

Ocean Literacy: Examining the Inclusion of the Ocean Literacy Principles within High School
Science Courses in Nova Scotia

by

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Abstract

The defining feature on earth, the ocean is an essential component in enabling the existence of life on earth. As anthropogenic threats to the ocean increase, it is integral for individuals to become ocean literate to better understand their effect on the ocean and make informed decisions regarding the health of this resource. Within Nova Scotia, the ocean plays an important role in terms of the economy and culture of the province. Despite this importance, research shows that Nova Scotian youth have low levels of knowledge on ocean concepts. This lack of ocean literacy may be partially a result of the formal education system. Recognizing the importance of developing ocean literate citizens, this study investigated the extent to which internationally-established Ocean Literacy Principles are included in the Nova Scotia high school science curriculum and examined the challenges and barriers of implementation experienced by high school science teachers within Nova Scotia.

List of Abbreviations and Symbols Used

AMOC	Atlantic meridional overturning circulation
B.Ed.	Bachelor of Education
BIO	Bedford Institute of Oceanography
BRIDGE	Bridge Ocean Education Teacher Resource Center
CaNOE	Canada Ocean Education
CMEC	Council of Ministers of Education, Canada
COSEE	Center for Ocean Science Education Excellence
DESD	Decade for Education on Sustainable Development
DOE	Department of Education
FC	Fundamental Concept
GCO	General Curriculum Outcome
HRSB	Halifax Regional School Board
NMEA	National Marine Electronics Association
NOAA	National Oceanic and Atmospheric Administration
OLP	Oceans Learning Partnership
ONC	Ocean Networks Canada
POP	Persistent Organic Pollutant

SCO	Specific Curriculum Outcome
STSE	Science, Technology, Society and Environment Education
UNEP	United Nations Education Programme
UNESCO	United Nations

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Chapter 1: Introduction

1.1 Motivation

Referred to as the blue planet, the ocean is the defining feature of earth. Covering approximately 71% of the planet (Maribus, 2010; IPSO, 2017), the ocean impacts global climate and weather systems (Schoedinger, Cava, & Jewell, 2006) and is essential in driving global biogeochemical cycles (Moran *et al.*, 2016). Yet, scholarly research demonstrates that ocean health is under unprecedented threat (Maribus, 2010, IPSO, 2017; UNESCO, 2017). This includes significant environmental problems such as ocean acidification (The Royal Society, 2005; Ateweberhan *et al.*, 2013), loss of biodiversity (Cheung *et al.*, 2009; Harley, 2011; Ramirez, Afan, Davis, & Chiaradia, 2017), and pollution and plastic contamination (Derraik, 2002; Wilcox, Seville, & Hardesty, 2015) that are caused by anthropogenic activities. Yet while the ocean is an essential component in enabling the existence of life on earth, the United Nations Environment Programme (UNEP) claims that the ocean is among the least understood and undervalued ecosystems on our planet (UNEP, 2016). Education is seen as one means to combat ocean illiteracy. In the words of UNESCO:

“Conserving the diversity of life on earth and ocean health is critical to global human welfare, yet essential resources are at risk from the direct results of unsustainable practices. Sustainable development requires quality education and learning at all levels and in all social contexts” (UNESCO, 2017).

While it is recognized that education alone cannot solve current problems related to the ocean, it is considered a vital component to realizing the goal of a sustainable and prosperous future (UNESCO, 2014).

Studies have found that there is a strong discrepancy between youth interest and appreciation of the ocean, and their overall understanding of ocean concepts (Cummins & Snively, 2000; Plankis & Marrero, 2010; Tran, Payne & Whitley, 2010; Guest, Lotze & Wallace, 2015). Research has indicated that Canadian students prefer learning about the ocean over any other type of environment (Cummins & Snively, 2000), yet research has also indicated that ocean concepts are not adequately reflected in curriculum across the country (Ashurst, 2008; Cummins & Snively, 2000; and Gough 2017). Further, a recent study of Nova Scotia youth found that despite a high proportion (96%) indicating that they valued the ocean, they were unable to answer general knowledge questions about the ocean (average scores of less than 50%), indicating that youth in Nova Scotians are not adequately educated on basic ocean concepts (Guest *et al.*, 2015). These results suggest that many youths in Nova Scotia are not ocean literate and as a result are likely unable to make reasonable and informed decisions regarding individual and societal actions that may impact this system.

Several studies have emphasized the connection between an individual's understanding and knowledge of environmental issues and their level of citizenship (Hawthorne & Albastor, 1999; Fletcher & Potts, 2009; McKinley & Fletcher, 2012). Fletcher & Potts (2007, p. 511) describe citizenship as members of society who share common values, understandings, and attitudes that contribute to the common good of society. While knowledge is not the only factor that influences citizenship, research indicates that individuals with a stronger understanding of critical issues also have stronger values associated with citizenship (Fletcher & Potts, 2009; McKinley & Fetcher, 2012).

Many Canadian organizations, including the Canadian Network for Oceans Education (CaNOE), Oceans Network Canada (ONC), and the Oceans Learning Partnership (OLP), have

begun to address the issue of ocean education by developing hands-on teaching resources designed for classroom use. The goal of these organizations is to connect ocean scientists and researchers, industry, and government with the school system to provide a collaborative, integrated, and hands-on approach to ocean education (OLP, 2015). These programs aim to develop ocean literacy among youth through opportunities to engage with innovative technologies, hands-on experience with marine organisms, and exposure to a variety of careers within the ocean sector. Resource materials provided by these organizations, however, are not part of any formal provincial curriculum and as such may never be seen by the majority of Canadian students.

One area where intervention could be effective for ocean education is within the formal high school curriculum. Studies show that it is in high school that youth begin to see their place in society and can make connections that their behaviours and actions can have significant impacts on the world around them (Ausubel & Ausubel, 1966). Cognitively during adolescence, youth become better equipped to analyze complex problems, think about multiple concepts at the same time and address the moral, social and political aspects of issues (Ausubel & Ausubel, 1966). In terms of education, high school students are beginning to make cross-curricular connections, relating knowledge from variety of subject areas. As such, it is an opportune time to examine the complexities associated with ocean studies.

While oceans can be studied within many disciplines, the sciences offer the opportunity to teach many fundamental concepts related to the ocean, as well as introducing issues and problems related to human-ocean interactions. Ocean science is considered multidisciplinary and as such can be taught in multiple science disciplines through topics such as ocean chemistry, waves and optics, diversity of life and ocean bathymetry (Lambert, 2006). Ocean science unifies

the concepts taught within life science, physical science, chemistry, science and technology, science and social perspectives through a systems approach where students can see the connectedness of the various natural science and social science disciplines (Lambert, 2006). Integrating ocean education into science curriculum at the senior high school level has the potential to create awareness of ocean concepts among youth, contributing to the development of ocean literate citizens. One example of ocean science within formal curriculum is the Oceans 11 course that is offered within the Province of Nova Scotia at the senior high school level (note: this is an elective rather than a required course). Oceans 11 is unique to Nova Scotia and was designed to address relevant issues in relation to the ocean. The Oceans 11 course has the potential to increase levels of ocean literacy for those students who enroll, but as it is an elective science course, it is not a course that is accessed by many students.

Within the Province of Nova Scotia, there have been some studies that investigate the degree to which environmental concepts are covered in Nova Scotia curriculum (Spence, Wright & Castleden, 2013), but to date no study has examined the degree to which ocean concepts are specifically incorporated into the formal high school curriculum, nor the degree to which teachers incorporate ocean concepts in their classrooms within the province. Thus, this thesis focuses on the extent to which the Ocean Literacy Principles are included within high school science curriculum in Nova Scotia and aims to develop a deeper understanding of the potential challenges and barriers to including these concepts within existing science curriculum experienced by teachers within the Halifax Regional School Board (HRSB). This study contributes to the environmental education and ocean literacy literature by examining the formal high school science curriculum to determine the degree to which ocean concepts are covered in the formal curriculum for high school science courses. In addition, this research attempts to

understand the challenges teachers from one school board within the province face when trying to integrate ocean concepts into high school science courses.

1.2 Context

1.2.1 The Significance of the Ocean

Life on earth is dependent on the complex interactions between the five major systems that comprise our planet; air (atmosphere), land (geosphere), ice (cryosphere), living things (biosphere), and water (hydrosphere) (IPSO, 2017). The ocean, the principle component of the hydrosphere, provides approximately 50% of the earth's atmospheric oxygen and is responsible for absorbing 25% of global anthropogenic carbon dioxide currently emitted to the atmosphere (Maribus, 2010; IPSO 2017). The photosynthetic process carried out by all marine plants and in particular the microscopic marine plants, or phytoplankton, allows for the absorption of carbon dioxide from the ocean and results in the production of oxygen as an essential waste product (Strang, DeCharon, and Schoedinger, 2007).

In addition to contributing oxygen to the atmosphere, the ocean also plays a significant role in climate and temperature regulation. Due to the high heat capacity of water, the ocean absorbs heat in the form of radiation from the sun. The equator receives more direct sunlight than anywhere else on earth and through ocean currents, heat that has accumulated in the low latitude ocean is transported towards areas at higher latitudes and helps to drive ocean circulation (Maribus, 2010; Bijma, Pörtner, Yesson, & Rogers, 2013). The climatic effects of heat transference through the movement of ocean currents can be illustrated by the Gulf Stream current which originates in the Gulf of Mexico and travels north along the Atlantic coast of the United States. As the Gulf Stream moves north, it encounters and partially mixes with the colder

south-bound Labrador Current off Atlantic Canada and a portion of the Gulf Stream is diverted across the North Atlantic Ocean towards Western Europe (Maribus, 2010). This results in a warmer climate for Western European countries than other areas at similar latitudes.

Anthropogenic activities increasing the levels of greenhouse gases, including carbon dioxide and methane, have altered the radiation balance within the atmosphere, significantly affecting ocean temperature, sea ice coverage and as a result sea level. As atmospheric and ocean temperatures increase, the amount and thickness of seasonal and permanent sea ice coverage decreases. In the decades since the 1950's, Arctic sea ice coverage has undergone an accelerated rate of decline (Stroeve, Holland, Meier, Scambos and Serreze, 2007; Cvijanovik & Caldeira, 2015). Changes in the cryosphere, the frozen part of the earth including both land and sea ice, has a significant affect on the ocean. Sea ice acts as insulation for the ocean, preventing heat loss and with its high albedo (reflective properties) sea ice prevents the absorption of excess heat by reflecting sunlight energy back out to the atmosphere (Cvijanovik & Caldeira, 2015; Maribus, 2010). The buffering effect of the cryosphere has played an essential role historically in regulating energy exchange between the ocean and the atmosphere and has a significant role in maintaining the earth's radiation balance (Gottelman & Rood, 2016). However, as the area of seasonal and permanent sea ice has shrunk, so too has its role in mediating ocean warming. A freshening of the North Atlantic, as a result of an influx of fresh water from melting sea ice, could weaken part of a major ocean circulation system known as the Atlantic meridional overturning circulation (AMOC) (Zickfield *et al.*, 2007). The AMOC, which includes currents such as the Gulf Stream, drives warm surface waters north preventing northern Europe from being uninhabitable.

The warming of the atmosphere as a result of increased heat trapped by atmospheric greenhouse gases, has resulted in the transfer of some of the additional heat to surface waters (Mimura, 2013). The resulting warming of surface waters, home to much of the marine life in the ocean, has and will continue to have into the future, substantial impact on the distribution and abundance of many marine species. This is because many marine species are sensitive to temperature changes, even slight changes in temperatures can have substantial direct and indirect effects, both negative and positive on individual species and ultimately oceanic communities (Mimura, 2013). Marine species may react to changes in species interactions and availability of food supply, due to warming waters, by searching out new habitats in more favorable conditions, resulting in a shift in species distributions (Cheung *et al.*, 2012). Changes in species distributions could have significant social and economic impacts for dependent human communities, the greatest of which are likely to occur in the tropics, where many individuals are reliant on the ocean for dietary protein, while at the same time, many species' ranges shift poleward (Cheung *et al.*, 2012).

A secondary effect of both warming sea surface waters and increasing rates of sea and land ice melting is sea level rise. In combination, the thermal expansion of water, due to warming ocean temperatures, and melting of large masses of land ice sheets, such as the Greenland ice sheet, are projected to raise ocean levels significantly over coming decades (Mimura, 2013). Heightened ocean levels will impact coastal land, making areas more susceptible to erosion and flooding. As seawater extends farther inland productivity of adjacent land will be compromised by contamination of soil and ground water by salt, loss of some coastal habitats and biodiversity, and for many, the loss of complete livelihoods (Mimura, 2013). Sea level rise is a global concern as a high percentage of the earth's population live in coastal

areas. In addition to affecting the global economy, millions of individuals in low lying coastal areas will be displaced as a direct result of rising sea levels (Williams, 2013).

Changes to the atmospheric radiation balance have also resulted in greater absorption of carbon dioxide into the ocean (Royal Society, 2005; Fabry, Seibel, Feely, & Orr, 2008; Maribus, 2010; Bijma *et al.*, 2013). This carbon dioxide, when absorbed into the ocean, undergoes a chemical reaction with water, forming carbonic acid, releasing hydrogen ions that are available to bond with other molecules (Fabry, Seibel, Feely, & Orr, 2008; Bijma *et al.*, 2013). Calcium carbonate, which is essential for calcifying marine species to build shells and exoskeletons, easily bonds with hydrogen to form bicarbonate, a compound that marine species are unable to use (Fabry *et al.*, 2008). The formation of bicarbonate, and removal of carbonate ions from the water dramatically affects the ability of many carbonate shell building species, most of which occupy lower trophic levels, to create shells and exoskeletons, particularly during early life history stages (Fabry *et al.*, 2008). Though research on this issue, widely known as ocean acidification, is relatively new, early results of potential future impacts modeling suggests that many organisms throughout ocean food webs may be negatively affected (Royal Society, 2005; Fabry *et al.*, 2008; Bijma *et al.*, 2013).

As a result of changes in water temperature and salinity, along with destructive and unsustainable fishing practices, biological diversity is rapidly declining (Worm *et al.*, 2006), likely impacting ecosystem resilience and the ability to adjust to environmental changes. However, limited knowledge of many oceanic species and their interactions makes it difficult to evaluate the impact of biodiversity decline and loss (Snelgrove, 1999; Maribus, 2010; UNEP, 2017). As conditions in the ocean continue to deteriorate, it is important to gain a strong understanding of the function and capacities of these ecosystems.

The ocean is one of the most diverse ecosystems on earth (Maribus, 2010; UNEP, 2016). High levels of biodiversity are essential in maintaining normal ecosystem function and productivity (United Nations, 2016). An ecosystem containing, multiple species, each with their own energy requirements, habitat and food preferences, contains diverse species interactions that are required for a healthy environment (Hooper *et al.*, 2005; Maribus, 2010). These ecosystems are more resilient to changes in the environment and are better able to withstand and recover from disturbances. Ecosystems with low biodiversity have limited species interactions, so when disturbances occur the effects can be more detrimental to the overall health of the ecosystem (Hooper *et al.*, 2005).

Globally, humanity relies on fish and other sources of seafood for 17% of our dietary animal-sourced protein (FAO, 2016). The global annual production of fish and fishery products from capture fisheries and aquaculture is estimated at approximately 140 million tonnes (Maribus, 2010). Despite, or perhaps because of, the global reliance on fishery resources, many marine fish stocks are fished beyond capacity. In 2013, 31.4% of fisheries were considered overfished, while 58.1% of fish stocks were assessed at being fully fished, with no potential for an increase in production (FAO, 2016). Improved fishing technologies have led to an increase in catch sizes; allowing fishers to locate fish more accurately and at greater depths, while using large factory ships has allowed fishing at greater distances for longer amounts of time (Maribus, 2010; FAO, 2016). Growing world population and increasing consumer demand has led to more extensive, and in some instances more destructive fishing efforts. The use of fishing techniques, that are either detrimental to marine habitats, such as bottom trawlers, or of techniques that result in unacceptably high levels of non-targeted bycatch, can contribute to the decline of fish stocks and associated marine communities.

Of the vast amount of area on earth that is the global ocean, under 5% has been well studied or explored thoroughly by humans (NOAA, 2017). There are significant obstacles in exploring the ocean, particular at depth, and include technology limitations, accessibility and cost just to name a few. The vast majority of the ocean, approximately 65% of the surface area, has a depth greater than 130 m, restricting accessibility to the use of remote-sampling gear or submersible vehicles (Snelgrove, 1999). Because these specialized equipment and the personnel required to operate them are not widely available, costs associated with such expeditions are high, and their use in deep ocean exploration is limited.

With coastal areas being the most densely populated areas on earth, marine pollution is a major concern. Marine pollution consists of a wide range of contaminants including oil and its many derived products (gasoline, diesel, etc.), untreated human sewage, nutrient run off, persistent organic pollutants (POP's), human garbage, plastic and micro plastic debris, etc. (UNEP, 2006). Due to ocean currents and the constant motion of the ocean, the amount of pollution contaminating the marine environment is difficult to determine. However, in 1997 it was estimated that approximately 6.4 million tonnes of garbage entered the ocean each year (Maribus, 2010). Plastic debris discarded by fishing boats, accidentally lost from shipping containers, or simply discarded by individuals, poses a significant threat to marine organisms (Derraik, 2002). Most traditional petroleum derived plastics are not biodegradable, however, over time plastic particles break apart into smaller bits of plastics. Plastic marine debris, including micro plastics are easily mistaken as prey by marine organisms such as zooplankton, small fish, turtles, and sea birds (Tanaka *et al.*, 2013). The consumption of plastic particles has adverse affects on organisms, such as the reduction of food intake, prevention of digestion and the potential blocking the intestinal tract, leading to malnourishment and potentially death of

individual animals (Derraik, 2002; Tanaka *et al.*, 2013). In addition, marine pollution can also negatively affect marine life through the consumption of chemically stable toxins, some of which can bio-accumulate as they are transferred through the food web (Derraik, 2002; Maribus, 2010). These threats are not, however, limited to organisms in the ocean, humans can also be negatively affected by direct and indirect ingestion of marine pollutants. In addition, and more visibly, are the aesthetic impacts and associated economic costs of some forms of marine pollution when they impact beach and coastal areas. Left unaddressed, heavily polluted coastal areas risk the loss of revenue from tourism (Maribus, 2010; Bijma *et al.*, 2013). Marine pollution threatens marine life, ocean ecosystems and humans, on many levels. The impacts of human interactions and use of the marine environment must be clearly understood for individuals to make informed and responsible decisions regarding their individual and collective behaviour and likely resulting impact on ocean health.

