eats plankton." (Cathy)

Holdfast
   "It takes food from the soil for the kelp to eat." (voyageur)

Kelp Forest
   "Kelp plants live in groups, but they can move around if they want." (Rod)

Moisture Retention
   "They die when they dry out." (Cathy)

Rapid Growth Rate
   "It stops growing if the stem breaks." (Hannah)

Seasonal Die-Off
   "They die and wash up on the beach all the time." (Nancy)

Size/Length
   "They can't live in deep water because they won't reach the sun." (voyageur)
APPENDIX C

Transcription of Hannah’s First Interview (Event One)

All student interviews were transcribed on my computer database. Hannah’s first interview was chosen as it shows examples of scientific and confused knowledge as well as Hannah’s style of knowing - The aesthete/ analogist.

I have included scientific or confused after some of Hannah’s responses to indicate her seashore knowledge and aesthete-analogist as examples of her style of knowing.

Interview Participants

HANNAH: Student
RES: Researcher as Interviewer

Colleague operating videorecorder

RES. I’m going to show you a few things and you can tell me what you think about them. What you know about them and anything you can think of. Now the first item I know you will recognize.

HANNAH: Yeah!

RES: He’s a very familiar sight. There you go, pick him up, touch him. Do whatever you feel like doing.

HANNAH: I think this is a Dungeness!?
RES: OOH, what makes you think that?

HANNAH: It’s shape and its colours. scientific-camouflage
RES: Mm hm.

HANNAH: It’s a female.
RES: Now tell me about a female crab.

HANNAH: That little thing right there. (Picks up crab and points to abdomen) I can’t remember what it was, but we talked about it last year. scientific-shell
RES: Yes!

HANNAH: That’s where the eggs come out. scientific-shell

RES: That’s right. Have you seen one with eggs before?

HANNAH: Nope. Shaking head. But I think you said they get really big when there’s eggs in it, and then one day it opens up, and the eggs fall out. scientific-shell

RES: That’s right.

HANNAH: And they hatch!

RES: Yes!

HANNAH: It feels like teeth on the claws right here. If you get pinched by a big one like this big, you can get badly bruised. scientific-aggression

RES: Why do you think they have such strong claws?

HANNAH: Oh for their enemies because if ... okay, let’s say if their claws are like your fingers, like this, they can’t hurt ... they go around ... let’s say this ... I don’t know, this little water snake comes up, and you want it to get out of your way because it could be coming to get your babies. You go like this and it comes around with its head and bites you, and it may bite off your claws, and you are defenseless, and the babies go, “Bye bye.” aesthete-analyst But if the crab can pinch, it will distract it, and put it into pain, and then it can leave. scientific-aggression

RES: What kind of animals do you think it might pinch?

HANNAH: Well, I can’t remember the name, but you said there’s a little sea snake and it steals animals like little babies eggs...

RES: That’s true ,yeah! That’s right there is a snake that actually swims into the tide pools yes, good remembering!

HANNAH: Oh yeah.

RES: The coast garter will come into the tide pools and take things. Any body else you can think of that might do that?

HANNAH: I don’t know but maybe a sea snail.?

RES: Mm hmm. Yes, Who might want to eat the crab?
HANNAH: A sea, no not a SEAgull ‘cause you told us about that because gulls fly everywhere, and if it’s at a bay, people would mistake it for a little bread food and call it a Bagel! aesthete-analogist

RES: That’s true!

HANNAH: So... a gull might want it Some other water animals, like maybe a king fisher or the eagles that we saw today !

RES: How do you think it can protect itself from something so huge like an eagle?

HANNAH: Well, it could hide its legs and get under a rock. (long pause) scientific-habitat and hiding

RES: Yes, excellent.

HANNAH: And make this (points to the carapace) look like another rock, a neat way of camouflaging! scientific-camouflage, hiding, and shell

RES: Yes, exactly and the eagles couldn’t see it.

HANNAH: Yeah! That could be it.

RES: Definitely. Any other ways it may want to protect itself?

HANNAH: Well, it’s just with the claws, it could grab the feet and it would have to bend down, but I don’t think birds can bend down too far. They can use their necks to get down like a vulture but not bend over ‘cause I don’t think they can bend at the waist right here. Come to think of it, they don’t have a waist. aesthete-analogist

RES: No they don’t really do they.

HANNAH: No, cause their legs don’t shoot out like this, kind of like a swan, you know how they sleep on one foot? aesthete-analogist

RES: That’s right.

HANNAH: Or a stork. aesthete-analogist

RES: Um hm.

HANNAH: That’s why.

RES: Yes, what else do you know about crabs?
HANNAH: Well, ... they're very common, there's lots of them, and last year Jane found a hermit crab. scientific-habitat

RES: Yes, how is the hermit crab different from the Dungeness that you have there?