1.2.2 Ocean Education

Education has been used as a powerful tool in creating positive change (Blackburn, 1983; UNESCO, 2005). According to the United Nations Educational, Scientific and Cultural Organization (UNESCO), “the goal of education is to make people wiser, more knowledgeable, better informed, ethical, responsible, critical and capable of continuing to learn. Education, in short, is humanity’s best hope and most effective means in the quest to achieve sustainable development” (UNESCO, 1997). Educators have the potential to influence how students gain knowledge, form positive attitudes about the environment, and as a result act in response (Chawla & Cushing, 2007). Hawthorne & Alabastor (1999) have established that effective education on environmental issues can lead to changes in human behaviors. Further, the inclusion of environmental (including ocean) education in classroom teaching is effective in

developing positive attitudes toward the environment, and that these attitudes are often retained over time (Chawla & Cushing, 2007). Education, by nature, is designed to increase knowledge and improve problem solving - as Sterling (2001) states “the difference between a sustainable and a chaotic future is learning” (pg. 10).

A lack of ocean knowledge has the potential to increase negative impacts on the oceanic environment due to higher levels of ignorance (Uyarra & Borja, 2016). As such, ocean education is an essential component of the future health of the ocean (Steel, Smith, Opsommer, Curiel, Warner-Steel, 2005; Tran *et al.*, 2010). Increasing individual understanding of environmental issues, including those related to the ocean, aids in the capacity for creating solutions (Steel, Smith *et al.*, 2005). Education on critical issues pertaining to the ocean has the potential to engage individuals in behaviours that are less destructive to the ocean environment.

Ocean education is not a new concept. Initially, the topics of ocean health and the availability of ocean resources was encompassed within the modern environmental movement that began to develop and gain speed in the 1960's and into the early 1970's (Carter & Simmons, 2010). The first United Nations Conference on the Human Environment was held in Stockholm, Sweden in 1972 (United Nations, 1972). This conference was the first major conference to address international environmental issues and attempt to create a common outlook to deal with the challenges of a more equitable human development and the impacts development has on the natural world (Handl, 2012). The conference highlighted the need for education on environmental matters, for current generations and for those yet to come (United Nations, 1972). Ocean concepts, including marine habitats and pollution, were addressed at the conference, however, it would be several years before the ocean became a focal point. As decades passed and degradation to the marine environment continued, in 1994 the United Nations began to focus

on the importance of ocean health and the necessity to conserve and protect ocean resources (UNESCO, 1998). As a result, the benefit of ocean conservation for current, as well as future, generations was highlighted by the United Nations as they declared 1998 to be the International Year of the Ocean (CDIAC, 1998). The goal of the Year of the Ocean was to develop global awareness regarding significant issues pertaining to the ocean (CDIAC, 1998). While there were some Canadian initiatives related to the International Year of the Ocean, such as the publication of the Oceans Conservation Report Series by the Department of Fisheries and Oceans intended to broaden public knowledge on issues pertaining to coastal areas and the ocean (Meltzer, 1998), the degree to which oceans education was incorporated into the formal education system as a result of the initiative remains unknown.

The year 2005 brought about a stronger focus on incorporating ocean concepts and sustainable practices into the education system. The United Nations named the decade spanning from 2005 through to 2014 the Decade of Education for Sustainable Development (DESD). The goal of the DESD was to facilitate, on a global scale, the integration of sustainable development principles, values and practices into all aspects of education (UNESCO, 2015). One of the main goals for sustainable development listed by the United Nations pertained to ocean health; dedicating sustainable development goal 14 to “conserve and sustainably use the oceans, seas and marine resources for sustainable development” (United Nations, 2017, p. 10). As a result, ocean education was considered to be a vital component of the DESD.

Ocean education can play a significant role in helping to create citizens who have higher levels of ocean knowledge (Guest *et al.*, 2015; Scully, 2015). Individuals who have a higher comprehension of basic ocean principles develop an understanding of how the ocean impacts our daily lives, may also have a stronger connection to, and a desire to act in a more sustainable way

towards the marine environment (Plankis & Marrero, 2010; Guest *et al.*, 2015). However, current thinking on ocean education is that curriculum must go beyond knowledge about the ocean, and extend toward incorporating skills, experience, and developing positive attitudes. Research indicates that the empowerment of actions is based on more than the impartment of knowledge (Chawla & Cushing, 2007). In other words, learning facts about the oceans will not necessarily translate into positive actions for the ocean, or stimulate pro-environmental behaviour (Steel, Smith *et al.*, 2005; Tran *et al.*, 2010; Guest *et al.*, 2015). Based on this knowledge, the Ocean Literacy Campaign (Cava, Schoedinger, Strang & Tuddenham, 2005) was established by an international group of scientists and educators to provide guidance on how to move beyond a more static vision of oceans education as a compilation of facts, to something more transformative and ultimately more useful in creating a sustainable future.

1.2.3 Ocean Literacy

In looking at ocean literacy, it is important to first discuss the concepts of scientific and ecological literacy. In general, scientific literacy implies that an individual has the knowledge and understanding of scientific concepts that are required for individual decision-making (Lambert, 2006). Scientific literacy applies to all members of the public regardless of whether they may or may not wish to become scientists, but who have a general understanding of scientific concepts and technology, albeit rapidly changing (DeBoer, 2000). As technology continues to develop and impacts on the natural environment increase, it is integral for individuals to understand scientific concepts to make informed and responsible decisions in both their personal lives and communities as a global population. As human impacts on the environment continued to degrade and negatively affect natural systems there became a greater need to focus on sustainable practices.

The term ecological literacy was introduced in the 1990's by David W. Orr and Fritjof Capra and encompasses a way of thinking that intrinsically links natural and human systems, including a consideration of how human interactions affect the environment (Cummins & Snively, 2000; Ashurst, 2008). Thus, an ecologically literate individual makes the connection that humans are part of the natural system and makes a conscious effort to minimize negative impacts (Ocean Literacy Network, 2013).

Ocean literacy is rooted in the beliefs of scientific and ecological literacy. In the late 1990's, the publication of the American National Science Education Standards caught the attention of several marine scientists. The American National Science Standard report provides the guidelines for science education through all grades in the United States. In addition, the report directs the areas in which teachers receive professional development and how teachers set student achievement goals (National Research Center, 1996). The published Education Standards contained little to no mention of the ocean or ocean concepts and as a result ocean science was largely left out of classroom teaching throughout the United States from kindergarten through grade 12 (Schoedinger, Tran & Whitley, 2010). When ocean science was included in the curricula it was simply being taught as an additional topic by teachers who were passionate about the ocean to students as a form of enrichment (Strang, 2008). In response to the formal absence of ocean materials from curricula, in the 1996 Education Standards report, the Ocean Literacy Campaign was developed as a strategy to bring key ocean concepts into the education system and ultimately into the classrooms, engaging students of all ages (Schoedinger *et al.*, 2010).

1.2.4 Principles of Ocean Literacy

The Ocean Literacy Campaign (Ocean Literacy Network, 2013) was developed in 2002 through the efforts of hundreds of scientists and educators with the intention of increasing the level of ocean literacy within society through education and outreach programs. In October 2004, as a result of a two week long online course involving approximately 100 individuals from various disciplines, including formal and non-formal educators, education policy makers, ocean science researchers, and federal agency representatives involved in education, a consensus on a definition of ocean literacy was reached (Schoedinger *et al.*, 2010). As defined by the Ocean Literacy Campaign an ocean-literate individual is essentially anyone who is able to understand fundamental ocean concepts and principles, can communicate about ocean issues and can make informed, responsible decisions regarding the ocean and ocean resources (Cava *et al.*, 2005). The concept of ocean literacy is guided by the understanding of “the ocean’s influence on you—and your influence on the ocean” (Cava *et al.*, 2005, p. 5). Two consensus documents were produced by the Ocean Literacy Campaign and were developed to provide direction for educators and curriculum developers in building comprehensible learning experiences around ocean concepts (Cava *et al.*, 2005). Together these two documents are considered the Ocean Literacy Framework (hereafter simply the Framework). While the Framework was initially developed to be used in the United States, it has been translated into Spanish, Chinese and Japanese and has been used in many countries worldwide (Ocean Literacy Network, 2013).

The Ocean Literacy Framework established seven essential principles and supporting fundamental concepts of ocean science that the Framework creators believe every individual should know to be considered ocean literate. In addition, the Ocean Literacy Framework

provides a scope and sequence for teaching ocean topics to develop ocean literacy. For example, if a grade 12 student is expected to be ocean literate, the scope and sequence provides a “road map” of what needs to be taught throughout elementary and middle school (Ocean Literacy Network, 2013). The scope and sequence identify the science concepts underlying each of the Ocean Literacy Principles and identifies what students need to know at each grade level through main topics and subtopics (Ocean Literacy Network, 2013). The Ocean Literacy scope and sequence, as represented in Table 1, serves as an instructional tool for educators (Ocean Literacy Network, 2013) and links the Ocean Literacy Principles to common topics addressed in high school science curricula. This allows teachers to easily connect the Ocean Literacy Principles to existing curriculum, regardless of their background in ocean education, and facilitates the addition of Ocean Literacy Principles into classrooms. Table 1 summarizes the main topics and subtopics of the scope and sequence for grade levels 9 – 12.

Table 1: Topics and Subtopics for the seven essential principles for Ocean Literacy Grade 9 - 12. (Ocean Literacy, 2013)

Ocean Literacy Principle	Main Topics	Subtopics
1. The earth has one big ocean with many features.	Properties of Ocean Water	Density, pH, Salinity, Temperature
	Geographic and Geologic Features	Generation of Earth's crust, Motion of lithospheric plates, Ocean basins, Ocean floor features, Tectonic activities
	Ocean Circulation	Coriolis effect, Currents (Density and wave-driven), Eckman forces, Effect on climate, Gyres, Prevailing winds, Tides, Transportation of living things, Upwelling, Water cycle, Waves
	Sea Level	Change over time, Effect on currents, Global temperature change, Movement of lithospheric plates, Prevailing winds, Regional differences
2. The Ocean and life in the ocean shape the features of the earth.	Coastal Erosion	Erosion, Deposition
	Plate Tectonics	Continental and Oceanic plates, Erosion, Geologic features from subduction, Subduction, Tectonic activity, Weathering
	Rock Cycle	Accretion, Igneous processes, Sedimentation, Volcanism
	Biogeochemical Cycle	Carbon cycle, Elements in ocean water, Nitrogen cycle, Phosphorus cycle, Silica cycle
3. The Ocean is a major influence on weather and climate	Weather and Climate	Atmospheric convection, Differential heating, El Niño and La Niña, Energy absorption, Energy transfer, Evaporation, Heat capacity, Ocean currents move heat, Precipitation, Weather and climate patterns, Wind energy
	Global Climate Change	Atmospheric warming, Carbon cycle, Carbon dioxide balance, Greenhouse gases, Greenhouse effect, Human effects, Ocean absorption of CO ₂ , Ocean circulation pattern, pH, Photosynthesis
	Consequences of Global Climate Change	Change in ocean circulation, Changes in ocean temperature, Decrease in solar reflection, El Niño and La Niña, Frequency and intensity of weather events, Melting of glaciers and ice caps, Ocean acidification, Rising sea level
4. The Ocean made the earth Habitable	Origins of Life	Fossil evidence, Life started in the ocean, Hydrothermal vents, Prokaryotes and eukaryotes, Theory of evolution
	Oxygen Production	Aerobic respiration, Balance of oxygen and carbon dioxide, Cyanobacteria, Decay, Dissolved oxygen, Earth's atmosphere, Photosynthesis, Oxidation, Ozone

Ocean Literacy Principle	Main Topics	Subtopics
5. The Ocean supports a great diversity of life and ecosystems	Primary Productivity	Autotrophs, Chlorophyll, Carbon fixation, Heterotrophs, Microbes, Nutrient cycling, Nutrients in photosynthesis, Organic molecules, Primary production definition, Upwelling
	Diversity of Ecosystems	Abiotic factors, Abundance of life, Adaptations to environmental conditions, Chemosynthetic organisms, Coral reefs, Diversity of life, Estuaries, Food webs, Habitat zonation, Hydrothermal vent communities, Intertidal habitats Niches, Kelp forests, Open Ocean, Physical properties of the ocean, Productivity, Upwelling
	Diversity of Life	Diversity of adaptations to environmental factors, Diversity of feeding behaviors, Diversity of life cycles and reproductive strategies, Phyletic diversity
6. The Oceans and humans are inextricably interconnected	Uses of the Ocean	Aquaculture, Fisheries, Food resources, Human impacts on the ocean, Non-renewable resources, Renewable resources, Sources of energy, Source of medicines, Source of mineral ores, Source of natural gas, Source of oil, Source of oxygen, Source of salt
	Where People Live	Careers, Climate, Commerce, Exploration, Global economy, Human cultures, Recreation, Transportation
	Human Impact on the Ocean and Atmosphere	Biomagnification, Fossil fuels, Changes to ocean temperature, Effect of technological advances, Eutrophication, Greenhouse gases, Global climate change, Human impact on topography, Human population growth, Hydrofluorocarbon emissions, Invasive species, Ocean acidification, Rising sea level
	The Ocean affects Weather and Climate	Effect of changing weather and climate, Effect of natural disasters, Effective natural disaster warnings
	Responsibility and Advocacy for the Ocean	Legal efforts to protect the ocean, Informed decision making, Marine Protected Areas, Marine Reserves Protecting marine resources, Reduction of biological and biogeochemical changes, Reduction of overfishing, Reduction of pollution, Sustainability
7. The Ocean is largely unexplored	People Explore the Ocean	Advances in research and technology, Collection long-term data, Discovery new habitats, Discovery of new species, Human benefits from discovery, Human impacts on the ocean, Sustainable use of resources
	Ocean Exploration Requires Collaboration	Careers in ocean exploration, Communication of information, Global participation in ocean exploration, Higher education in ocean exploration, Making informed decisions Political engagement Science careers, Sustainability, Technology
	Ocean Exploration Requires Technological Innovation	Computer technology, Continuous data collection technology: sensors and transmitters, Molecular analysis, Ocean-observing systems, Physical properties of the ocean, Satellites, Satellite image technology, Scientific models, Simulations, Submersibles

1.2.5 Systems Thinking and Teaching of Ocean Education

In order to develop ocean literacy among students, they must be empowered with knowledge and inspired to act. The multidisciplinary aspect of ocean education highlights the interconnectedness and complexities of earth systems. In order to understand and interpret complex systems individuals need to go beyond the acquisition of knowledge and develop the ability to think critically in a systems way of thinking. Developing systems thinking allows individuals to interpret complex systems and incorporates a variety of learning types and thinking skills (Richmond, 1993). Studies have found that a systems approach to understanding critical concepts and processes in the ocean, such as the water and carbon cycles, may support ocean literacy (Tran, Payne, & Whitley, 2010). Learning in this way places an emphasis on big picture ideas that form the foundation for understanding how earth systems work.

The Ocean Literacy scope and sequence (see Table 1) identifies how ocean concepts are interconnected and provides educators with a systems approach to teaching about the ocean (Tran *et al.*, 2010). In addition, within the Ocean Literacy Principles, ideas develop and build over grade levels, indicating where scaffolding exists, and is needed, from one level to the next (Tran *et al.*, 2010). As Tran and colleagues observe “Concepts conveyed by use of the conceptual flow diagrams and engaging learning experiences will allow students to reflect, articulate, and share their thinking; build personal connections that will have a long-lasting effect on their motivations to learn and act; and ultimately to become ocean literate” (2010, p. 24).

1.2.6 Global Efforts in Ocean Education

Globally, the declining health of the ocean is gaining attention and as a result there is a need to develop ocean literate citizens and focus on ocean education. However, ocean concepts remain difficult to find in the curriculum of most countries (Gough, 2017). An analysis of both England and New Zealand's curriculum revealed limited inclusion of ocean concepts, with neither of the terms "coastal" or "marine" being included within the science curriculum. In addition, studies have indicated similar findings within the Australian (Gough, 2017) and Brazilian (Berchez et al., 2016) curriculum.

Despite the lack of inclusion of ocean content in educational curricula, there are several independent educational groups that provide ocean related resources for teachers. Within Australia there are several small groups that provide access to ocean related resources, The Great Barrier Reef Marine Park Authority (GBRMPA, 2016) is one group that offers resources for educators and students on coastal ecosystems, climate change, and responsible practices. Cool Australia is another online resource that provides lesson plans for a variety of disciplines based on national curriculum guidelines, to assist teachers in educating for a sustainable future (Cool Australia, 2014). Within England, additional groups, such as the environmental group Surfers Against Sewage have developed educational programs for schools, in this case called "Seas for Life" (Surfers Against Sewage, 2016). The program includes several interactive sessions on ocean issues including; ocean pollution and its impacts, and what schools, communities and organizations can do to help (Surfers Against Sewage, 2016). The mission statement of this group is to protect the "UK's oceans, waves and beaches for all to enjoy safely and

sustainably, via community action, campaigning, volunteering, conservation, education and scientific research.” (Surfers Against Sewage, 2016). Also based in the UK, the non-governmental organization Sea Change is an organization committed to improving ocean literacy among European citizens through engaging activities and resources (Donert *et al.*, 2015). In addition, there are a multitude of similar organizations based throughout the United States including, NOAA Ocean Explorer Education (NOAA, 2018), BRIDGE (Bridge Ocean Education Teacher Resource Center, 2016), and National Geographic (National Geographic, 2017), that aim to improve ocean education within schools and for the general public. Non-formal methods of ocean education can be successful in raising awareness of complex ocean issues, however, for these programs to be effectively incorporated into a school’s curriculum, ocean concepts must be included in curriculum outcomes.