HANNAH: Well a hermit crab does not have all its legs out, well it does have all its legs out but it's kind of like, when you sit on a garbage can and you can't get it off your bum! It has this little shell stuck to it. aesthete-analagist

RES: Why do you think it has a shell, and this crab doesn't?

HANNAH: Because, didn't you say they were really hard to find, well maybe animals like a gull and birds like to eat them so they cover up into their shells so they can hide. scientific-shell

RES: Right, so they hide in their shells.

HANNAH: Yeah, like hibernate except that when they are in danger they do it like some other sea animals. scientific-hiding

RES: That's what they do. By looking at the two, the hermit crab and the Dungeness crab, do you see any differences in the way they are made, their structure, how their bodies are?

HANNAH: The hermit crab being a bit softer and smaller size, they are really small, the hermits.

RES: Yes they really are. So, have you ever eaten crab before?

HANNAH: No. I've had calamari because we used to go to a Greek restaurant.

RES: How do you think a crab may protect itself from people because we are pretty smart when it comes to collecting. How would you protect yourself if you were a crab?

HANNAH: Well, unless you had a big muscle man with you, you could hide under a big heavy rock that the average person can't lift up. That could be it. scientific-hiding and habitat

RES: Yes, that would be a good way to hide. Have you seen that type of crab when we go walking on the beach? Have you ever seen that type of crab?

HANNAH: You're talking about a shore crab. scientific-habitat

RES: Yes, we see lots of those don't we. Sometimes we see these as well but not the living crab. Do you remember finding the shells of them?
HANNAH: Yeah, cast-offs.

RES: Yes, tell us about cast-offs.

HANNAH: Well when they ... when the inside gets too big for the shell, they leave it behind and go find and grow a new one. scientific-molting

RES: Why would they want to do that?

HANNAH: Well because it’s kind of like going into a box. You could do it for a few years, and then you forget about it then three years later, you come back, you are seven now, and you can’t get into the box! aesthete-analogist

RES: Exactly!

HANNAH: Or your favourite clothing you like to wear every day. It’s too small and you try to get yourself into it but it’s just not going to work. aesthete-analogist

RES: Do you think that’s how the crab feels too?

HANNAH: Yup.

RES: Can you tell us about what the crab’s new shell is like.

HANNAH: Well, I think it’s really soft. As soon as it gets the right size, then it becomes hard. scientific-molting

RES: How does it protect itself while it’s waiting for the shell to become hard?

HANNAH: Well, it could go into puddles and have other crabs surrounding it, climbing under a rock. scientific-habitat; confused-male protecting female

RES: Anything else that you find interesting about the crab?

HANNAH: I like the way it walks.

RES: Tell us about that.

HANNAH: Well it kind of walks up on one foot then and on to the other so it kind of goes boing boing. It’s kind of neat. scientific-locomotion

RES: Yes it is neat how it walks.

HANNAH: Some of them walk like this, very fast. scientific-speed
RES: How does running fast help them?

HANNAH: The claws might be able to grip and help them go faster. scientific-locomotion

RES: Anything else you would like to say about our crab?

HANNAH: He’s dead. Actually I think it’s a cast off. How did he get out of this!? Usually they lift this off sometimes they break the bottom of it. scientific-molting

RES: You’re right. It is a cast-off.

HANNAH: I’ve just noticed that you can see right there, there is kind of like saran wrap except harder, and you look into it. Nothing’s in there so there is another clue that it is a cast off. scientific-molting

RES: Good.

HANNAH: That’s about all I know.

RES: Well that’s a lot!

The researcher shows Hannah the marine algae.

HANNAH: Seaweed isn’t it?

RES: Yes. How do you know it’s sea weed.

HANNAH: Well, because what it looks like, its shape, and what it feels like, and because I felt dried seaweed because my family comes from the East and we eat a lot of dulce there. I don’t care for it.

RES: How come?

HANNAH: Because I’m not really a seafood person

RES: How is that similar to dulce?

HANNAH: It’s both seaweed, but seaweed is dried out and preserved, and so if you just went in there into the water, picked up a clump of seaweed on a piece of wood, and stuck it under a big light, and picked it up and ate it, you couldn’t have done that because of the toxic waste that is poured into the inlet over there. It wouldn’t be healthy. They do it in clear water.
RES: How do you think the seaweed can survive in toxic water?

HANNAH: Well, there is a little coat on top of it that keeps the part that really needs to be covered from being exposed to the toxic waste. The coat keeps it wet too. scientific-moisture retention

RES: So you have felt live seaweed before.

HANNAH: Oh yeah, I’ve held it right out of the water.

RES: How does it feel?

HANNAH: It’s really slimy. It’s kind of like noodles over-cooked by 20 minutes. If you stick it on somebody’s back while they are in a swim suit, it just creeps down their back. It’s like AHHHH! something’s on me. It’s like seaweed. They go, “Get it off please!” aesthete-analogist

RES: Have you seen this particular seaweed on our walks?

HANNAH: Yes.

RES: Where have you found it?

HANNAH: When the big waves come up in the bubbly part, there’s seaweed under it and, it goes swish over the rocks, and if it’s not fast enough it gets stuck there and dries out onto the rocks. That’s what happens.

RES: How does the seaweed stay put when those big waves come by or does it?

HANNAH: When the waves come by it’s kind of like a water earthquake, and so if you are stuck to something, and you don’t have a good grip on it, you come right off it, but most of the time seaweed is just floating around. It doesn’t have anything to hold on to. It comes up toward the surface of the water, and so when it sees a wave coming it can’t get under there in time, because you have to go a bit of a ways to get out of the earthquake or tide. scientific-holdfast; aesthete-analogist

RES: Good analogy! If you look at this one it’s still attached by this structure, could you tell me about that structure.

HANNAH: Well, a part of it is really stringy and loose. It’s kind of like cheese string, you know you thread it out, and so if it wants, if the seaweed wants to get out of the water, it will have that attached to a rock, and usually waves don’t take rocks back with them unless they are little tiny grains of sand, and then when the wind comes up and you are on a sandy beach then sand goes swish, right in there. If you look right in, there are barnacles. You can see the seaweed has attached to a rock that had barnacles on it. They
are really painful when you slip on them. In the summertime, I cut my foot on a big barnacle. It was really painful because of the salt water gets in there, and it starts to sting.  

**scientific-holdfast; aesthete-analogist**

RES: Can you describe some of the different colours of kelp you’ve seen?

HANNAH: Well, really bright green like over there, and I think I’ve seen some yellow, orangey. White, we saw some white last time, but it’s more like algae. **aesthete**

RES: How do you think a kelp grows? What is it using for food?

HANNAH: Well, little water bugs. And maybe sometimes little tiny sand grains, seaweed maybe, mmmm. I think that’s about it. **confused-food source**

RES: Anything else you would like to tell us about the kelp, the seaweed in front of you? Do you think that it is living or dead?

HANNAH: Absolutely dead ‘cause if the seaweed is living it is wet. It’s kind of like a fish. If it’s out of the water too long, it dies. **scientific-moisture retention**

RES: How about when the tide goes out?

HANNAH: Well, there’s little tide pools, little tiny ones, and sometimes there’s a little animal and it splashes. The water will go up and get onto it, so it will have some water. Kind of like a desert. This one kind of looks like a feather. Like in that movie “The Pursuit of Happiness”. They have that big feather pen. (Hannah then writes with kelp) **aesthete-analogist**

RES: It’s like a feather pen, but I don’t know if it would work as well.

HANNAH: No, I don’t think so.

RES: Anything else you would like to say about kelp.

HANNAH: Well, kelp is really neat it’s like a long rope, and it has like a little candle holder except it’s covered up on the top, and it’s got like, big, kind of like palm tree leaves coming off it. Usually you can find the really hard stuff stretched out, some people find it six feet and it’s, big and it’s got the little water cup on top, and if you crack it open, water goes everywhere like a volcano. **scientific-size; aesthete - analogist**

(The researcher shows Helen the barnacle.)

HANNAH: Whoah. This is a really big one!
RES: Yes!

HANNAH: Well, where I went, it's on Bowen Island, in the big water. It's really cold there. There's these big rocks there about this big, and they've got huge barnacles on them, and you step on them, and you're in mortal pain.

RES: Why do you think they have such a hard outer part?

HANNAH: To protect what's inside. It's kind of like the crab or another animal. It keeps it from someone eating it or something. Yeah and usually you find them about this big on the rocks in every beach in Vancouver.

RES: Where do you usually find them?

HANNAH: Attached to big rocks. On a little rock about the size of your fist. You don't find them that much on small rocks.

RES: Why do you think they don't want to be on the small rock?

HANNAH: Because some people at the beach, they like to take little tiny rocks and move them and make like a big pattern. So they think, if we get onto a big one no one can move us unless you get like a big bull dozer and ahhhh! scientific-habitat

RES: Then they'd be in trouble.

HANNAH: It looks kind of like a mountain. Like the mountains driving on the Coquihalla highway or it could be like a little dress for my thumb. (Places barnacle on thumb) aesthete-analogist

RES: Have you ever seen the barnacle animal itself?

HANNAH: No.

RES: Here's a picture of one.

HANNAH: Neat. It looks like those pen fish that we saw, and that big whole pen that looked like that seaweed.