1.2.6 Ocean Education in Canada

The education framework within Canada is structured separately and varies across the country. Under the Canadian constitutional division of powers, there is no federal department of education (with the exception of aboriginal education and education in each of the three federal Territories). Rather, each of Canada’s ten provinces, has sole authority over the education system within its domain (CMEC, 2014; Weinrib and Jones, 2014). The Canadian government oversees a Council of Ministers of Education (CMEC) whose primary function is to facilitate interaction and collaboration among the 10 provinces and 3 territories (CMEC, 2001), however, curriculum is determined individually at the province/territory level. Individual Ministers of Education are responsible for the organization and assessment of the education system at the

provincial/territorial level, and typically individual school decisions are entrusted to the school board or similar local body by the provincial/territorial government (OECD, 2015). Individual school systems encompass each of the provinces or territories unique culture and heritage and implemented curricula mirrors issues of importance to that region (CMEC, 2001). Ocean education is relevant for all provinces and territories and despite proximity, the ocean has a significant impact on global weather, climate and biogeochemical cycles (Hoffman & Barstow, 2007; Strang, 2008). Ocean education, however, is not seen as a priority for all provinces and territories. Studies have found that that ocean concepts are not represented well within Canadian curriculum (Cummins & Snively, 2000; Gough, 2017).

Despite the low levels of inclusion of ocean concepts in Canadian curriculum (Cummins & Snively, 2000; Gough, 2017), there are provinces who have established partnerships with external organizations to assist in the implementation of strategies and the development of curriculum resources related to the ocean. Within Newfoundland and Labrador, the Ocean Learning Partnership (OLP) fosters ocean literacy among high school students. This innovative project attempts to engage senior high students through the integration of technology and hands-on field studies (Ocean Learning Partnership, 2016). Students are able to take part in educational cruises where they collect data and operate marine equipment and study the resulting real time underwater data as a form of citizen science. Using hands-on, practical activities students are engaged in real world situations and research with a subject that is relevant to their personal community (Ocean Learning Partnership, 2016). This program also provides ocean training for teachers, a significant gap existing within the educational system, who may not have a strong

background in marine sciences. The OLP has secured support from the provincial Department of Education and the Newfoundland Teachers Association, which will help in the implementation of ocean concepts into specific curriculum, reinforcing this program (Ocean Learning Partnership, 2016).

British Columbia is home to several organizations focusing on marine research and oceans literacy, one of which is the Oceans Network Canada (ONC). The ONC is home to two world-leading observatories where live videos of the ocean can be viewed, and data collected (Oceans Network Canada, 2016). The ONC provides educational resources to teachers that allow students to explore real world research in real time. Connecting students to relevant issues and challenges that are occurring in the world engages them in solutions thinking and critical analysis. The ONC combines real scientific research with technological advances (such as apps and live video) that can be used to enrich the establishment of ocean concepts within the classroom (Oceans Network Canada, 2016). Also based in British Columbia is the Canadian Network for Oceans Education (CaNOE), which is dedicated to advancing ocean literacy within Canada, connecting Canadians from coast to coast to build national ocean literacy (Canadian Network for Oceans Education, 2016). By connecting educators with scientists, CaNOE provides a platform for learning, development and communication for ocean literacy within Canada (Canadian Network for Oceans Education, 2016). Through the establishment of Professional Development for teachers, provision of classroom resources and support, the goal is to increase the regional and national understanding of the oceans for the present and the future (Canadian Network for Oceans Education, 2016).

On a local scale, the ocean has an integral role in the economy for Nova Scotia. Nova Scotia describes itself as “Canada’s Ocean Playground” (White, 2008). This is appropriate considering that along Nova Scotia’s 7579 kilometers of coastline, there is an abundance of ocean related services and industry including; fisheries (commercial and recreational), aquaculture, offshore energy projects, tidal energy, ports, shipyards, underwater acoustics and imaging, research, tourism, along with a wide range of recreational opportunities (Province of Nova Scotia, 2011). Within Nova Scotia, all eleven universities and various post-secondary education facilities offer courses in marine science or specific trades that can be applied to the ocean technology industry. There are more than 450 individuals residing in Nova Scotia with doctorate degrees in ocean-related disciplines; apparently the highest concentration anywhere in the world (Province of Nova Scotia, 2011). Canada’s largest center for ocean research, the Bedford Institute of Oceanography, employs over 700 scientists, engineers and technicians (Province of Nova Scotia, 2011). Despite all of the above, within Nova Scotia there are few public groups focused on ocean education at the primary or secondary levels. While not exclusively dedicated to the ocean, two local non-governmental organizations, the Clean Foundation (Clean Foundation, 2018) and the Ecology Action Center (Ecology Action Center, 2018), both offer information and opportunities to get involved with current local issues relating to the health of the ocean.

However, overall, Canada has not made much progress around the area of ocean education regardless of the stated importance of doing so (Guest *et al.*, 2015; Scully, 2015; UNESCO, 2015; Scully, 2016). Ocean education was not indicated as an area of priority or a topic of importance in moving forward after the completion of the DESD

(CMEC, 2014; UNESCO, 2014; Guest *et al.*, 2015). Further, there is little indication that the Ocean Literacy Principles established by the global community is a priority area for Canada's Ministers of Education (Guest *et al.*, 2015).

1.4 Literature and Knowledge Gaps

While the topic of environmental education is prominent within the peer-reviewed literature, publications on ocean education and oceans literacy are much less prevalent. Ocean literacy is a relatively new term, being established in 2004, and since its conception only 46 papers have been published using this term (Uyarra & Borja, 2016).

Within the literature there is a relatively small group of studies that have focused on evaluating ocean literacy, however, the focus of these studies has been almost exclusively on students and the general public. Of those studies, the majority have been completed within the United States (Lambert 2005; Steel, Smith *et al.* 2005; Fletcher *et al.* 2009; Plankis & Marrero 2010) with a few in Canada (Cummins & Snively 2000; Guest *et al.* 2015), and other countries (Markos, Boubonari, Mogias, & Kevrakedis, 2017). While there is one study that focused on the knowledge of ocean concepts among pre-service teachers (Mogias, Boubonari, Markos, & Kevrakedis, 2015), there are no studies within the literature on ocean literacy that focus specifically on Canadian science curriculum or teacher knowledge and implementation of ocean concepts into science classrooms.

1.5 Research Goals and Objectives

The objectives of this study were to determine the extent to which the established universal Ocean Literacy Principles are included in Nova Scotia's high school science

courses and to better understand the potential challenges and barriers experienced by teachers when integrating the Ocean Literacy Principles into the science curriculum. To complete these objectives a mixed methods approach, composed of a detailed content analysis of Nova Scotia high school science curriculum documents and semi-structured interviews with high school science teachers was carried out.

1.6 Research Questions

This study attempted to meet the research objectives of the inclusion of the Ocean Literacy Principles as established by the Ocean Literacy Network by answering the following questions:

- 1) To what extent are the internationally established Ocean Literacy Principles represented in high school science curriculum in Nova Scotia?
- 2) What are the main challenges and barriers that HRSB high school science teachers experience in implementing concepts related to ocean literacy into established science curriculum?

1.7 Scope

This thesis adds to the growing body of knowledge in the area of ocean education and ocean literacy by examining the extent to which the Ocean Literacy Principles are incorporated into the Nova Scotia high school science curriculum and the perceptions of how ocean content is addressed within these courses by educators. This study focused on alleviating knowledge gaps related to this topic and providing suggestions to improve the inclusion of Ocean Literacy Principles.

While this study investigated the inclusion of Ocean Literacy Principles in high school science curriculum, the results are based on an analysis of Nova Scotia science curriculum and a cohort of teachers from the HRSB. Therefore, the results of this study are not generalizable or representative of all school boards within Nova Scotia. The results of this study attempt to provide insight into improving ocean literacy among Nova Scotian Youth.

1.8 Structure of Thesis

The overall structure of this thesis consists of five chapters. The first chapter provides an introduction and context for the research problem. The second chapter focuses on the specific research methods used within this study and gives an overview of the methodological theory used to inform the process. The third and fourth chapters are designed as stand-alone chapters presented in publication format. Each of these chapters contain their own abstract, introduction, methods, results, discussion, and conclusion sections. Chapter three focuses on the analysis of Nova Scotia high school science curriculum documents including, Science 10, Biology 11, Biology 12, Chemistry 11, Chemistry 12, Physics 11, Physics 12, Human Biology 11, Food Science 12, Geology 12 and Oceans 11, to determine the quantity of content that relates to the seven principles for ocean literacy. Chapter four focuses on interpreting how a cohort/group of senior high school science teachers perceive the challenges and barriers associated with implementing ocean concepts and meeting the Ocean Literacy Principles in high school science courses teaching in the HRSB. Finally, chapter five includes a summary of these findings and is the concluding chapter that gives an overview on the significance and

contributions of this thesis to educational practice and provides recommendations for education researchers and practitioners.

Chapter 2: Methods

The objectives of this study were to: (1) determine the extent to which ocean education is included in Nova Scotia's high school science courses and to determine how the context relates to the seven principles of ocean literacy, and (2) to better understand the potential challenges and barriers teachers face to integrating ocean education into their teaching practices. The first objective was achieved through a thorough content analysis of the Nova Scotia provincial high school science curriculum. To achieve the second objective of this study, semi-structured interviews were conducted with a cohort of high school science teachers to understand how they include ocean education in their teaching of the Nova Scotia science curriculum, and to identify any challenges they experience including these concepts in their classrooms. The following section offers a more fulsome description of the research approach and methods applied in this thesis.

2.1 Methodology and Theory

2.1.1 Design Methods

This study used a combination of exploratory and transformative research methods to analyze separate but complementary data (Ardoin, Clark, & Kelsey, 2012) that relates to the central issue of the inclusion of ocean education content in high school science curriculum. As Creswell (2014) notes, an exploratory design method aims to investigate and/or gain familiarity with a qualitative data set in order to determine which findings need to be further developed. The methods in this study align with this understanding of exploratory design as they are focused on investigating participant

perspectives on the inclusion of ocean concepts within high school science curriculum. In addition to exploratory perspectives, this study aims to expose gaps within educational programs in the area of the inclusion of ocean related concepts, and as a result also embraces a transformative design method.

Transformative research methods are focused on the ongoing process of social development that includes an action agenda and establishes a call to action for change (Creswell, 2014). Fletcher and Potts (2007) state that the exposure to discussions related to sustainability are a significant factor in the development of sustainable citizenship and the change process. As Ornetzeder and Rohrer (2005) state, people exposed to discussions about environment and sustainability are an important, though often neglected, factor in social learning and change processes. As communication is seen as a vector for social change in the sustainability movement (Filho 2000, Oepen, 2000), this research may serve as an important channel for advancing discussions and initiatives around oceans education through engagement with the teachers who are responsible for delivering curriculum.

2.1.2 Social Constructivism

Similar to other studies within educational research (Ardoin *et al.*, 2012; Kulneikes, Young & Longboat, 2013; Spence *et al.*, 2013), this study is centered in a social constructivist worldview. Social constructivism places an emphasis on the individual and how they perceive and make sense of their own world and experiences (Greene 2007; Lodico *et al.*, 2010; Creswell, 2014). Individuals will have different and unique perspectives based on their own experiences and personal beliefs. The researcher must assimilate meaning from multiple view points and perspectives of the participants

(Lodico *et al.* 2010; Creswell, 2014). Within social constructivism it is believed that in order to understand the “whole” one must consider all components; such as connections to the historical, socioeconomic and cultural contexts in which the experiences exist (Lodico *et al.* 2010). In this framework participant knowledge is the main focus as the researcher develops a strong contextual understanding of the central issue (Greene 2007). Thus, it is important to note that since our reality is a result of our background and experiences, researcher interpretations are also influenced by their own subjective experiences. As Creswell (2014) states, the only way for researchers to fully develop an understanding is to interact with participants and become involved in their reality. To achieve this, research studies based in social constructivism are typically qualitative in nature, focusing on an open-ended questioning style to maximize the participant’s view.

Developed by Vygotsky (1978), the social constructivism worldview emphasizes the role of social and cultural interaction in cognitive development. Social constructivists believe that through the process of sharing individual perspectives ideas can be constructed and deeper learning occurs (Amineh & Asl, 2015). In an educational setting, students construct their own meaning from their experiences, where learning integrates new knowledge with pre-existing knowledge allowing for the synthesis of concepts and the formation of new ideas (Kalpana, 2014). Teachers play an integral role in facilitating collaborative learning and guiding the application of previously acquired knowledge. In the context of this study, a social constructivism approach is significant due to the impact teachers have on student learning. Understanding teacher perspectives on the inclusion of ocean concepts in high school science courses attempts to offer insight into the development of initiatives surrounding ocean education.

2.2 Study Design

2.2.1 Study Description

School curriculum and the individuals who deliver it are the two fundamental components of a successful education program (Chatzifotiou, 2006). The curriculum dictates the “what” that is taught, and teachers use their expertise to decide the “how”. The analysis of curriculum documents has been previously used to determine the inclusion of concepts related to sustainability and environmental education. For example, Jóhannesson *et al.* (2011) created a key to analyse public school curriculum documents in Iceland for the inclusion of aspects related to education for sustainable development. In addition, Spence (2011) analysed three curriculum documents from the Nova Scotian grade 6 educational program to determine the quantity of environmental education included. This study examines the “what” through an in-depth curriculum analysis. The how is determined via interviews with teachers. Each of these two analyses are described separately below.

2.2.2 Curriculum Analysis

The first objective, determining the extent to which ocean education is included in Nova Scotia’s high school science courses and to determine how the context relates to the seven principles of ocean literacy as established by the Ocean Literacy Network (Table 1) was achieved through an analysis of the Nova Scotia high school science curriculum documents. This study used a mixed methods technique informed by Mayring (2014), in which science curriculum documents were systematically analysed for themes relating to oceans. This involved both the analysis of themes within the text (qualitative) using *a priori* codes and analysing the frequencies of each code (quantitative). High school

science curriculum documents used within this study were accessed through the Nova Scotia Department of Education's website "Document Depot". Curriculum documents are available for electronic download as a pdf or through ordering by mail. All eleven science documents (n = 11) were analysed including; Science 10, Biology 11 & 12, Chemistry 11 & 12, Physics 11 & 12, Human Biology 11, Oceans 11, Food Science 12 and Geology 12. Prior to analysis, curriculum documents were imported into *NVivo 10*. *NVivo 10* is a qualitative data analysis program created by QSR International that allows the researcher to organize and find insights and connections within qualitative data (QSR International, 2017). Data were saved and stored using *NVivo 10* and *Microsoft Excel* spreadsheets.

The analysis and coding of the documents was guided by the seven principles for ocean literacy (Table 1). Coding is often used in qualitative research to determine patterns and relationships that originate from data. Within qualitative studies, codes have been defined by Saldana (2013, pg. 4) as symbols constructed by the researcher that "attributes interpreted meaning to each individual datum for later purposes of pattern detection, categorization, theory building and other analytic processes". Coding is used for several purposes that include, data reduction, organization and exploration (Cope, 2010). *A priori* codes established using the Ocean Literacy Principles provided the basis for the analysis of the eleven curriculum documents (See Table 2). The seven principles of Ocean Literacy Network were developed to provide educators and curriculum developers with a guide to build ocean centered relevant learning experiences (Schoedinger *et al.*, 2010). Each of the essential principles are further broken down into smaller fundamental concepts, offering more specific criteria that relates to each of the

individual principles (Ocean Literacy, 2013). The principles and fundamental concepts are represented in Table 2.

Table 2: Ocean Literacy Principles and Fundamental Concepts (Modified from Cava *et al.*, 2005) (For full account of the Fundamental Concepts see Appendix F)

Ocean Literacy Principle	Fundamental Concept (FC)
1. The earth has one big ocean with many features	A: The ocean is the defining physical feature on our planet Earth.
	B: Ocean basins are composed of the seafloor and all of its geological features.
	C: Throughout the ocean there is one interconnected circulation system powered by wind, tides, the force of Earth’s rotation (Coriolis effect), the Sun and water density differences.
	D: Sea level is the average height of the ocean relative to the land. Sea level changes as plate tectonics cause the volume of ocean basins and the height of the land to change.
	E: Most of Earth’s water (97%) is in the ocean. Seawater has unique properties.
	F: The ocean is an integral part of the water cycle and is connected to all of Earth’s water reservoirs via evaporation and precipitation processes.
	G: The ocean is connected to major lakes, watersheds, and waterways because all major watersheds on Earth drain to the ocean.
	H: Although the ocean is large, it is finite, and resources are limited.
2. The ocean and life in the ocean shape the features of earth	A: Many earth materials and biogeochemical cycles originate in the ocean.
	B: Sea level changes over time have expanded and contracted continental shelves, created and destroyed inland seas, and shaped the surface of land.
	C: Erosion occurs in coastal areas as wind, waves, and currents in rivers and the ocean, and the processes associated with plate tectonics move sediments.
	D: The ocean is the largest reservoir of rapidly cycling carbon on Earth.
	E: Tectonic activity, sea level changes, and the force of waves influence the physical structure and landforms of the coast.
3. The ocean is a major influence on weather and climate.	A: The interaction of oceanic and atmospheric processes controls weather and climate by dominating the Earth’s energy, water, and carbon systems.
	B: The ocean moderates global weather and climate by absorbing most of the solar radiation reaching Earth.
	C: Heat exchange between the ocean and atmosphere can result in dramatic global and regional weather phenomena, impacting patterns of rain and drought.
	D: Condensation of water that evaporated from warm seas provides the energy for hurricanes and cyclones.
	E: The ocean dominates Earth’s carbon cycle.
	F: The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon, and water.
	G: Changes in the ocean-atmosphere system can result in changes to the climate that in turn, cause further changes to the ocean and atmosphere.
4. The ocean made earth habitable.	A: Most of the oxygen in the atmosphere originally came from the activities of photosynthetic organisms in the ocean.
	B: The ocean is the cradle of life; the earliest evidence of life is found in the ocean.
	C: The ocean provided and continues to provide water, oxygen, and nutrients, and moderates the climate needed for life to exist on Earth.

Ocean Literacy Principles	Fundamental Concepts (FC)
5. The ocean supports a great diversity of life and ecosystems	<p>A: Ocean life ranges in size from the smallest living things, microbes, to the largest animal on Earth, blue whales.</p> <p>B: Most of the organisms and biomass in the ocean are microbes, which are the basis of all ocean food webs.</p> <p>C: Most of the major groups that exist on Earth are found exclusively in the ocean and the diversity of major groups of organisms is much greater in the ocean than on land.</p> <p>D: Ocean biology provides many unique examples of life cycles, adaptations, and important relationships among organisms that do not occur on land.</p> <p>E: The ocean provides a vast living space with diverse and unique ecosystems from the surface through the water column and down to, and below, the seafloor.</p> <p>F: Ocean ecosystems are defined by environmental factors and the community of organisms living there.</p> <p>G: There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms.</p> <p>H: Zonation patterns influence organisms' distribution and diversity.</p> <p>I: Estuaries provide important and productive nursery areas for many marine and aquatic species.</p>
6. The ocean and humans are inextricably interconnected	<p>A: The ocean affects every human life. It supplies freshwater and nearly all Earth's oxygen. The ocean moderates the Earth's climate, influences our weather, and affects human health.</p> <p>B: The ocean provides food, medicines, and mineral and energy resources.</p> <p>C: The ocean is a source of inspiration, recreation, rejuvenation, and discovery. It is also an important element in the heritage of many cultures.</p> <p>D: Humans affect the ocean in a variety of ways.</p> <p>E: Changes in ocean temperature and pH due to human activities can affect the survival of some organisms and impact biological diversity.</p> <p>F: Much of the world's population lives in coastal areas.</p> <p>G: Everyone is responsible for caring for the ocean.</p>
7. The ocean is largely unexplored.	<p>A: The ocean is the largest unexplored place on Earth—less than 5% of it has been explored.</p> <p>B: Understanding the ocean is more than a matter of curiosity. Our very survival hinges upon it.</p> <p>C: Over the last 50 years, use of ocean resources has increased significantly.</p> <p>D: New technologies, sensors, and tools are expanding our ability to explore the ocean.</p> <p>E: Use of mathematical models is an essential part of understanding the ocean system.</p> <p>F: Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, physicists, animators, and illustrators.</p>

The Nova Scotia high school curriculum documents are part of the Atlantic Canada Science Curriculum, which includes the four Atlantic Canadian Provinces, and was developed as a strategy to implement consistency in science education (APEF, 1998). The development of scientific literacy for all students is a primary focus of the Atlantic Canadian curriculum (APEF, 1998). It is important for students in all science courses, from primary through to grade 12, to develop appropriate skills in critical thinking and to become equipped with the tools which enable them to make informed scientifically relevant decisions.

Structurally, science curriculum documents are based on an outcome framework that consists of essential graduation learnings, general curriculum outcomes, and specific curriculum outcomes (Council of Ministers Education, 1997). The essential graduation learnings are general statements that focus on the knowledge, skills and attitudes that students are expected to know upon graduating from secondary school (Council of Ministers Education, 1997). For Nova Scotia, the essential graduation learnings are: aesthetic expression, citizenship, communication, personal development, problem solving and technological competence (APEF, 1998). General curriculum outcomes (GCO's) are designed to include the key components of scientific literacy and are divided into four categories that establish the basis for the outcomes framework (APEF, 1998). The four categories include: STSE (Science, Technology, Society and the Environment); Skills; Knowledge; and, Attitudes. These four categories are consistently used throughout all science curriculum documents within Nova Scotia. Within STSE category, curriculum is designed so that students focus on the relationships between science and society and outcomes are centered around topics such as: nature of science and technology,

relationships between science and technology, and social and environmental contexts of science and technology (APEF, 1998). Skills required for scientific inquiry, collaboration and communication are the goals of the skill category and the focus is on initiating and planning, performing and recording, analysing and interpreting communication and teamwork (APEF, 1998). The knowledge category is course specific and targets acquiring knowledge surrounding the content area of the course, often divided into specific units of study. The development of attitudes that support the responsible acquisition of scientific and technological knowledge along with the benefit to the individual, society and the environment is the focus of the attitudes category (APEF, 1998). A flowchart of the outcome framework is represented in Figure 1.

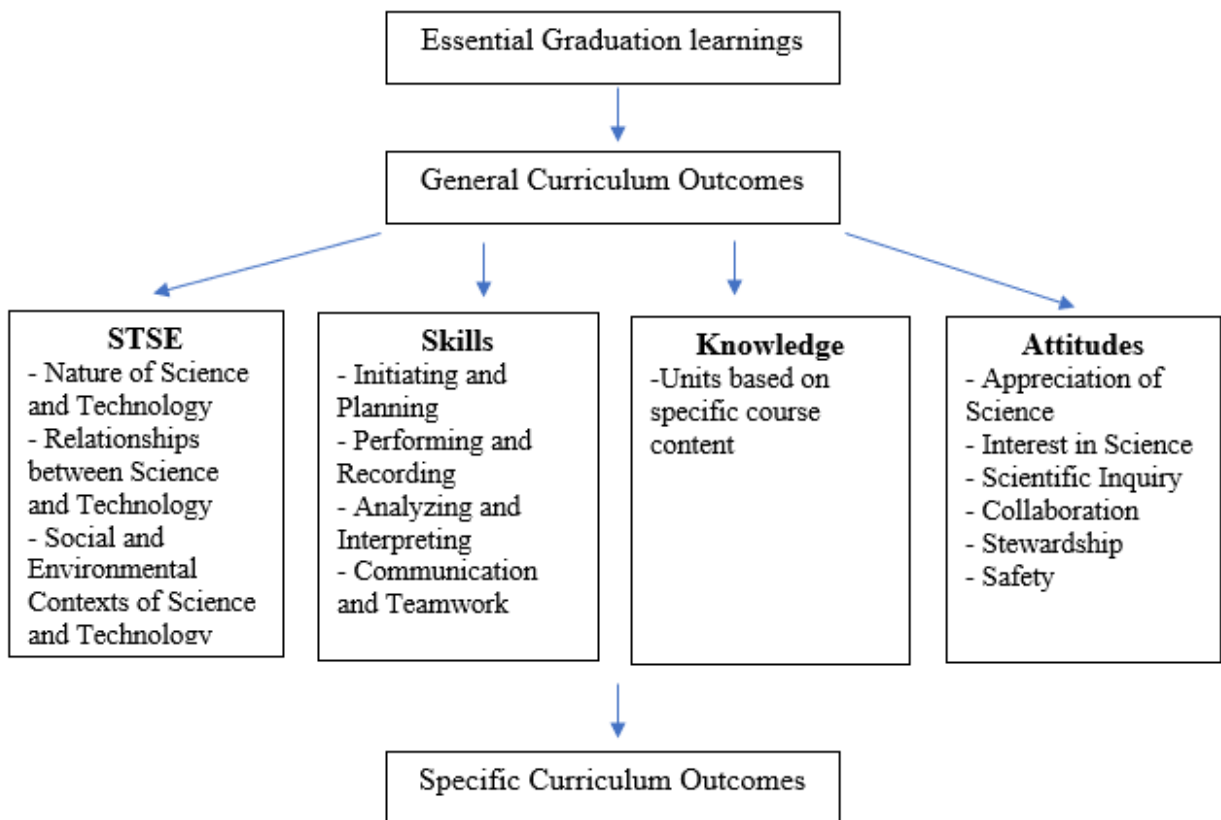


Figure 1: Common Framework of Science Learning Outcomes K – 12. (Adapted from APEF, 1998)

Specific curriculum outcomes (SCO's) are representative of each individual course and directs teaching practices and student learning. The SCO's serve as benchmarks to what each student should know upon course completion. Based on the SCO's teachers design learning experiences and develop assessment strategies that assist students in achieving the intended outcomes for the course, and the overall essential graduation learnings (APEF, 1998). In this study, I chose to code only the curriculum outcomes for each of the 11 curriculum documents, based on the belief that the outcomes are what direct teaching practices.

From the general curriculum outcomes, the knowledge, skills and STSE categories were selected for analysis. These categories are represented within the specific curriculum outcome framework which facilitated the ability to determine where ocean concepts are strongly represented and where they are lacking. Previous studies (Guest & Lotze, 2015; Scully, 2016) have indicated that youth in Nova Scotia have scored low in knowledge on ocean concepts and awareness on marine related employment opportunities. Insight into which outcome categories contained low inclusion of ocean concepts was of interest to help to explain the results indicating low ocean knowledge among Nova Scotian youth. The attitudes category was not selected for analysis as the focus of this aspect, responsible acquisition and application of scientific and technological knowledge (APEF, 1998), can be achieved through the analysis of the knowledge and STSE categories. In addition, the specific curriculum outcomes emphasize knowledge, skills and STSE, as such the attitudes category would not be specifically addressed in the outcomes framework.

Curriculum outcomes were initially coded using *a priori* codes that were developed from the key concepts represented in Table 2. From the initial analysis, the quantity of ocean education was determined by calculating the number of outcomes within each document that were categorized within each of the established Ocean Literacy Principles. Outcomes that were coded for multiple principles, were counted each time they appeared in a different Ocean Literacy Principle. For example, within the curriculum document for Science 10 the knowledge outcome 331-1, which states a student should be able to use scientific theory and identify questions explaining heat energy transfers that occur in the water cycle (Nova Scotia Department of Education, 2012), applied to both Ocean Literacy Principles 1, the earth has one big ocean, and 3, the ocean is a major influence on weather and climate. This outcome was counted twice as it appeared in two of the Ocean Literacy Principles and as such both concepts would be addressed in the teaching of this outcome.

In order to determine the context of the included ocean education, the coded outcomes were further analysed and categorized into sub-codes based on the Fundamental Concepts, also developed *a priori* (See Table 2). A sub-code is used to generate more detail and enrich the analysis process (Saldana, 2013). For example, outcomes that related to Principle 1, the earth has one big ocean, were further coded to determine what Fundamental Concept the outcome best represented; such as referencing the water cycle or the impact of finite and limited resources. Several outcomes reflected multiple Fundamental Concepts, indicating areas where the Ocean Literacy Principles would be included. Coding the outcomes into sub-codes gave deeper insight into where

the key concepts from the Ocean Literacy Principles would be addressed within each of the curriculum documents.

2.2.3 Interview Process

To determine the potential challenges and barriers teachers face in integrating ocean concepts into high school science classrooms, semi-structured interviews were conducted with a cohort of high school science teachers from the Halifax Regional School Board (HRSB). Prior to participant recruitment and data collection, ethical approval was required from both Dalhousie University's Social Sciences and Humanities Research Ethics Board and the HRSB's Research Committee. I submitted the ethics approval for Dalhousie University which included a complete project description, consent and process forms, proposed interview questions for participants, along with a risk assessment and confidentiality and anonymity assessments. A copy of the University's ethical approval is included in Appendix A: Dalhousie University Ethics Approval. To obtain ethical approval from the HRSB, an application including a detailed study description and explanation of the theoretical framework and methodology of the study, a letter of explanation for teachers, the interview script, process of data collection and analysis along with a copy of ethical approval from Dalhousie University was required. A copy of the ethics approval from the HRSB is included in Appendix B: HRSB Ethics Approval.

Participant interviews were selected as the main methodological tool in this study as to gain a more in depth and detailed account (Boyce & Neale, 2006) of the perception of the inclusion of ocean concepts within courses taught by the participants. To recruit participants for this study, high school science teachers were contacted through the use of

individual e-mails provided by the HRSB and school websites. High school principals were also contacted with the request to pass along the information to any additional teachers who might find the study relevant. A copy of the information letter is included in Appendix C: Information Letter for Teachers. After initial contacts were made through e-mail, individual times were set up, at the convenience of the teachers, to meet for the interview. It should be noted that teachers are incredibly busy and often requests that require additional time commitments are dismissed, as a result, snowball sampling techniques were used to recruit additional participants. Snowball sampling is a useful technique where a participant provides the researcher with names of potential additional participants and is often used in studies where participants are marginalized or hard to reach (Atkinson & Flint, 2001). While teachers are not typically marginalized or hard to reach, due to the nature of my position as a teacher myself, snowball sampling was useful in gaining access to participants outside of personal connections. A total of ninety teachers were contacted, two declined to take part, seventeen were interviewed and the remainder provided no response. With this method of recruitment, there is the possibility of biased selection as participants are not recruited on a random basis. Participants selected this way may have previous knowledge of or interest in the subject matter. However, individuals were not asked to disclose any reason for taking part in the study. Studies using snowball sampling should not be considered representative of the larger population (Biernacki & Waldorf, 1981), as such this study is not considered to be a representative sample of teachers within the HRSB or the province of Nova Scotia and the results of the study cannot be generalized.

Pilot Tests. In order to prepare for the interview process and data collection, pilot test interviews were conducted. Pilot tests are extremely useful for researchers, providing insight into research methodologies and bringing attention to possible flaws that may require minor adjustments (Dikko, 2016). Pilot tests are thought to improve the level of validity and reliability adding value and credibility to a research project (Van Wijk & Harrison, 2013; Dikko, 2016). As noted by Dikko (2016) pilot tests in research studies using interviews as the main research instrument, can help to draw attention to unnecessary or ambiguous questions, determine an accurate length of time required for the interview, ensure researcher has asked all pertinent questions and to determine if there are aspects that were not covered so that the researcher can add or change questions. In this study, the pilot tests assisted in creating familiarity with the semi-structured interview process and identifying questions that needed to be clarified, restructured or removed. Feedback provided based on the pilot interviews was invaluable in developing interview skills and fine tuning the interview questions. Pilot interviews took place during May 2015 at Charles P. Allen high school in Bedford Nova Scotia, where four high school science teachers were interviewed. Each interview question was read to the participants and responses were recorded as to simulate the intended interview process. Following the completion of the interview participants were given time to provide feedback about specific questions, length and overall flow of the interview. The feedback provided was recorded and notes were compared from all four interviews. The pilot studies provided insight into key aspects of the data collection process which helped to ensure the questions were clear and concise. In addition, specific questions were broken up to allow for participants to give less structured and more in-depth personal

responses. One of the most significant modifications that arose from the pilot tests was an accurate representation of the time commitment required and being able to shorten the time frame to make it appealing for teachers. Often teachers are apprehensive in making time commitments beyond the scope of their profession, being able to communicate the amount of time required facilitated the recruitment process.

Seventeen high school science teachers (n = 17) were interviewed in total from various schools within the HRSB. The HRSB is the largest school board in Atlantic Canada, created in 1996 through the amalgamation of three separate school boards (HRSB, 2017). Within the HRSB there are 136 schools, sixteen of which are secondary schools (HRSB, 2017). Consisting of eight districts, the HRSB has an extensive catchment area (Figure 2); encompassing all communities within Halifax, Dartmouth, Bedford, Eastern Passage and extending from Ecum Secum to Terrance Bay to Hubbards Nova Scotia.

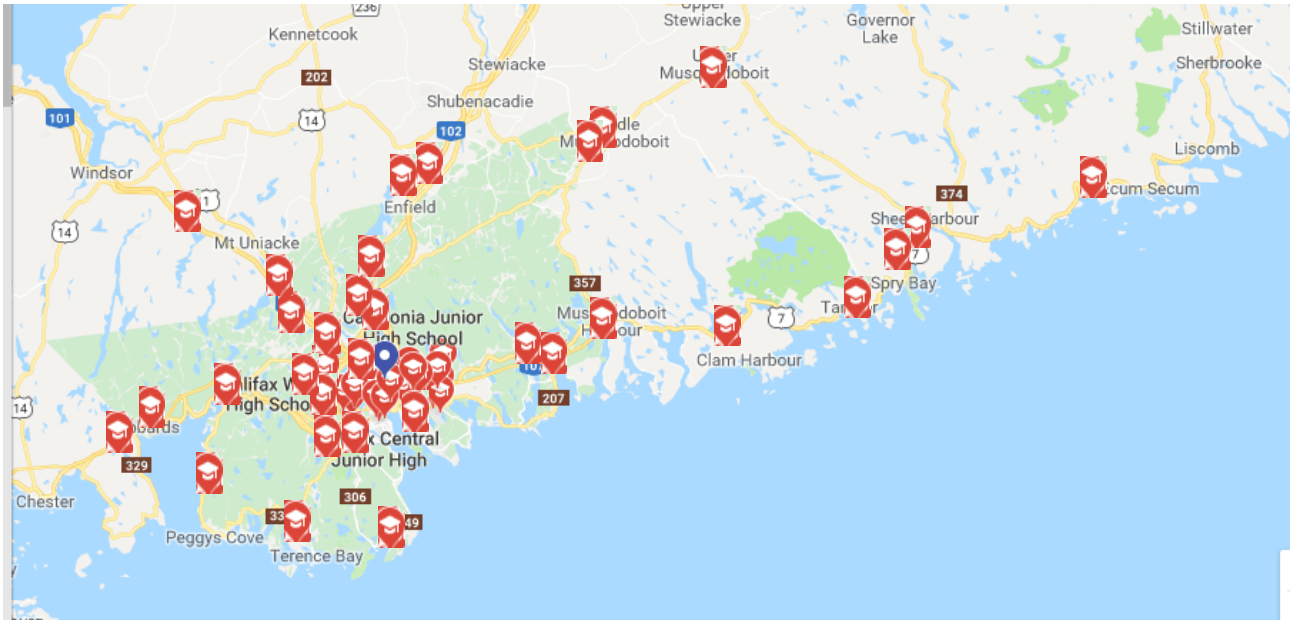


Figure 2: Catchment area of the Halifax Regional School Board. (Modified from Google Maps 2017)

Interviews were completed in person at each participant’s individual school, or if preferred, in a public venue such as a coffee shop. Each of the interview questions was verbally communicated to the participants and they were encouraged to express their own opinions and contribute additional information where they felt appropriate. A copy of the questions asked during each interview is included in Appendix D: Interview Script. The interviews were conducted from November 2015 through to May 2016. Participants completed a consent form giving permission to be recorded and indicating if they requested a copy of the transcript to review. A copy of the participant consent form is included in Appendix E: Interview Consent Form. On average, interviews were completed in thirty minutes. I audio recorded and transcribed all interviews. The interviews were semi-structured and open ended in nature, allowing for flexibility and to gain a deeper insight into participant experiences (McCammon, 2017). Twenty-five questions, ranging from general education background and personal connection to the

ocean, to their perception of the Oceans 11 curriculum and the inclusion of ocean concepts in the overall science curriculum were asked. The interviews were concluded with questions regarding the support from the Department of Education and opportunities for training centered around oceans education.