RES: Yes, very much so. How would you say a barnacle protects itself?

HANNAH: Because of its outer shell and usually the bump right there has a covering and let's say a little fish comes by, OK, and he has this, let's say it's a tour guide thing. If you watch right here or even get up really close you will see a little animal and they go like "Oooh, ahhh!" and they get really hurt.
RES: So you think the fish would want to eat the animal?

HANNAH: Yes, they would because they like smaller animals. It’s kind of like the food chain, smaller animal eats. It gets eaten by a bigger animal and then the big animal gets eaten by another bigger animal and. You know that whale song where the whale got eaten by the shark, and it starts out with a little tiny salmon. aesthete-analogist

RES: Why do you think the barnacle animal comes out if he doesn’t want to be eaten?

HANNAH: Water, because if you look at this, it is pretty stable and probably a little tiny fish could probably get its teeth in there, and when it comes out to get water, and maybe catch a little bit of food, but it’s got to do it at the best time or whoops no head. scientific-shell

RES: So when would be a good time for them to come out?

HANNAH: I don’t really know. But it might be good, it wouldn’t be good at low tide because what’s the point of coming out if it’s getting no water. I think it could kind of feel the high tide ‘cause it might feel a bit heavier as the water’s caving in than when it’s in low tide because it will be light. Kind of like in the winter you feel more heavier cause of your clothing, but in the summertime you can wear a T-shirt, and you feel really light. That’s why. scientific-shell; aesthete-analogist

RES: Anything else you can tell us about the barnacle?

HANNAH: They’re like a rock, a different shape. Well you could make it kind of like a candle-holder if you stuck a candle in, a very thin one. aesthete-analogist

RES: OK I have another shell to show you.

HANNAH: Is it like those, what was it a “cocker” shell that you had last year.

RES: Oh yes, a cockle. I didn’t bring one of those today. I brought another shell.

(The researcher presents Hannah with the oyster.)

HANNAH: OYSTER!

RES: Very good. Why would you think that’s an oyster? You’re right.

HANNAH: Well, because most shells we find here are really smooth and flat but an oyster shell has different layers, and it’s really really bumpy. scientific-shell; aesthete

RES: Why do you think it has a different shape?
HANNAH: Because the animal inside is could be like in a knot, could be like that. 
*confused-shell*

RES: So the shape of the animal makes the shell the shape it is?

HANNAH: Um hm.

RES: Where do you usually find oysters?

HANNAH: You usually find them on very wet beaches where the tide is in between and sometimes they'll be with a bunch of cockle shells, and I remember we found one this year. It looked like a hologram because it was really shiny. 
*scientific habitat; aesthete-analogist*

RES: What part of the beach do they like to be on?

HANNAH: Close to the water because, OK let’s say here’s where the water comes. OK right there is the sand. They like to be just over the sand part right there. Would that be right? *scientific-habitat*

RES: Yes. What else can you tell us about oysters?

HANNAH: Well, a lot of people eat oysters, unlike most shells.

RES: How do you think the oyster protects from being eaten?

HANNAH: It spits water out. Like go away and then sometimes it could be sleeping and someone lifts it up.

RES: Have you tried to do that?

HANNAH: Oh yeah, I have tried to do it many times.

RES: How did that work?

HANNAH: Oh. I couldn’t get it open ‘cause when there’s an animal inside, and it’s really hard to get open unless you take a rock this big and drop it on it. 
*scientific-clamping down*

RES: Why do you think it’s so hard to get open when there’s an animal inside?

HANNAH: Because there’s a little ceiling. There’s a ceiling around there, and so it stays shut. This looks like the top of the oyster because usually the bottom part is more like this, more flat. Let me see, and you can also hear the ocean through this but not through this
one ‘cause it’s more flat. Usually shells when you can hear the oyster are downwards like this, like a bowl. aesthete-analogist

RES: Have you seen living oysters or just the shells?

HANNAH: Usually just the shells. I remember when we took the long path. We started out where we usually start out, and we ended up just beyond the little hill. We came down. I picked up three shells and they all looked like this.

RES: Anything else you would like to say?

(Pause)

RES: Does it remind you of any other sea animals?

HANNAH: It kind of reminds me of a jelly fish because jelly fish sometimes curl up and sometimes they don’t do it perfectly, and they end up in a knot, and it’s really bumpy, and the outside is really dirty and really ugly and so most people say “Ah yuck, what’s the point of picking it up.” And some people say “Oh neat an oyster shell!” They pick it up and turn it over, and it’s really neat on the inside and really smooth and on the outside. It’s really bumpy. aesthete-analogist

RES: Why do you think it’s so smooth on the inside?

HANNAH: Because the animal keeps it clean. Time for spring cleaning! aesthete

RES: Good, OK I have another shell for you to look at. (The researcher shows Hannah the limpet.)

HANNAH: Isn’t this a “cocker” shell, cockle?

RES: What do you think it is?

HANNAH: I think it’s a cockle shell, no this is a mussel shell.

RES: What do you think?

HANNAH: I don’t know.

RES: You don’t have to worry about what it is, just tell me anything you might know about it.

HANNAH: It looks like a limpet in the wrong shape. Is it a limpet?
RES: Ahh, it is a limpet. Why do you think it's a limpet?

HANNAH: Because limpets look like little triangle hats, but it looks like somebody stepped on it from the side.

RES: Why do you think it would be that funny shape, if it were natural?

HANNAH: Because maybe during its lifetime the shell was really soft it could have had something pushed against it so it’s shell shaped a bit from going into a perfect triangle.

RES: Here’s a photo of a limpet animal. Is that more along the lines of what you think a limpet shell should look like?

HANNAH: Yeah, but you know what it looks like, a harbour seal or an elephant seal they flop their ears, “Arr Arr.” Oops, I forgot. Seals don’t make noise.

RES: So what can you tell me about a limpet. Where do you find them?

HANNAH: Around barnacles. They get into the rocks. They like dark areas. I remember earlier in the year I found one this big I went “WOW, WOW WOW!” and everyone went bolting over saying “Cool, neat awesome!” scientific-hiding and habitat

RES: Why do you think they like those dark areas?

HANNAH: Because, umm no one comes toward dark areas except for crabs, but they don’t have to worry about crabs ‘cause they are off the ground. scientific-hiding

RES: Have you ever seen the animal that lives inside the shell?

HANNAH: Yup, in a book.

RES: Can you tell us a little about what that animal’s lifestyle is like. What it may eat?

HANNAH: Well it may eat little microscopic animals that live on rocks If they’re on rocks they usually don’t come out or they are stuck against the rock. They come out and the shell is stuck, and wooh, they can’t get up. Their shell can’t come down and say super shell. They can’t do that. confused-feeding

RES: How do you think they protect themselves on the beach?

HANNAH: Well, they are like the oyster. They have like sticky glue, like, “Oh oh, the sticky glue is coming off.” Put a new layer, and it gets really hard to pull off, and usually if you pull one off, the animal dies into the shell because it goes crack. Because you really need a good grip, and your hand starts caving in on it, and it breaks. confused-suction-cup foot
RES: Other than people trying to take them what else do you think might go after a limpet?

HANNAH: Bird, like maybe a hawk, kingfisher, an eagle, a gull, crow. Other animals that like eating animals that aren’t hard to get. Because for them, all they have to do is perch on it, and they weigh so much, they squish it. First floor eating. aesthete

RES: That’s an excellent description. First floor eating.

HANNAH: What else can you tell us about our limpet?

HANNAH: It looks like a little sun hat. You could get like a hamster and stick it on the hamster’s head. aesthete-analogist

RES: Good. OK our final example.

(The researcher shows Hannah the flounder)

HANNAH: Starry flounder.

RES: Right What is the clue that tells you it’s a flounder?

HANNAH: Because of how fat it is. It kind of goes skinny, fat, fatter, fattest towards the middle. (Touches it ) Oooh! I could tell it’s a fish because of its scales and its shape and by the eyes right over here. scientific-body shape and scales

RES: Tell us about those eyes.

HANNAH: Well, the eye can move. Not like our eyes. We only see that way, but they can see forward by moving their eye like “I’m tired of looking this way.” They can move their eye and look that way, and that way, that way, and that way until (long pause). scientific-migrating eye

RES: Why would they want to have their eyes like that?

HANNAH: So they can see if their predators are coming. scientific-migrating eye

RES: What kind of predators would go after the starry flounder.

HANNAH: A bigger fish maybe a salmon, but I don’t know how big they are. Maybe even a bird because you know how the mallard ducks are swimming along “Hey fish!” and they are trying to (pause) I saw this loon last year trying to get this fish into its mouth and it was squiggling, “I don’t want to go!” aesthete-analogist
RES: That’s right. The fish was fighting back wasn’t it?

HANNAH: Yeah it’s like “Put me down!”

RES: So how was the fish protecting itself?

HANNAH: By slapping it in the face.

RES: How do you think the fish would protect itself from the loon finding it in the first place?

HANNAH: Camouflage. They’re like chameleons. They go to something and it changes colour. Usually they lay on rocks like this and not move, really lazy.

scientific-camouflage, habitat, and hiding

RES: Have you seen this fish before?