Once interviews were completed, they were transcribed into *Microsoft Word* in preparation for data analysis. Copies of individual's transcripts were sent to participants who requested to review their interview (n=1). Participants were given a time frame of one week to identify any concerns or comments regarding their transcript. Comments were communicated to me through e-mail prior to the data analysis process.

Once complete, all transcribed data were imported into *NVivo 10* for data analysis. Analysis of participant interviews within this study employed inductive techniques including open (or initial), in vivo and axial coding strategies (Table 3). Open and in vivo coding strategies are considered to be first cycle methods and are used during the initial breakdown and analysis of the data (Saldana, 2013). Axial coding is a second cycle method and is employed to form a more complete and precise understanding of the phenomenon (Strauss & Corbin, 1990). These techniques are described in Table 3 and were used to develop themes and understand connections and relationships within the data.

Table 3: Description of Coding Methods (Saldana, 2013; Strauss & Corbin, 1990)

Coding Method	Description
Open Coding	Data is broken down and into smaller categories based on similar concepts. These categories are then compared for similarities and differences. (Ex: “no exposure to ocean concepts” and “not comfortable with material” are categorized into “comfort level”)
In Vivo Coding	Categories derived directly from the participants own words. (Ex: “lack of resources” is established from “there is a serious lack of resources for this course”)
Axial Coding	Used to determine which codes are the dominant codes and which are less important. Allows the researcher to systematically determine relationships between categories. (Ex: Curriculum limitations and time constraints are combined to form “challenges”)

During the first cycle coding analysis, 22 parent codes were developed from participant interviews. The initial codes consisted of accessibility to field trips, background education, comfort level with ocean concepts, curriculum, educational value of oceans, employment opportunities, heritage, importance of youth connections, importance of ocean education, inclusion of ocean concepts in science courses, interest in ocean training, knowledge of ocean concepts, Oceans 11, oceans in Nova Scotia, personal connections, personal experiences, resources, teaching experience, time constraints, training received, youth understanding and youth interest. Through further analysis of the initial codes, relationships between the codes were established and five central themes emerged; knowledge, values, challenges, ocean education in high school science curriculum, and youth connection.

Trustworthiness. In order to achieve trustworthiness within a study, the researcher must take into consideration four criteria; credibility, transferability, dependability and confirmability (Shenton, 2004). Within this study various efforts were taken to ensure the trustworthiness of the research design. I made the initial contact with

participants, completed all interviews and any follow up contact that was required. All interviews followed the same format and procedure to ensure consistency. *NVivo*, a qualitative data analysis software, was used to enhance dependability and confirmability (Houghton, Casey, Shaw, & Murphy, 2013), by matching queries with set criteria to multiple participants. This indicated that the findings of the study were reflective of the perceptions of multiple participants.

Shenton (2004) notes that triangulation of data and a familiarity with the study culture act to improve trustworthiness with a study. Triangulation, which confirms data and ensures that data are complete (Houghton *et al.*, 2013), was achieved through the use of various research methods. The use of multiple methods, including a detailed content analysis of high school science curriculum documents and semi-structured interviews with high school science teachers, improved the credibility of the project as results were not based solely on one method. Due to my professional position, as a high school science teacher, prolonged engagement with the study group was achieved. This unique situation presented many aspects that were beneficial to the research study. Being a member of the study population of high school science teachers facilitated access to school buildings, knowing the system allowed for easier access to teacher e-mails and sending e-mails from a teacher recognized e-mail address improved chances for engagement. In addition, during the interview process a sharing of similar experiences with the participants aided in forming connections with participants and the feeling of being on the “same side”. This increased the opportunity for more open and honest conversations regarding issues in the classroom and curricular content. The closeness to the study also presented challenges, such as maintaining objectivity, over participation

and researcher assumptions (Maier & Monahan, 2009). To address these challenges, I created the interview questions and pilot tested the questions during interviews previous to the study. Feedback was provided to prevent the inclusion of biased or leading questions. Participants were asked to fully explain their answers to avoid assumptions based on commonality. The challenges associated with incorporating ocean concepts into education have been addressed in many studies (Schoedinger *et al.*, 2006; Lambert, 2006; Stock, 2010; Scully, 2016) and these challenges are consistent with the findings of this study. As such, despite the limited generalizations that can be made from this study, this research achieves transferability and contributes to a baseline understanding (Shenton, 2004) of the challenges faced by secondary school educators.

2.3 Methodological limitations

As with any research study, methods employed to achieve the research objectives come with limitations. This section attempts to discuss the various methodological limitations experienced within this study.

First it is important to note that there were considerable time restrictions placed on this study. In order to complete participant interviews approval was received from the HRSB ethical committee, allowing for interviews to take places between November 2015 and May 2016. All participants had to be contacted and interviewed during the allotted time frame. In addition, December and January proved to be difficult months in which to access high school science teachers, due to winter holidays through December and exam preparation during January. The time constrictions made it difficult to set up interviews with teachers in rural communities and individuals that expressed interest after May 2016 could not be included in the study. This study also only focused on the HRSB, and while

it is the largest school board within Atlantic Canada, it is not representative of all school boards. The physical distance between school boards, financial and time constraints for travel, limited this study to the confines of the HRSB.

Second, the potential for participant bias was difficult to avoid. To recruit participants for this study, high school science teachers were contacted through individual e-mails provided by each individual school, by the individual school principals, or referred by other participants. It is possible that the teachers who responded in the recruitment process had a vested interest in ocean education or the established Oceans 11 course. Participants were not asked for their reasons as to why they chose to take part in the study, however, no controls were put into place to avoid selection bias (Diefenbach, 2009). While it is important to acknowledge these limitations, it should be noted that this research study is non-probabilistic and does not attempt to make general statements about the perceptions of all high school science teachers. Instead, this research focuses on a sample group of teachers and their perceptions on the inclusion of ocean concepts. The findings of this study will still add value to the understanding of how ocean concepts are included in Nova Scotia high school science curriculum.

Finally, researcher bias may also present limitations on the findings of the study. In one sense, researchers who are in close collaboration with participants have the potential to gain access to data that other researchers cannot and achieve findings that are richer and more insightful (Diefenbach, 2009). However, it is also possible for researchers in these cases to unconsciously influence participant responses, and in turn the data. Given my professional position in this study, careful consideration was given to reflexivity. Data collection and analysis were completed concurrently and were re-

read throughout the process of further analysis to ensure that themes were based on original data (Fereday & Muir-Cochrane, 2006). While there is little that can be done regarding my position in this study it is important to note it as a limitation of this study.

Chapter 3: Examining the Nova Scotia Science Curriculum for International Ocean Literacy Principle Inclusion.

Abstract: Within Nova Scotia the ocean has an integral role in the economy and culture of the province. Nova Scotia is home to abundant marine resources and a rapidly developing ocean technology sector. Despite the importance of this resource and access to resources, youth in Nova Scotia have exhibited low knowledge of basic ocean concepts. This study investigates the extent to which the internationally established Ocean Literacy Principles are included in the curriculum outcomes of the Nova Scotia high school science curriculum. Data analysis of all high school science curriculum documents were guided by the seven Ocean Literacy Principles and the supporting fundamental concepts. Results from this study reveal limited inclusion of ocean concepts throughout the high school science curriculum. The effect of the diminished and marginalized inclusion of ocean education is the production of individuals with limited knowledge of basic ocean principles, who are ill prepared to make informed decisions regarding the health of the ocean and the future of Nova Scotia.

McPherson, Kerri¹ & Wright, Tarah²

¹Kerri McPherson was responsible for the research and writing of this manuscript.

²Tarah Wright was the thesis supervisor and provided guidance, revision, and feedback

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3.1 Introduction

The ocean covers approximately 71% of the surface of planet Earth (Maribus, 2010), and contains 97% of all water found on Earth (United Nations, 2016). The ocean is responsible for regulating weather systems and temperature (Schoedinger, Cava, & Jewell, 2006), is integral to driving the global water and carbon cycles (Moran *et al.*, 2016), and is an essential component in enabling the existence of life on Earth (Maribus, 2010; IPSO, 2014; United Nations, 2016). Yet, scholarly research demonstrates that the ocean is among the least understood and undervalued ecosystems on our planet (UNEP, 2016). Further, research shows that significant knowledge gaps exist between the public's perception of marine environmental issues and the actual threats to the marine

environment (Eddy, 2014). In general, studies have found public understanding of ocean literacy to be low, ultimately impacting the ability to make informed decisions regarding the overall health of the ocean (Belden, Russonello, Stewart & American Viewpoint, 1999; Fletcher & Potts, 2009; Plankis & Marrero, 2010; Eddy, 2014; Guest *et al.*, 2015;).

Oceans education is now seen as an essential component to the future health of the planet (Steel, Smith, Opsommer, Curiel, Warner-Steel, 2005; Tran, Payne, & Whitley, 2010). Education on critical issues pertaining to the ocean has the potential to engage individuals in behaviours that are less destructive to the ocean environment, and to aid in the capacity for creative solutions (Steel, Smith *et al.*, 2005). In addition, lack of knowledge on these issues has the potential to increase negative impacts on the oceanic environment due to higher levels of ignorance (Uyarra & Borja, 2016). Without education that provides a strong connection to, and understanding of, ocean processes and the consequences of human actions on the oceans themselves, changes in attitudes and positive action toward the ocean that develop into sustainable behavior are unlikely to occur (Steel, Smith *et al.*, 2005; Tran *et al.*, 2010; Guest, Lotze, & Wallace, 2015).

A focus on ocean education began to develop and gain speed in the 1960's and into the early 1970's (Carter & Simmons, 2010). In 1972, the first United Nations Conference on the Human Environment was held in Stockholm, Sweden, which addressed "education in environmental matters, for the younger generation as well as adults" (United Nations, 1972). While ocean concepts such as marine habitats and pollution were addressed at the conference, it became clear as decades passed and degradation to marine environments increased, that education specific to ocean concepts was essential (UNESCO, 1998). The importance of ocean health and the need to

conserve and protect ocean resources for the health of current and future generations was highlighted by the United Nations in 1994 as they proclaimed 1998 to be the International Year of the Ocean (CDIAC, 1998). The Year of the Ocean was designed to create new thinking and generate awareness on a global scale surrounding significant issues pertaining to the ocean (CDIAC, 1998). Undoubtedly this year created awareness regarding significant ocean issues and inspired change among government policies, including the passing of the Oceans Act (*Ocean's Act*, 1996), however, the degree to which oceans education was included within the public-school system is unknown.

In the late 1990's, the publication of the American National Science Education Standards caught the attention of several marine scientists. The published Education Standards contained little to no mention of the ocean or ocean concepts and as a result ocean science was largely left out of classroom teaching from kindergarten to grade 12 (Schoedinger *et al.*, 2010). Oceans scientists reacted quickly, developing the Ocean Literacy Campaign as a strategy to bring key ocean concepts into the education system and ultimately into the classrooms. The Ocean Literacy Campaign is a collaborative effort by scientists and educators aiming at creating a more ocean literate society through the development of a comprehensive framework (Schoedinger *et al.*, 2010). The Ocean Literacy Framework consists of two documents, *Ocean Literacy: The Essential Principles of Ocean Sciences K-12* and *Ocean Literacy Scope and Sequence for Grades K – 12* (Schoedinger *et al.*, 2010) that outline the seven essential principles of ocean sciences that every individual should know to be considered ocean literate along with identifying specific topics that connect to each of the essential principles. In addition, each essential principle is supported by fundamental concepts that further develop each

principle. Table 4 outlines the essential Ocean Literacy Principles and the supporting fundamental concepts.

Table 4: Ocean Literacy Principles and Fundamental Concepts ((Modified from Cava *et al.*, 2005) (For full account of the Fundamental Concepts see Appendix F)

Ocean Literacy Principle	Fundamental Concept (FC)
1. The earth has one big ocean with many features	A: The ocean is the defining physical feature on our planet Earth.
	B: Ocean basins are composed of the seafloor and all of its geological features.
	C: Throughout the ocean there is one interconnected circulation system powered by wind, tides, the force of Earth’s rotation (Coriolis effect), the Sun and water density differences.
	D: Sea level is the average height of the ocean relative to the land. Sea level changes as plate tectonics cause the volume of ocean basins and the height of the land to change.
	E: Most of Earth’s water (97%) is in the ocean. Seawater has unique properties.
	F: The ocean is an integral part of the water cycle and is connected to all of Earth’s water reservoirs via evaporation and precipitation processes.
	G: The ocean is connected to major lakes, watersheds, and waterways because all major watersheds on Earth drain to the ocean.
	H: Although the ocean is large, it is finite, and resources are limited.
2. The ocean and life in the ocean shape the features of earth	A: Many earth materials and biogeochemical cycles originate in the ocean.
	B: Sea level changes over time have expanded and contracted continental shelves, created and destroyed inland seas, and shaped the surface of land.
	C: Erosion occurs in coastal areas as wind, waves, and currents in rivers and the ocean, and the processes associated with plate tectonics move sediments.
	D: The ocean is the largest reservoir of rapidly cycling carbon on Earth.
	E: Tectonic activity, sea level changes, and the force of waves influence the physical structure and landforms of the coast.
3. The ocean is a major influence on weather and climate.	A: The interaction of oceanic and atmospheric processes controls weather and climate by dominating the Earth’s energy, water, and carbon systems.
	B: The ocean moderates global weather and climate by absorbing most of the solar radiation reaching Earth.
	C: Heat exchange between the ocean and atmosphere can result in dramatic global and regional weather phenomena, impacting patterns of rain and drought.
	D: Condensation of water that evaporated from warm seas provides the energy for hurricanes and cyclones.
	E: The ocean dominates Earth’s carbon cycle.
	F: The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon, and water.
	G: Changes in the ocean-atmosphere system can result in changes to the climate that in turn, cause further changes to the ocean and atmosphere.
4. The ocean made earth habitable.	A: Most of the oxygen in the atmosphere originally came from the activities of photosynthetic organisms in the ocean.
	B: The ocean is the cradle of life; the earliest evidence of life is found in the ocean.
	C: The ocean provided and continues to provide water, oxygen, and nutrients, and moderates the climate needed for life to exist on Earth.

Ocean Literacy Principles	Fundamental Concepts (FC)
5. The ocean supports a great diversity of life and ecosystems	<p>A: Ocean life ranges in size from the smallest living things, microbes, to the largest animal on Earth, blue whales.</p> <p>B: Most of the organisms and biomass in the ocean are microbes, which are the basis of all ocean food webs.</p> <p>C: Most of the major groups that exist on Earth are found exclusively in the ocean and the diversity of major groups of organisms is much greater in the ocean than on land.</p> <p>D: Ocean biology provides many unique examples of life cycles, adaptations, and important relationships among organisms that do not occur on land.</p> <p>E: The ocean provides a vast living space with diverse and unique ecosystems from the surface through the water column and down to, and below, the seafloor.</p> <p>F: Ocean ecosystems are defined by environmental factors and the community of organisms living there.</p> <p>G: There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms.</p> <p>H: Zonation patterns influence organisms' distribution and diversity.</p> <p>I: Estuaries provide important and productive nursery areas for many marine and aquatic species.</p>
6. The ocean and humans are inextricably interconnected	<p>A: The ocean affects every human life. It supplies freshwater and nearly all Earth's oxygen. The ocean moderates the Earth's climate, influences our weather, and affects human health.</p> <p>B: The ocean provides food, medicines, and mineral and energy resources.</p> <p>C: The ocean is a source of inspiration, recreation, rejuvenation, and discovery. It is also an important element in the heritage of many cultures.</p> <p>D: Humans affect the ocean in a variety of ways.</p> <p>E: Changes in ocean temperature and pH due to human activities can affect the survival of some organisms and impact biological diversity.</p> <p>F: Much of the world's population lives in coastal areas.</p> <p>G: Everyone is responsible for caring for the ocean.</p>
7. The ocean is largely unexplored.	<p>A: The ocean is the largest unexplored place on Earth—less than 5% of it has been explored.</p> <p>B: Understanding the ocean is more than a matter of curiosity. Our very survival hinges upon it.</p> <p>C: Over the last 50 years, use of ocean resources has increased significantly.</p> <p>D: New technologies, sensors, and tools are expanding our ability to explore the ocean.</p> <p>E: Use of mathematical models is an essential part of understanding the ocean system.</p> <p>F: Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, physicists, animators, and illustrators.</p>

Despite the strategies of the Ocean Literacy Campaign, ocean concepts remain difficult to find in the curriculum of most countries (Gough, 2017). Castle, Fletcher and McKinley (2010) noted that the perceived lack of ocean content contained in England's

curriculum had been significantly criticized. On further analysis of England's curriculum, Gough (2017) states that neither of the terms "coastal" or "marine" appear within the science curriculum. New Zealand's science curriculum also came up short on the inclusion of ocean concepts, with the same two terms "ocean" and "marine" being absent (Gough, 2017). An analysis of the Australian curriculum revealed minimal references to ocean related content (Gough, 2017), and Berchez *et al.* (2016) reported similar findings on the inclusion of environmental-education activities in Brazil. A report analyzing the earth science education standards within the 50 United States conducted by Hoffman and Barstow (2007) found that Ocean Literacy Principles are not commonly implemented, with most states only including minimal references, and three not addressing any of the Ocean Literacy Principles. None of the state education standards examined received a grade higher than a C on their inclusion of Ocean Literacy Principles (Hoffmann & Barstow, 2007).

Within Canada, a formal ocean education framework including the entire country does not exist. The Canadian system is set up so that there is no federal department of education (with the exception of education for aboriginal Canadians which is nationally run). Rather, the education system is decentralized and under provincial jurisdiction (CMEC, 2014; Weinrib and Jones, 2014). The Canadian government does convene a Council of Ministers of Education (CMEC) that exists with the goal of promoting discussion and collaboration among the; 10 provinces and 3 territories (CMEC, 2001), but curriculum is specifically set by each province/territory. Each individual school system is designed to reflect the unique cultural and historical heritage and to reflect issues of importance specific to that region (CMEC, 2001). It can be argued that oceans

education is relevant for all provinces, whether bordered by the ocean or not, as the ocean has a major impact on weather, climate and the water table (Hoffman & Barstow, 2007; Strang, 2008). However, not all provinces put ocean education as a priority area for their curriculum. In fact, research examining educational curriculum from British Columbia, another coastal province, found that ocean concepts are generally lacking (Cummins & Snively, 2000; Gough, 2017). Further research indicates that Canada has made little progress in developing oceans education (UNESCO, 2014; Guest *et al.*, 2015; Scully, 2015; Scully 2016).

Within the province of Nova Scotia, the ocean has an integral role in the economy and heritage of the province (Scully, 2015). The ocean industry in Nova Scotia is growing and encompasses an abundance of ocean related services including; fisheries (commercial and recreational), aquaculture, offshore hydrocarbon energy projects, tidal energy, ports, shipyards, research, tourism, among many more and in addition to countless recreation opportunities (Province of Nova Scotia, 2011). Nova Scotia is home to eleven universities and various post-secondary education facilities that offer marine science courses ranging from marine biology and oceanography to marine navigation, engineering, and maritime safety. Within the province there are more than 450 individuals with PhD's in ocean related disciplines; reportedly the highest concentration anywhere in the world (Province of Nova Scotia, 2011). Yet, despite potential access to these resources, youth in Nova Scotia have achieved low scores in knowledge on ocean concepts (Guest *et al.*, 2015). These results imply that education efforts need to be improved in order to increase student understanding of ocean concepts. A similar study investigating the inclusion of environmental education in Nova Scotia curriculum found

that environmental concepts were significantly marginalized in both the quality and consistency of delivery (Spence, 2011).

This study sought to better understand the extent to which the internationally established Ocean Literacy Principles are included in the curriculum outcomes of the Nova Scotia high school science curriculum.

3.2 Methods

This research involved an in-depth analysis of the Nova Scotia high school science curriculum documents in order to determine the extent to which ocean education is included in Nova Scotia's high school science courses and to determine how the context relates to the seven principles of ocean literacy.

The curriculum documents used for the Nova Scotia high school science courses are part of the Atlantic Canada Science Curriculum, developed regionally so as to create consistent science curriculum across the four Atlantic Canadian Provinces (APEF, 1998). Science curriculum within the Atlantic Provinces is primarily focused on the development of scientific literacy among all students through the three fundamental processes of scientific inquiry, problem solving and decision-making (APEF, 1998).

Structurally, science curriculum documents are based on an outcome framework that consists of essential graduation learnings, general curriculum outcomes, and specific curriculum outcomes (Council of Ministers Education, 1997). The essential graduation learnings are not subject specific, but are broad statements reflecting the knowledge, skills and attitudes expected of those students graduating from secondary school (Council of Ministers Education, 1997). General curriculum outcomes (GCO's) have been divided

into categories that encompass the key components of scientific literacy and provide the overall categories and basis for the outcomes framework (APEF, 1998). The four categories include: Science, Technology, Society and the Environment (STSE), Skills, Knowledge, and Attitudes and are consistent throughout all science curriculum documents within Nova Scotia. Specific curriculum outcomes are intended to reflect content that is specific to each individual course. The outcome statements indicate what each student is expected to know upon course completion. The outcomes are designed to direct educators in developing learning experiences and assessment tools that are appropriate for the intended course and assist students in achieving the general curriculum outcomes and essential graduation learnings (APEF, 1998). In this study, we chose to code only the curriculum outcomes for each of the 11 curriculum documents, based on the belief that the outcomes are what direct teaching practices. Specific curriculum outcomes inform what is to be taught within the course and are supported by suggested strategies and techniques throughout the curriculum document. As the outcomes are the only section explicit to teaching instruction they are the focus of this study.

The categories from the general curriculum outcomes, knowledge, skills and STSE were selected for analysis. These categories are represented within the specific curriculum outcome framework which facilitated the ability to determine where ocean concepts are strongly represented and where they are lacking. The attitudes category was not selected for analysis as the focus of this aspect, responsible acquisition and application of scientific and technological knowledge (APEF, 1998), can be achieved through the analysis of the knowledge and STSE categories. In addition, the specific

curriculum outcomes emphasize knowledge, skills and STSE, as such the attitudes category would not be specifically addressed in the outcomes framework.

High school science curriculum documents used within this study were accessed through the Nova Scotia's Department of Education website's "Document Depot". All eleven science documents (n = 11) were analysed including: Science 10, Biology 11 & 12, Chemistry 11 & 12, Physics 11 & 12, Human Biology 11, Oceans 11, Food Science 12 and Geology 12. Prior to analysis, curriculum documents were imported into *NVivo 10*, a qualitative data analysis program created by QSR International that allows the researcher to organize and find insights and connections within qualitative data (QSR International, 2017).

3.2.1 Data Analysis

The analysis and coding of the documents was guided by the seven principles for ocean literacy. *A priori* codes established using the Ocean Literacy Principles provided the basis for the analysis of the eleven curriculum documents. The seven principles of ocean literacy were developed by the Ocean Literacy Campaign to provide educators and curriculum developers with a "roadmap" to build ocean centered relevant learning experiences (Schoedinger *et al.*, 2010). Each of the essential principles are further broken down into smaller fundamental concepts, offering more specific criteria that relates to each of the individual principles (Ocean Literacy, 2013). (See Appendix F).

Curriculum outcomes were initially coded using the *a priori* codes established from the Ocean Literacy Principles and the Fundamental Concepts. From the initial analysis, the quantity of ocean education was determined by calculating the number of

outcomes within each document that were categorized within the established Principles. There were many outcomes that were coded for multiple Principles. In order to determine the context of the included ocean education, the coded outcomes were further analysed and categorized into sub-codes based on the Fundamental Concepts, also developed *a priori*. Several outcomes reflected multiple Fundamental Concepts, indicating areas where Ocean Literacy Principles would be included. Coding the outcomes into sub-codes gave deeper insight into where the key concepts from the Ocean Literacy Principles would be addressed within each of the curriculum documents.

3.3 Results and Discussion

3.3.1 Quantity of Ocean Education

Figure 5 presents the results of the quantitative analysis of the degree to which ocean education is contained within science curriculum documents and how it corresponds to the Principles of ocean literacy. All seven Ocean Literacy Principles are represented in some capacity within the cadre of courses available to students in Nova Scotia, with the exception of principle seven which was not included in any of the courses. The Oceans 11 curriculum contains the most direct references to the Ocean Literacy Principles; however, the curriculum falls short in regard to the inclusion of all 7 essential principles. It is also pertinent to note that 8 of the 11 courses make no mention of the ocean literacy concepts at all. Principles included in each of the 11 courses is represented in Figure 3.

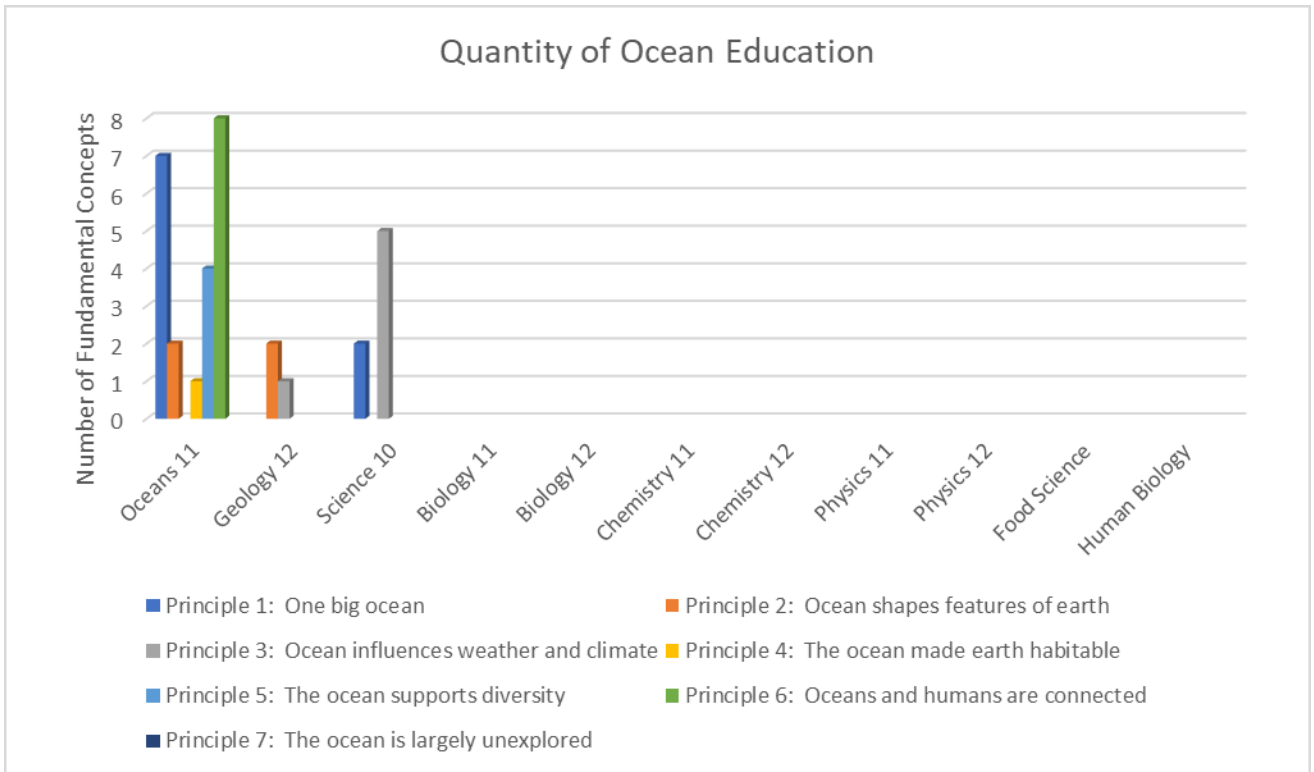


Figure 3: Quantity of Oceans Education relating to the Ocean Literacy Principles

3.3.2 Ocean Literacy Principles Included within Science Curriculum

Six of the seven Ocean Literacy Principles are represented within the curriculum, however, on further examination the majority of the supporting Fundamental Concepts are not (See Table 4). Table 5 illustrates how many of the Fundamental Concepts within each literacy principle are included within the three science curriculum documents that referenced the Ocean Literacy Principles. We will examine each of the three courses that include ocean concepts in more depth below.

Table 5: Fundamental Concepts in Science Curriculum

Ocean Literacy Principle	Fundamental Concept (FC)	Oceans 11	Geology 12	Science 10
1. The earth has one big ocean with many features	A	✓		
	B	✓		
	C	✓		
	D			
	E	✓		
	F			✓
	G	✓		
	H			
2. The ocean and life in the ocean shape the features of earth	A			
	B			
	C	✓	✓	
	D			
	E			
3. The ocean is a major influence on weather and climate.	A		✓	✓
	B			✓
	C			✓
	D			
	E			
	F			✓
	G			
4. The ocean made earth habitable.	A			
	B	✓		
	C			
5. The ocean supports a great diversity of life and ecosystems	A			
	B	✓		
	C			
	D	✓		
	E			
	F			
	G	✓		
	H	✓		
	I	✓		
6. The ocean and humans are inextricably interconnected	A			
	B	✓		
	C	✓		
	D	✓		
	E	✓		
	F	✓		
	G	✓		
7. The ocean is largely unexplored.	A			
	B			
	C			
	D			
	E			
	F			

Science 10. Graduation requirements for high school in Nova Scotia require that each student complete a minimum of two science courses. Science 10 is the only mandatory science credit that must be completed by all students. The course is divided into four equally weighted units including; weather dynamics, chemical reactions, motion and sustainability of ecosystems. Science 10 has 69 outcomes that teachers must address. Our analyses show that only seven of the sixty-nine outcomes reference the topics encompassed by the Oceans Literacy Principles. A further examination shows that those seven outcomes are situated within the confines of Principle 1 and Principle 3 (i.e. Principles 2, 4, 5, 6 and 7 are absent from the Science 10 course curriculum outcomes). We then further examined and broke down Principle 1 and Principle 3 to address how many of the fundamental concepts associated with each Principle are touched upon. Our analyses reveal that for Principle 1, only one of the fundamental concepts associated with this principle (out of a possible 8) is covered. Principle 3 addresses four of a possible seven fundamental concepts associated with it. This shows us that the overall coverage of the Principles and Fundamental Concepts is not robust in the Science 10 curriculum.

It is interesting to note that the seven course outcomes that do touch on the Principles and Fundamental Concepts are found exclusively within the weather dynamics unit. Further, when examining the references to ocean literacy within the Science 10 outcomes, we found that each was related specifically to knowledge outcomes alone. While it is essential for students to understand concepts from the knowledge category, the skills and STSE categories focus on collaboration and the social and environmental contexts of science and technology (APEF, 1998).

What is equally interesting to note is what Principles and Fundamental Concepts are not represented in the Science 10 curriculum. For example, while there are two outcomes related to Principle 1, both are encompassed within Fundamental Concept F (FC 1F), the other Fundamental Concepts including the ocean as a prominent feature of the Earth (FC A1) and the connectedness to lakes and waterways (FC 1G), geological features (FC 1B), global circulation (FC 1C), composition of seawater (FC 1E), sea level (FC 1D) and finite resources (FC 1H) are not mentioned at all. A prior survey on ocean literacy given to Nova Scotian youth found that questions pertaining to the causes of sea level rise received the highest proportion of incorrect answers (Guest *et al.*, 2015). In addition, Guest *et al.* (2015) state that students often confused concepts, explaining one concept using knowledge they had acquired on a related topic resulting in misconceptions. For example, students mistakenly associated sea level rise with the motion of tides, along with believing that high tides were a result of high waves (Guest *et al.*, 2015). Findings of students making similar mistakes have also been noted in studies from the United States (Brody & Koch, 1990) and South Africa (Ballantyne, 2004). The lack of inclusion of the concepts from the first ocean literacy principle corresponds to studies indicating that youth have limited understanding of basic ocean processes (Plankis & Marrero, 2010; Guest *et al.*, 2015.).

Another example where Fundamental Concepts are absent from the Science 10 curriculum is clear in the coverage of Principle 3 that focuses on the ocean as a major influence on weather and climate. As previously mentioned, the unit on weather covers Principle 3 to some extent, with five outcomes situated within four of the Foundational Concepts. Topics include the moderating effect of oceans on weather and climate and the

impacts of heat exchange on climate change and weather phenomenon. However, Fundamental Concepts D, E, and G are not included in the Science 10 curriculum, and main concepts that are not addressed in the curriculum include the role of the ocean and the water cycle in the formation of hurricanes and severe storms, impacts of a changing ocean-atmosphere system, the role of the ocean in the carbon cycle and the significance of ocean primary productivity. The lack of inclusion of significant issues has the potential to exacerbate misconceptions and the ability of graduates to make informed decisions. A study conducted for the Ocean Project (1999) (Belden *et al.*, 1999), found that while most individuals in the United States, were able to identify climate change as one of the most prominent environmental issues, many did not associate climate change with the ocean.

It is also of particular interest that there is no mention of pollution or significance of human impacts (Principle 6) in the Science 10 curriculum, which are two critical components in raising student comprehension and awareness of ocean issues. Several studies have indicated that most individuals exhibit a concern for ocean health, however fewer individuals are able to recognize the impacts of their own personal actions (Steel, Lovrich, Lach, Fomenko, 2005; Plankis and Marrero, 2010). In addition, Steel, Lovrich *et al.* (2005) found that amongst citizens of the United States, a strong relationship exists between level of ocean knowledge and the degree of support given to ocean restoration projects. Higher levels of knowledge and awareness of critical ocean issues is associated with heightened levels of marine citizenship, resulting in individuals feeling that they have a responsibility to act sustainably (Fletcher & Potts, 2007; McKinley & Fletcher, 2012).

Finally, we note that the unit focused on the sustainability of ecosystems contains no reference to any of the established international Ocean Literacy Principles and makes no direct mention of ocean education. The unit focuses on sustainability as a concept and aims to develop student connection to local environments and economy, deepening global thinking and decision-making (Nova Scotia Department of Education, 2012). Given that the science curriculum was designed as an Atlantic Canadian framework, the proximity of Atlantic Canada to the ocean, and the impact of the ocean on both Nova Scotia livelihoods and the economy, it is surprising that none of the Principles are mentioned.

Geology 12. Geology 12 is an elective science course offered at most high schools within Nova Scotia. The course is divided into six units including; nature of geology, Earth's materials, internal processes, surface processes, historical geology and environmental geology. Geology 12 has eighty-one outcomes that teachers are expected to address. Our analysis of the curriculum found that only Principle 2 and Principle 3 were addressed within the curriculum. Further analysis indicated that for Principle 2, only one fundamental concept was addressed out of a possible five. Similarly, from a potential seven fundamental concepts within Principle 3 only one was covered in the curriculum. Our findings indicate that the overall inclusion of the Principles and Fundamental Concepts within the Geology 12 curriculum is minimal.