HANNAH: Yes, we saw them. I think we saw them at the Aquarium last year. It was laying on its side taking a nap and I remember the wheel of life, salmon, and only one percent of salmon eggs live.

aesthete-analogist

RES: That’s right a very low survival rate. You can turn the flounder over and look at the other side.

HANNAH: It looks like a little paint brush right there. (points to caudal fin)

RES: Where do you think it lives?

HANNAH: At the bottom of the water because it’s really dark, and they can take naps and no one will bug them. There are rocks down there.

scientific-habitat

RES: What do you think they eat when they are down there?

HANNAH: Umm those fish that have those glow-in-the-dark eyes that we saw. Because it’s down in a dark area so it can’t see. It looks up and sees these little blue things, delicious, now for a bit of lichen for dessert. Did you put that in there?

RES: Yes, it’s a paper towel.

HANNAH: It looks like an egg case.

RES: Yes, it had eggs, but I took them out.

HANNAH: Oh! It looks like it’s gurgling right there because you can see the little tiny mouth.
RES: Yes. What else about it that you find interesting?

HANNAH: Well, that right there it has a dent in it. I find the little fins really neat. The little fins that they have. It’s kind of like their hair standing on end. A bad hair day, oh no!

aesthete-analogist

RES: Have you ever eaten flounder before?

HANNAH: No. The only fish I’ve had are cod, salmon, and halibut.

RES: Well, halibut is very similar.

HANNAH: Yeah, fish and chips are cod and halibut. Those are the fish that get stuck into those. We had salted cod at my grandmother’s house once. I’m not sure if you did this or not but there is a little line going up across.

RES: Oh isn’t that fascinating. No, I didn’t do that.

HANNAH: Neat.

RES: What do you think that line is all about?

HANNAH: It may mark the half point. Which side you can bend or not so when it gets to that side it has to use its tail to flip itself over to get on its back.

RES: Do you think that fish would want to go on its other side?

HANNAH: No, because right here is really soft. It’s hard because of its scales, but if you flip it over like this it looks like there’s the meat. So you can just get it. It looks like it has two bruises right there. And it has that very tiny one right there. It has little waves right there.

scientific-scales

RES: You mentioned this, (points to the pectoral fin underneath) What do you think that’s used for?

HANNAH: It’s a little fin to, so, cause it might want to go to a different rock. It’s like an old car that needs a little boost. And the little tiny one might be really strong so it goes like this so it pops it fin and goes to another rock.

aesthete-analogist

RES: Anything else you want to tell us about our flounder.

HANNAH: Well, if you leave it out in the sun or overnight and come back tomorrow, “pee yu” bring a close pin! (holds her nose)
RES: So if you were walking on the beach where would you find it?

HANNAH: On a rock 'cause a wave might catch it and land it on a rock.

RES: Thank you Hannah.

On Hannah's Changes In Student Knowledge Chart (Table 7, Chapter Four) her knowledge of some of the physical adaptations and survival strategies are designated incomplete as she did not include three relevant facts to support her knowledge.
APPENDIX D

The Field Trips

The children experienced nine field trips during the study. Field trips one through four took place after the first interview. Field trips five and six occurred after the second interview. The final field trips seven, eight, and nine took place after the third interview.

Field Trip One: Tiny Day

The first session was referred to by the children as the “Tiny Day” as the voyageurs’ first discovery was an abundance of miniature, delicately-pink tellen clams scattered among a carpet of cobalt blue periwinkles. The children were quick to overturn mounds of stranded rockweed and sea lettuce to expose an army of energetic beach hoppers foraging for tasty morsels. Shield limpets were spied resting within the sheltering crevices of barnacle encrusted rocks, and abandoned oyster shells created hideouts for stranded shore crabs and their hermit cousins. A group of sanderlings (a small sandpiper) patrolled the beach as the children investigated a plethora of amphipods, arthropods, and gastropods. All were declared official “Wow!” sightings.

Field Trip Two: Oyster Day

The second beach day occurred the following week. “Oyster Day” sightings included the tenacious “velcro bug” or rockweed isopod, living and dead shore crabs, and beautifully sculpted pieces of shipworm-riddled wood.
Field Trip Three: Petrified Day

Even a high tide can yield an interesting array of intertidal inhabitants as the children discovered on the third beach day one week later. During this excursion, christened “Petrified Day”, shore crab cast-offs were discovered tangled among the amber-brown fronds of fucus algae and green blades of eel grass. Manila clams, barnacles, and blue mussels were the most frequently encountered representatives of the littoral world. The “Wow!” discovery of this field trip was a duck skeleton complete with razor edged bill and webbed feet.