Similar to Science 10, the outcomes that specifically reference the Principles and Fundamental Concepts are found exclusively within one unit, surface processes. Concepts incorporated in Principle 2, such as the process of erosion and factors, such as wind, waves and currents that can cause surfaces to erode at a faster rate, align with the Geology 12 curriculum. However, it is interesting to note that there is no mention of

ocean bathymetry or tectonic activity referring to the ocean, such as sea floor spreading, and the relation to the development of landforms. Tectonic activity in the ocean has a direct impact of features on land, understanding these processes is critical in understanding formation of geological features. Guest *et al.* (2015) found that knowledge gaps were common amongst Nova Scotian youth in topics related to the physical ocean, and scores were typically lower on questions that involved connections between the Earth's systems. In addition, all of the references to the Ocean Literacy Principles are found solely within the knowledge category, with no inclusion of the skills or STSE categories.

Oceans 11. Oceans 11 is an elective science course offered at most high schools within Nova Scotia and is the only course that has a focus specifically on ocean education. The course is divided into five units, four of which are required for the completion of the course. There are three compulsory units of study that include; structure and motion, marine biomes, and coastal zones. For the fourth unit, educators have the option of studying fisheries or aquaculture, depending on which unit they feel is more relevant to their students based on interest, school or community (Nova Scotia Department of Education, 2012). Oceans 11 is designed to give students an introduction to basic ocean concepts and to develop student understanding on the complex issues of ocean and resource management. The course presents current issues pertaining to ocean health and offers students the opportunity to learn about emerging technologies and ocean related career opportunities (Nova Scotia Department of Education, 2012).

An analysis of the Oceans 11 curriculum indicated that all Principles were included, with the exception, of Principles 3 and 7. Oceans 11 has twenty-eight

outcomes that teachers must address. Our analysis indicated that twenty curriculum outcomes make specific reference to the Ocean Literacy Principles, and all units of study referred to these Principles to some degree. Further analysis found that Principle 6 was the most represented within the Oceans 11 curriculum achieving all Fundamental Concepts with the exception of one. Principle 6 pertains to the human connection to the ocean. Prior studies have found individuals to be generally interested in the ocean and view the ocean as important, however their knowledge and connection of personal actions tend to be low (Walter & Liem, 1985; Belden *et al.* 1999; Cummins & Snively, 2000; Plankis & Marrero, 2010; Guest *et al.*, 2015). With a strong focus on human connections to the ocean, such as discussing sustainable fisheries and human impacts through pollution and waste, the Oceans 11 course helps to develop student awareness and fill gaps in knowledge.

Principle 1 and Principle 5 also included many specific references, with Principle 1 including five out of the potential eight Fundamental Concepts and Principle 5 containing five of the nine Fundamental Concepts. Principle 1 addresses concepts on the importance of the ocean (FC 1A), the geological features of the ocean (FC 1B), tides and currents (FC 1C), the structure of water (FC 1E), and the connectivity between watersheds and the ocean (FC 1E) are included within the structure and motion unit. As prior research in Nova Scotia has identified that knowledge in this area is recognized as needing development (Ballantyne, 2004; Plankis & Marrero, 2010; Guest *et al.*, 2015), it is important that it is addressed in the Oceans 11 curriculum. Principle 5 addresses food webs (FC 5C), feeding levels (FC 5D), levels of biodiversity (FC 5G), interconnectedness within the marine biome (FC 5H), and the diversity of marine environments (FC 5I).

Topics centered around marine animals and life in the ocean draw more engagement from students and studies have shown that youth are more knowledgeable in these areas (Ballantyne, 2004; Guest *et al.*, 2015). Interest in marine life can be used as a “hook” to build on and develop an understanding of the Ocean Literacy Principles. A further analysis of Principle 2 and Principle 4 show the inclusion of only one Fundamental Concept from each principle.

References to ocean education within the Oceans 11 curriculum are connected to all categories from the outcome framework, including; knowledge, skills and STSE. As a grade 11 course, it is expected that students have acquired a basic understanding of science concepts. Guest *et al.* (2015) noted that Nova Scotian grade 11 students surveyed received higher scores on the ocean literacy survey than other grades, although it is not known how many of the students surveyed were enrolled in or had taken the Oceans 11 course. It is important to identify the Principles and Fundamental Concepts that are not included within the Oceans 11 course. Gaps in the inclusion of the Ocean Literacy Principles are addressed in the following section.

3.3.3 Gaps in the Inclusion of Ocean Literacy Principles

As a course designed to deepen student understanding of basic ocean education, and as a science course with an objective of developing scientific literacy, the Oceans 11 course does a respectable job in providing information. Of the three compulsory units, all outcomes, apart from one from the coastal zones unit, are aligned with the Ocean Literacy Principles. While this represents a strong correlation, there are still many of the Fundamental Concepts that are not included in the Oceans 11 curriculum and several of the outcomes do not relate to any of the Ocean Literacy Principles. In order to address

the gaps in the Oceans 11 course the Principles and Fundamental Concepts absent from the curriculum must be examined.

An analysis of Principle 1 indicated that Fundamental Concepts D, F and H were absent from the Oceans 11 curriculum. Further research found that Fundamental Concept D (FC 1D), which addresses factors that impact changes to sea level, is not only absent from the Oceans 11 curriculum but from all high school science curriculum. It has been well documented that knowledge is low and considerable misconceptions exist in understanding concepts from the first ocean literacy principle (Walter & Liem, 1985; Brody & Koch, 1990; Ballantyne, 2004; Plankis & Marrero, 2010; Guest *et al.*, 2015). The lack of inclusion of these concepts in the Oceans 11 curriculum support these findings and implies that students are not receiving the skills to be considered ocean literate in this principle.

Research has shown that systems thinking at the junior high and high school level is challenging, and that making connections between the Earth's systems, land, atmosphere, and ocean, are difficult for students (Assaraf & Orion, 2004). Fundamental Concept F (FC 1F) illustrates the integral role the ocean has in the water cycle, the absence of FC 1F from the Oceans 11 curriculum misses an opportunity to examine the connection between Earth systems. Principle 4 also addresses the connection between Earth systems. Fundamental Concept A (FC 4A), which identifies the importance of nutrient cycles and photosynthetic marine life, is not directly referenced within the curriculum. Research indicates that while youth value the ocean, mainly for recreation use, Guest *et al.* (2015) noted that only 42% of youth surveyed recognized the ocean as a source of atmospheric oxygen and 23% identified climate regulation as being important.

The absence of these concepts from the science curriculum misses a critical link in student comprehension. It is essential for individuals to have knowledge about the ocean, such as being responsible for half of the Earth's primary productivity and free oxygen in the atmosphere, so that they can make connections to the impacts of their actions and in order to understand the resulting consequences of changes to the ocean-atmosphere system (McKinley & Fletcher, 2012).

Our analysis found that the Fundamental Concepts of Principle 2 were largely lacking from the Oceans 11 curriculum, with the exception of FC 2C, which was included in both the Oceans 11 and Geology 12 curriculum. Principle 2 incorporates biogeochemical and carbon cycles, aiding in the development of a deeper understanding of the composition and cyclic nature of our earth. Guest *et al.* (2015) found that questions pertaining to the chemical nature of the ocean, including salinity and ocean acidification, received low scores and when given the option students chose not to answer those questions, indicating a lack of understanding of concepts.

While Principle 3 is absent from the Oceans 11 curriculum it is well represented within the Science 10 curriculum. However, the Fundamental Concepts relating to the carbon cycle and changes within the ocean-atmosphere system (FC 3E, FC 3G) are not represented in any high school science curriculum. Knowledge of the carbon cycle is essential in understanding current global issues, such as climate change and ocean acidification, and the impacts that these issues will have on communities and individuals. Clear links have been established between climate change, carbon pollution and the health of the ocean, including the connection between decreasing oceanic pH, reduction of oceanic productivity and alteration of food web dynamics (Plankis & Marrero, 2010).

Several studies have indicated that low knowledge of ocean concepts combined with an inability to connect global issues to ocean processes results in individuals who are not engage in marine citizenship or are invested in ocean related protection (Fletcher & Potts, 2007; McKinley & Fetcher, 2012).

Our findings indicated that all Fundamental Concepts from Principle 7 were completely absent from not only the Oceans 11 curriculum but from all of the reviewed high school science curriculum documents. Principle 7 focuses on the interdisciplinary nature of ocean science and the importance of understanding of ocean systems, not simply for curiosity but for survival (Ocean Literacy, 2013). Many of the Fundamental Concepts (FC 7B, FC 7D, and FC 7F) have a focus on new and innovative technology for ocean exploration, and for youth in Nova Scotia the exclusion of this principle is a significant concern. The ocean technology sector within Nova Scotia is growing rapidly, doubling revenues between 2003 and 2009 to \$500,000,000 (Province of Nova Scotia, 2011). The Oceans 11 curriculum document states that significant time is to be designated to learning about local economic and community interests, including the development of new economies and opportunities (Nova Scotia Department of Education, 1998). While the curriculum does include references to ocean industry, including units on fisheries and aquaculture, there is no mention of ocean technology within the outcomes. Guest *et al.* (2015) noted that youth in Nova Scotia do not have a strong awareness of many of the job opportunities and careers available within the ocean sector, finding only 54% of students expressing an interest in ocean related careers. For a province where the economic future is uncertain, due to a combination of slow economic growth and a declining and aging population (NSCBNE, 2014), the ocean industry assists

in creating a solution. The inclusion of ocean related industries and career information in Nova Scotia science curriculum may contribute to not only the creation of ocean literate citizens but to the improvement of the economic state of the province. Retention of youth for employment purposes would help to build a younger, working population, which has been acknowledged as an issue within Nova Scotia (NSCBNE, 2014; Guest *et al.*, 2015)

3.4 Conclusion

This research has examined Nova Scotia high school science curriculum to determine the degree of inclusion of the seven Ocean Literacy Principles. Results have indicated that, with the exception of the Oceans 11 course, these principles are largely lacking from high school science curricula. These findings are consistent with a considerable number of studies from within Canada, United States, England, and South Africa (Brody & Koch, 1990; Cummins & Snively, 2000; Ballantyne, 2004; Cudaback, 2006; Plankis & Marrero, 2010; Guest, *et al.*, 2015) that have all indicated low levels of ocean knowledge among youth. The Ocean Literacy Principles were designed to inform and improve understanding of ocean concepts to help engage individuals in the sustainable use of this resource. This study indicates that students in Nova Scotia are not being provided with the opportunity in school to develop the skills necessary to make informed decisions regarding the health of the ocean, not only as a valuable resource, but as a lifeline for the planet. Without the inclusion of explicit references to the Ocean Literacy Principles within the curriculum, ocean education will continue to be inconsistent and marginalized in the classroom.

Moving forward, it is important that emphasis is placed on developing ocean literate citizens through improving ocean education. There are multiple informal groups

providing ocean education across Canada. While this is a positive addition to ocean education, due to the small catchment and limited funding for many of these groups, the education provided is independently conceived and implemented, resulting in inconsistencies in availability and delivery (CaNOE, 2016). In order for ocean education to reach students in Nova Scotia classrooms on an equal and consistent basis, changes to the science curriculum must occur.

In consideration of these challenges, it is important to note that science curriculum documents can shift towards the inclusion of Ocean Literacy Principles. It is recommended that the Nova Scotia Department of Education alter science curriculum to include the explicit reference to Ocean Literacy Principles within the curriculum outcomes. The Oceans 11 course specifically should be realigned to reflect more of the Ocean Literacy Principles and include all fundamental concepts. While this would be a good start to improving the conditions of ocean education, this alone would not be enough to create ocean literate citizens. With the abundance of ocean related resources available in Nova Scotia there is the potential to include these resources in the education of students on potential career opportunities as well as developing ocean-based knowledge. One recommendation would be for the Nova Scotia Department of Education to develop partnerships with government, universities, and ocean research facilities and within the ocean technology sector to fully expose students to the vast resources and opportunities that exist in Nova Scotia. In addition, appropriate training would have to be provided to educators, many of whom have no background in ocean science, so that the newly implemented curriculum would be effectively delivered.

This research contributes to the understanding of the quantity of ocean education included within high school science curriculum and to the growing recognition that ocean education has a significant space in formal education. Future research should explore these results further, examining the inclusion of Ocean Literacy Principles in other disciplines such as the social sciences and language arts. In addition, research focusing on different age groups, such as elementary, junior high, or university age students, may provide deeper insight into the inclusion of ocean education.

Chapter 4: Challenges and barriers to the implementation of ocean education into high school science courses in Nova Scotia

Abstract: Anthropogenic threats to the ocean are increasing. As human activities continue to negatively impact ocean ecosystems and resources it is important for individuals to become ocean literate citizens in order to make informed decisions regarding ocean health. Education on ocean concepts has the potential to improve understanding and engage individuals to act sustainably. However, within Canada, a country bordered by three oceans with vast ocean resources, there is no formal mandate to teach ocean literacy within the formal school system. Further, in Nova Scotia the ocean has a significant impact on the economy, culture, and ecology. This study examines the challenges and barriers experienced by a cohort of high school science teachers within Nova Scotia to the implementation of ocean education into high school science courses. Data was collected through semi-structured interviews with teachers investigating ocean knowledge, background and the challenges and barriers experienced within the classroom to the implementation of ocean concepts. Results from this study indicate that despite placing high value on the ocean the main challenges teachers incurred were limited background knowledge on ocean concepts, lack of resources, packed curriculum and lack of time. This study presents recommendations designed to improve the level of ocean education addressed in high school science courses within Nova Scotia.

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¹Kerri McPherson was responsible for the research and writing of this manuscript.

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4.1 Introduction

It has been argued that in order for an individual to understand the functioning of the planet, they must be literate in ocean concepts (Lambert, 2006; Payne & Zimmermann, 2010). As stated by Hoffman and Barstow (2007, p. 7) ocean concepts are the “conceptual glue that binds together many aspects of Earth science study”. Research has shown that ocean science education can be used to improve student understanding of complex systems when integrated into classroom teaching (Lambert, 2006; Payne and Zimmermann, 2010). Yet in Canada, a country with vast ocean resources, there is no

formal mandate to teach ocean literacy within the formal school system. Further, in Nova Scotia, a province where the ocean has a significant impact on the economy, culture, and ecology, McPherson & Wright (2017 - see Chapter 3) found that very few ocean education concepts were included in the high school science curriculum outcomes. While ocean literacy could possibly be acquired through non-formal learning activities, one can posit that most students will not acquire basic ocean literacy without some form of formal oceans education within the school system. While there is little provincial mandate for oceans education within the formal curriculum, it may be that teachers are introducing oceans concepts to students as an add-on to the current curriculum outcomes. The objective of this study is to examine the extent to which high school science teachers in Nova Scotia address ocean education in their classrooms, and the challenges and barriers associated with teaching about the oceans within the current Nova Scotia curriculum.

4.2. Background

4.2.1 Ocean Literacy

The development of the concept of ocean literacy began in 2002 as a response to the lack of ocean concepts included in the American National Science Education Standards publication (Schoedinger, Tran & Whitley, 2010). The publication contained little to no mention of the ocean or ocean concepts and as a result, ocean science was largely absent from classroom teaching from kindergarten through to grade 12 (Schoedinger *et al.*, 2010). At this time, ocean science was simply taught as an additional topic by teachers who were personally invested in ocean science as a form of enrichment

(Strang, 2008). Driven by the lack of inclusion of ocean concepts in education, organizations including the Center for Ocean Sciences Education Excellence (COSEE) and the National Marine Educators Association (NMEA), along with several scientists established a two-week workshop taking place in 2004 (Schoedinger *et al.*, 2010). The workshop involved approximately 100 individuals and consisted of participants from within formal and informal education, ocean science researchers, department of education, education policy makers and federal agency representatives involved in education (Schoedinger *et al.*, 2010). At the end of the workshop a definition for ocean literacy had been developed and the document Ocean Literacy: The Essential Principles and Fundamental Concepts of Ocean Science K-12 was created (Schoedinger *et al.*, 2010).

Ocean literacy is defined as “an understanding of the ocean’s influence on you and your influence on the ocean” (Cava, Schoedinger, Strang, & Tuddenham, 2005, p 5). Someone who is ocean literate is able to understand fundamental ocean concepts and principles, can communicate about ocean issues and can make informed, responsible decisions regarding the ocean and ocean resources (Cava *et al.*, 2005). To assist in developing an ocean literate citizenry, the ocean literacy campaign identified seven essential principles that all ocean literate citizens should understand (Cava *et al.*, 2005):

1. The Earth has one big ocean with many features.
2. The ocean and life in the ocean shape the features of the Earth.
3. The ocean is a major influence on weather and climate.
4. The ocean makes the Earth habitable.
5. The ocean supports a great diversity of life and ecosystems.

6. The ocean and humans are inextricably interconnected.
7. The ocean is largely unexplored.

The principles are based on key aspects of ocean science. Due to its multidisciplinary nature, ocean education unifies the concepts taught within life science, physical science, science and technology, science and social perspectives, and natural sciences in a systems approach where students can see the connectedness of the various natural science and social science disciplines (Lambert, 2006).

4.2.2 Ocean Education in Canada

For a country largely surrounded by ocean, it can be argued that ocean education is relevant for all provinces and territories within Canada. Whether bordered by the ocean or inland, the ocean has a substantial impact on weather, climate and the economy (Hoffman & Barstow, 2007; Strang, 2008). Despite the importance of the ocean, not all provinces put ocean education as a priority area within their curriculum. In fact, studies have indicated that ocean concepts are generally lacking from Canadian curricula (Cummins & Snively, 2000; Gough, 2017). An assessment of the British Columbia curriculum found limited exposure to ocean related terms including; marine, coast, and ocean, and when the terms were included references were focused on geological features as opposed to concepts of the broader notion of ocean literacy (Gough, 2017). Only two provinces, Prince Edward Island and Nova Scotia, were found to offer any courses specific to ocean education.