Field Trip Four: A Blustery Day

On the fourth field trip, our “Blustery Day!” the children were fascinated by the human inhabitants of the seashore. Brightly coloured sails and wetsuit clad adventurers heralded the arrival of a boardsailor invasion. The childrens’ attention was soon diverted by the exhumation of a shark skeleton. Other non-living “Wow!” treasures included Dungeness crab cast-offs and the shells of a diverse selection of bivalves.

Field Trip Five: A Crabby Day

Spring was late this year, and the children were eager for some excitement. They had endured a week of dreary, drizzly weather, and though the morning was not promising, the children refused to allow the soggy conditions to dampen their spirits. They were elated to discover that a low tide had uncovered a vast intertidal landscape just waiting to be explored.
Within a few minutes everyone had scooped up one of the squadron of scurrying shore crabs. The diminutive size of some of the individuals and the varied colours of their patterned carapaces were topics of discussion. Other crustaceans, the rockweed isopod, the beach hopper, and the gribble were caught and closely examined. The children counted "everybody's legs" and checked for any evidence of females "in berry".

The low tide combined with a stormy sea had produced a colourful array of marine algae. The children examined the translucent fronds of emerald and crimson algae. The intricate structure of the vein-like holdfasts were prodded and compared to the roots of a tree.

The gathering clouds heralded the end of this expedition. All discoveries were returned to their place of origin, and the voyageurs turned their steps "homeward".

Field Trip Six: A Spring Day

Finally a sunny day for the week's beach trip. Spring was in evidence as salmonberry and thimbleberry bushes crowded the trail creating a leafy pathway through the forest. A winter wren's jubilant chorus accompanied the spiralling song of a secretive Swainsons thrush. Emerald green fiddleheads of the Western sword fern towered above a delicate carpet of starflower and false lily of the valley. The voyageurs were excited as they covered the last few steps to the beach. The sight of a low tide complete with sandbars and great blue herons enhanced their jubilant mood.

The children scattered in different directions according to their preferred area of investigation. The rockhounds eagerly investigated the hideouts of shore crabs, barnacles,
and limpets while the sand enthusiasts checked out tide pools and sandbars. The “Wows!” echoed across the beach attracting small groups of explorers to the various finds. The rocky environment group observed the multitude of shore crabs and found one expectant female “in berry”. Shield and plate limpets were a common sight as were the ever present barnacles. A large sandworm was a “Wow!” discovery, but the annelid’s potentially painful bite prompted the children to quickly exchange it for the harmless oyster and littleneck clam.

Those voyageurs who selected the sandy beach area soon reported the discovery of a grape-sized sea gooseberry jellyfish. Clumps of fucus yielded the well camouflaged rockweed isopod which the children placed in a tide pool to observe its “motor”. The isopod began to speed-swim on its back using its tail plates as a propeller. The exposed sand bars revealed eel grass plants which the voyageurs compared to the more commonly seen species of algae.

The log-table discussion produced a variety of interesting finds. As the children examined the plethora of Dungeness cast-offs, they discussed the crab’s preference for sandy, shallow water environments during the molt. An unusual find was the pincer of the burrow dwelling ghost shrimp, a lovely translucent crustacean often uncovered by clam diggers. The children discussed the animal’s large right pincer which is for display purposes only leaving the shrimp quite defenseless. The large number of ghost shrimp pincers found on the beach lead the voyageurs to conclude that is was their cast-off time.
Field Trip Seven: An Exploding Isopod Day

The end of the school year was quickly approaching, and the voyageurs’ collective mood was a mix of excitement and sadness. This was one of the last beach days, and the group was eager to observe spring intertidal phenomena such as crabs “in berry”, “baby hermies”, and brooding isopods.

This trip was an observational day, and the voyageurs’ were relaxed and keen. One group spent the entire morning observing shorecrabs in a tidepool. They placed an enticing morsel of mussel in the pool and waited for the wary crustaceans to venture forth. Within a few minutes an army of green shorecrabs converged upon the potential meal, and employing their sharp pincers, dexterously picked the bivalve clean.

The most incredible “Wow!” discovery of the day was a very pregnant isopod. The first clue concerning the crustacean’s expectant condition was a bulging “stomach”. The voyageurs carefully pulled apart the animal’s “belly plates” to reveal a multitude of baby isopods. After the children discussed the female isopod’s maternal duties (which consist of brooding the eggs and carrying the young until they are ready to go it alone) they replaced the protective flaps, and returned the isopod to her fucus covered home.

During this field trip the children discovered an abundance of hermit crabs. The voyageurs held the timid crabs in their open palms and waited for the leggy crustaceans to appear. The children knew that without its borrowed shell the arthropod would not be able to protect its soft abdomen from predators. “Hermies” were a favourite discovery among the children as they were abundant, amiable, and “extremely cute”.

This field trip’s concluding log-table discussion focused on the “exploding” isopod and the feasting shorecrabs. The children were eager to handle the crabs and isopods but expressed a reluctance to touch the crustaceans’ land-dwelling relatives the woodbugs and spiders.

Field Trip Eight: A Pileated Day

It was the first sighting of the year. A large, dark bird with a flashing red crest glided across the forest path directly in front of the beachward group of voyageurs. The children chorused in unison, “It’s our pileated!” The presence of this regal woodpecker was a good omen for the journey. Even the winter wren hidden somewhere in the surrounding brush warbled excitedly.

As the group neared the beach two great blue herons surveyed the party from their prospective lookouts. Despite the high tide the children enthusiastically approached the shore eager to investigate the colourful multitude of marine algae. “Look moss animals!” More “Wow!” discoveries followed as numerous colonies of the bryozoans were detected on the olive-brown blades of kelp. Many of the kelp’s long stipes remained attached by their gnarled holdfasts to small rocks and broken barnacles.

There were more treasures to be uncovered beneath the rocks of the high tide zone. “Look a cozy nest for periwinkles.” A group of the small indigo coloured snails were nestled in the protective curve of a beach rock. A depression on the surface of a neighbouring rock created a miniature tidepool complete with feeding barnacles. The
children watched transfixed as the crustaceans' feathery appendages strained the water in search of plankton.

Farther down the beach a fisher sat in wait for iridescent schools of smelt (a small, silver coloured fish). There was evidence of successful fishing expeditions as the voyageurs discovered small bones and the occasional silvery fish body along the tideline. Gulls hoping for fishy leftovers stalked the shoreline, while those flying overhead noisily harassed the resident bald eagles.

During our log-table discussion two of the voyageurs presented a mystery find. The children initially identified the discovery as a shark skeleton, but the object’s protruding breast plate and bone-like quality ruled out the cartilaginous fishes. The mystery find was christened “the overdone chicken” as the group concluded that it was either the remains of a seaduck or somebody’s leftover lunch.

The log-table itself became the subject of our next discussion. The children were curious about the small white circles patterned over the log’s surface. The marks were identified as barnacle scars, the remains of long dead barnacles. Two small crustaceans were then brought to the log table for discussion. The children believed they had discovered a shrimp, but the organism’s uniform shape and distinctive legs lead to an amphipod identification. One of the subjects rolled itself into a perfect ball. The voyageurs listened in amazement as one of the group informed them that these tiny isopods were once ingested by people for medicinal purposes hence their common name pill bug.
The remaining log-table discussion topics included both Japanese and native oysters, Dungeness and shorecrab molts, and interesting rocks and beach glass. The arrival of a clothing optional sunbather prompted a quick conclusion to the discussion. The giggling voyageurs hurried up the path hoping to catch another glimpse of the pileated woodpecker.

Field Trip Nine: A Teaching Day

The school’s Kindergarten class joined the final beach expedition. Every voyageur was buddied with a partner from the younger class. The children were enthusiastic about their new roles as guides and looked forward to teaching the younger students about “our beach” inhabitants.

As they started down the path the guides’ discussed the chorus of bird song and the abundance of wildflowers. Some of the guides discussed the aesthetic attributes of the forest path. Every glistening banana slug, multi-coloured berry, and velvet-white fungi was examined and discussed. One guide conversed excitedly with his younger sibling about the scientific names and biological niches of the local flora and fauna. Others were content to simply observe and enjoy the sounds, smells, and colours of a warm spring day.

The children bounded down to the shore ready to embark upon their shared adventure. The guides patiently explained the safety rules and beachcombing etiquette to the less experienced voyageurs. The children first discovered a few shorecrabs huddled under the larger beach rocks. The subsequent discussion focused on the fieldmarks of a purple shorecrab, the cast-off phenomena, and the crustacean’s ominous pincers. Males
were compared to females and the search was on for a female "in berry". As the voyageurs traversed the beach more organisms were discovered and investigated. Some teams draped themselves with the multi-coloured fronds of marine algae while others investigated the secretive barnacles and miniature periwinkles. A very dead and pungent seastar was discovered among the tidal debris. The children investigated the echinoderm's punctured skin and "chewed" tubefeet and concluded a gull was responsible for its demise.

The "buddies" decided to build sand castles as a respite from beach investigations. As the children began their castle construction a multitude of sand fleas erupted from their subterranean abodes. The younger children were frightened by the energetic amphipods, but their guides assured them of the crustaceans' benign nature. A game of "catch the flea" enabled the children to examine the beach hoppers' small compact bodies and their specialized jumping legs.

During the log-table discussion the children were more interested in their snack food than the beach finds. After listening to a series of amphipod stories, limpet reports, and crustacean observations, the children concluded that the crabs (and the food!) were the highlight of this buddy expedition.