While ocean education could be addressed through a variety of disciplines and at various levels, this study focuses on the inclusion of ocean education in high school

science courses. Studies show that it is in high school that youth begin to see their place in society and can make connections that their behaviours and actions can have significant impacts on the world around them (Ausubel & Ausubel, 1966). Cognitively during adolescence, youth become better equipped to analyze complex problems, process multiple concepts simultaneously and address the moral, social and political aspects of issues (Ausubel & Ausubel, 1966). In terms of education, it is during this time that youth are also starting to make cross curricular connections, relating knowledge from a range of different classes. Ocean science by nature is multidisciplinary, requiring students to make connections between the various science disciplines. The majority of ocean-based education is focused on creating Science, Technology, Engineering, and Mathematics (STEM) learning. Ocean education is also broadly based on environmental education, and it has been argued that ocean literacy is paramount to achieving scientific literacy (Strang, DeCharon, & Schoedinger, 2007; Payne & Zimmerman, 2010). McPherson & Wright (2017) (See Chapter 3) contains a full synthesis of the inclusion of ocean education in Nova Scotia high school science courses.

Within Nova Scotia, Oceans 11 is an optional science course offered at the senior high school level that is dedicated to ocean concepts. Oceans 11 is unique to Nova Scotia and was designed as an introductory level course. This course addresses relevant issues in relation to the ocean and has the potential to increase levels of ocean literacy for those students who enroll. The inclusion of Oceans 11 within the Nova Scotia curriculum plays an important role; however, the efforts are not sufficient, and many students are completing high school unaware of ocean issues and with a lack of ocean literacy (Guest *et al*, 2015). This may be a result of how the Oceans 11 curriculum is portrayed and

implemented as a high school science course. The course is taught on its own, as a unique discipline, further emphasizing the separation among science disciplines. In addition, Oceans 11 is offered as an elective science course, often promoted as an option to fulfil the graduation requirement of a second science course for students not interested in the science disciplines. Moreover, students who are interested in pursuing science at a post secondary level are often unable to take the Oceans 11 course due to course scheduling and timing due to the requirements of other required academic courses.

A recent study of Nova Scotian youth found that despite associating a high degree of personal value to the ocean (96% indicated they valued the ocean), they were unable to answer general knowledge questions about the ocean (average score of less than 50%), implying that young Nova Scotians are not adequately educated on basic ocean concepts (Guest *et al.*, 2015). These results point to an issue of significant concern, that many youths in Nova Scotia have not acquired the skills to be considered ocean literate and are therefore unable to make reasonable informed decisions regarding issues pertaining to the ocean. Many studies have emphasized the connection between an individual's understanding and knowledge and their level of citizenship (Hawthorne & Albastor, 1999; Fletcher & Potts, 2009; McKinley & Fletcher, 2012). Fletcher & Potts (2009) describe citizenship as members of society who share common values, understandings, and attitudes that contribute to the common good of society. While knowledge is not the only factor that influences citizenship, research indicates that individuals with a stronger understanding of critical issues also have stronger values associated with citizenship (Fletcher & Potts, 2009; McKinley & Fletcher, 2012).

4.2.3 Challenges and Barriers to Implementing Ocean Education

There are limited studies related specifically to the inclusion of ocean education, however the challenges and barriers could be similar to the results of other studies addressing the challenges to implementing environmental education into the classroom (Puk & Makin, 2006; Tan & Pedretti, 2010; Spence, 2011). One of the main challenges for teachers in incorporating environmental education into classroom is the lack of specific inclusion of these issues in the curriculum (Puk & Makin, 2006; Tan & Pedretti, 2010; Spence, 2011). Often curriculum is overcrowded and there is not enough time to include material that is not specifically referenced. Puk & Makin (2006), referring to education in Ontario, found that as long as ecological literacy was not part of the required provincial curriculum, teachers indicated that there was not enough time to include it as an extra topic. Tan & Pedretti (2010) echoed this statement noting that participants in their research in Ontario expressed pressure to teach to the curriculum, leaving little room for extra activities. In addition to a crowded curriculum, studies indicated that resources were not readily available to assist in the inclusion of these topics (Puk & Makin, 2006; Tan & Pedretti, 2010). Payne & Zimmerman (2010) found low levels of ecological literacy among pre-service teachers in the United States and indicated a strong need for resources devoted to teacher preparation and classroom resources in the area of ocean education. One example of where these resources are lacking is within the Oceans 11 course, offered as an academic science course at the majority of high schools in Nova Scotia without an assigned text book for students or reference book for teachers. The lack of hands on resources or time given to create these resources is a significant barrier to their implementation (Puk & Makin, 2006).

An additional challenge to the incorporation of ocean education into science courses could be related to a teacher's background knowledge on ocean concepts. Research has shown that teachers have an integral role in developing student knowledge and have the potential to impact student beliefs based on their role in the classroom (Mogias, Boubonari, Markos, Kevrekidis, 2015). Adequate subject knowledge is essential for delivering effective curriculum and engaging students. Several studies suggest that teacher knowledge directly impacts teacher instruction and content delivery; with teachers placing a stronger emphasis on areas where they are more knowledgeable and avoiding content where they are less comfortable (Grossman, 1995; Payne & Zimmerman, 2010; Mogias *et al.*, 2015). McPherson & Wright (2017) (see Chapter 3) found that ocean education is largely lacking from Nova Scotia high school curriculum, and much of the inclusion of these concepts is teacher directed. With teachers expressing only a moderate level of ocean education, the likelihood of inclusion of ocean concepts is low (Payne & Zimmerman, 2010; Mogias *et al.*, 2015). If teachers are not knowledgeable on ocean education, it is not expected that they would be able to pass this information along to students. Mogias *et al.*, (2015) found that teachers in Greece do not receive adequate training in teacher education programs and pre-service teachers are not prepared to teach ocean science in the classroom. If teachers themselves are not educated on critical ocean issues they will not be able to effectively communicate these ideas to their students, and ocean literacy will not be developed (Puk & Makin, 2006; Payne & Zimmerman, 2010; Spence, 2011).

The objective of this study is to examine the challenges and barriers that teachers experience implementing ocean education into high school science courses in Nova

Scotia, Canada. Through in-depth interviews with high school science teachers this research provides insight into the extent to which ocean education is addressed and the difficulties associated with it.

4.3 Methods

This study involved interviews with high school science teachers in the Halifax Regional School Board (HRSB). The HRSB is the largest school board in Atlantic Canada and is made up of 136 schools, sixteen of which are secondary schools. The school board employs approximately 5,500 teachers and administrators and educates nearly 48,000 students annually (HRSB, 2017).

4.3.1 Recruitment and Data collection

To recruit participants for this study, high school science teachers were contacted through personal e-mail provided by individual schools within the HRSB. High school principals were also contacted with the request to pass along information about the study to teachers who might be interested in participating in the study. Snowball sampling techniques were also used where individuals who expressed interest in participating in the study were asked to recommend additional teachers who might be willing to participate. Of the ninety teachers contacted, two declined, seventeen consented to participate and seventy-one did not respond.

The cohort of seventeen high school science teachers that agreed to participate came from various schools within the HRSB. Interviews took place between November 2015 and May 2016 and were completed in person at each participant's individual school, or if preferred, in another venue of his/her choice. On average, interviews were completed in

thirty minutes and were audio recorded. Interviews were semi-structured and open ended in nature, allowing for flexibility and to gain a deeper insight into participant experiences (McCammon, 2017). Twenty-five questions, ranging from general education background and personal connection to the ocean, to their inclusion of ocean concepts in the classroom along with questions pertaining to particular challenges and barriers to the implementation were asked. The interviews were concluded with questions regarding the support from the provincial Department of Education and opportunities for training centered around oceans education.

4.3.2 Data Analysis

Once interviews were completed, they were transcribed into *Microsoft Word* in preparation for data analysis. Transcribed data were imported into *NVivo 10* for data analysis. Analysis of participant interviews within this study employed inductive techniques including open (or initial), *in vivo* and axial coding strategies. During the first cycle coding analysis, 22 parent codes were developed from participant interviews. The initial codes consisted of accessibility to field trips, background education, comfort level with ocean concepts, curriculum, educational value of oceans, employment opportunities, heritage, importance of youth connections, importance of ocean education, inclusion of ocean concepts in science courses, interest in ocean training, knowledge of ocean concepts, Oceans 11, oceans in Nova Scotia, personal connections, personal experiences, resources, teaching experience, time constraints, training received, youth understanding and youth interest. From the initial codes, the key challenges and barriers preventing the inclusion of ocean education were then examined. After further analysis, relationships between the codes were established and four central themes emerged as the key

challenges for teachers; teacher knowledge of ocean concepts, access to resources, curriculum outcomes, and time. In addition, from the analysis it became clear that in order to understand the challenges and barriers associated with implementing ocean education into science classrooms the perceived importance and value of the ocean must also be considered. The result was the formation of five central themes.

4.4 Results and Discussion

Results from this study indicated that while teachers do express a connection to the ocean and value its' importance, ocean education is not commonly included in their teaching practice within the classroom. In addition, participants identified challenges that impacted the ability to include ocean education into science courses which included; teacher knowledge of ocean concepts, curriculum outcomes and time, resources, and one participant indicated that the subject was not relevant to the students in the given location (some teachers indicated that curriculum and time were both their number one challenges) (Figure 4). These results are discussed more fully below. Figure 4 outlines the main challenges and barriers expressed by participants.

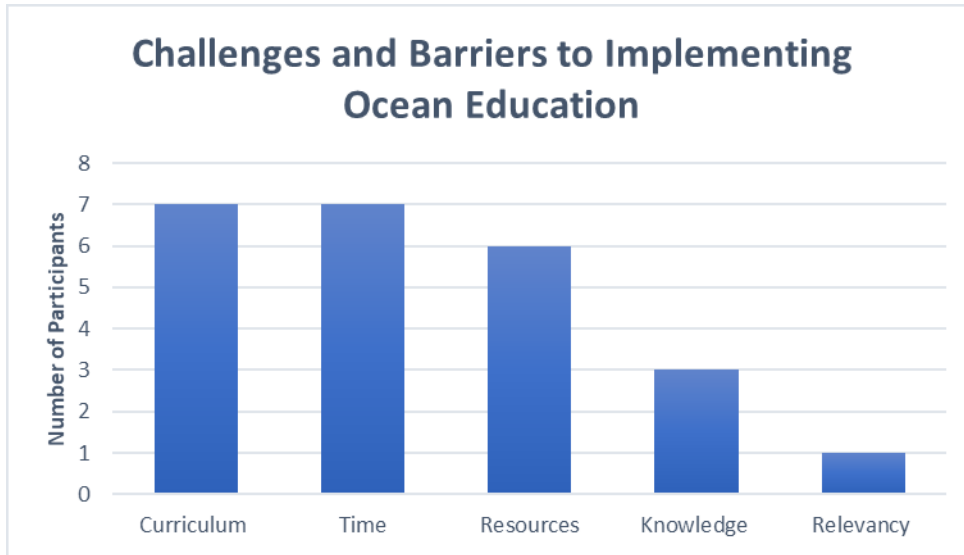


Figure 4: Participant Challenges and Barriers to implementing Ocean Education as identified by interviewees

4.4.1 Teacher Connections to the Ocean

All participants interviewed within this study indicated that they felt a connection to the ocean. Many of the participants expressed that they felt that the ocean was a significant part of life in Nova Scotia, and many indicated it had a strong connection to their choice to live in Nova Scotia:

I grew up in Bedford which is very, very, close to the ocean, and drove by it on my way to school every day. My job at the Calgary zoo was probably my dream job but I couldn't stay there because it was too far away from the ocean. I don't think I could live anywhere else. (Participant 12)

Growing up in PEI, I was very close to the ocean. In the couple of years I lived in Ontario it was very different. I missed the ocean a lot. (Participant 17)

In reflecting on their personal connections to the ocean, participants indicated that the ocean gave them a sense of well-being and associated it with feelings of being on

vacation, relaxation and calmness. Most participants associated the ocean with Nova Scotian heritage, and felt that in developing a sense of place, strong attachments to the ocean should be passed onto future generations. Two participants noted:

When I think of a safe place I think of an ocean, when I think of a calming sound, I think of an ocean. For me that represents Cape Breton and my roots, I want my children to have that as well. (Participant 3).

I grew up in the Maritimes. I've never left here I don't really intend to leave here. Growing up in Nova Scotia, the ocean is just kind of part of your life you know you take for granted that sometimes you can go to the beach and walk the waterfront and things like that. I think that growing up near the ocean is going to be important for my kids to have a similar experience." (Participant 15).

Participants unanimously agreed on the importance of the ocean and inclusion of ocean education in high school science courses. Every participant expressed that not enough resources were devoted to ocean education, despite the existence of the Oceans 11 course. The connection of the ocean to earth systems, in aspects such as weather and climate along with global issues including climate change, were the main reasons given by participants for the importance of ocean education.

"I think it comes back to climate change primarily. The oceans are basically our gage for how healthy our planet is" (Participant 2).

The importance of the ocean to the local economy and to Nova Scotian heritage were also included as important by many participants. For example, participants noted:

"The ocean impacts a lot of our life. Our economy, our weather, our planet. The environmental side is the biggest thing for me" (Participant 17)

"It affects our climate, it affects our economic situation, it affects our mental well being, all aspects of human development are tied into the ocean" (Participant 14).

One participant discussed the importance of using ocean education to develop a stronger sense of marine citizenship:

I think if we can educate kids about making better decisions and choices in terms of what they are doing to their environment, I really feel that small changes make a big difference. If they understand a little bit more about it, they'll treat the ocean with value. If they can't see it then they don't know about what's happening, so I think we need to educate more. (Participant 8)

Studies have found there to be a strong association between knowledge of ocean concepts and the individual responsibility to act sustainably; higher knowledge correlates to heightened responsibility (Fletcher & Potts, 2007; McKinley & Fletcher, 2012). This point, made by Participant 8, addresses the critical issue of educating our youth so that they can develop the skills for ocean literacy and so that they can make decisions regarding critical ocean issues. Given the proximity of Nova Scotia to the ocean, stewardship for the ocean has both global and local ramifications. Eleven of the seventeen participants felt that while ocean education is important everywhere it should be included to a greater extent in Nova Scotia high school curriculum. Participants noted that career opportunities (e.g. "It could directly impact employment opportunities" (Participant 13)), and relatability (e.g. "I think it is more relatable here, when I lived in Ontario and I would talk about tides the students really had no idea" (Participant 6)) are crucial factors for greater inclusion.

The results related to teacher's connections to the ocean reveal that the majority of participants have an affinity for the ocean. Payne and Zimmermann (2010) noted that when teachers have positive attitudes towards environmental issues they are more likely to pass on these views to students. When a teacher is passionate about a subject, students are more likely to engage with the subject matter. Yet, many also alluded to a

discrepancy between their beliefs about the importance of the ocean education and their practice. These findings echo results found in other studies (Puk & Makin, 2006; Payne & Zimmerman, 2010; Tan & Pedretti, 2010; Spence, 2011) indicating that while ocean education is personally valued by teachers there are significant challenges and barriers that prevent the inclusion of concepts.

4.4.2. Inclusion of Ocean Education in the Classroom

The multidisciplinary nature of ocean education opens up the potential for inclusion of these concepts into a variety of high school science courses. McPherson & Wright (2017) (See Chapter 3) detailed and extensive list of science courses that could include ocean concepts in teaching the curriculum outcomes. Given the potential for inclusion and positive attitudes towards the ocean exhibited by participants, the results of actual inclusion of these topics is surprising. Many of the participants indicated that while they do include some ocean education in courses that they taught, for example Science 10 and Biology 11, the concepts are discussed briefly and on a superficial level:

A little bit, but more just in looking at food webs, very much on that kind of superficial level (Participant 17)

We talk briefly in Biology 11...[referring to ocean education]...about biomes, but so very briefly (Participant 4)

In Science 10 we do a little bit in the weather unit, sometimes depending on who's teaching it what year and what section and who's in front of them and what's the class make up (Participant 10)

Some participants were conscious to pull in ocean concepts when there were real world examples to draw on, such as hurricanes in the news, if it related to course curriculum. Some participants did express that due to low student prior knowledge of ocean education including ocean concepts as a way of meeting outcomes is often confusing to students.

I think the connection the students have is challenging, like if we're looking at a food web and I put 10 different ocean organisms on the board, they're not going to know what all of them are unless they're very clearly labelled. A lot of kids don't know what plankton is, or what microorganism means. (Participant 1)

The low level of ocean knowledge acquired by students exacerbates the difficulty of including ocean concepts. The concepts often take more time to teach due to the additional instruction required for understanding. Participants indicated that while they could identify areas where ocean education would fit into the science curriculum, time and resources would be required to include the concepts in a meaningful way.

4.4.3 Challenges and Barriers to the Implementation of Ocean Education

A number of challenges and barriers to the incorporation of ocean education into the Nova Scotian high school science classroom were identified by participants. These included an overcrowded curriculum and limited time, lack of teaching resources and lack of background knowledge in ocean science without the opportunity for professional development and training as discussed below.

4.4.3.1 Curriculum

A major barrier to the implementation of ocean education into high school science courses was a combination of curriculum restrictions and time constraints. While over

half of the participants specifically identified curriculum outcomes and time allotment as the biggest challenge, all participants did express that adding concepts in addition to the outcomes presented major challenges. Teachers use the curriculum outcomes to direct their teaching and success in a course is determined by how well students are able to achieve these outcomes. Assessment policies mandate that teachers build their assessments around the outcomes, often requiring teachers to explicitly state which outcomes are being addressed on each assessment (HRSB, 2012). Participants indicated that the number of outcomes that they are required to teach along with the strict adherence to these outcomes limited their inclusion of additional concepts. For example, several participants noted:

I think the biggest problem is there are so many specific outcomes in courses like biology and chemistry, there is just no time to add extra connections. (Participant 2)

Very tough with the curriculum guides and the outcomes that we're supposed to meet, we don't seem to have a lot of freedom to incorporate things outside that curriculum. (Participant 7)

By providing us with such strict outcomes and timelines that we don't have any flexibility to incorporate other material. (Participant 15)

You just focus directly on specific outcomes related to your course, so you don't get a lot of opportunity to elaborate on different concepts. (Participant 4)

Participants explained that there is significant pressure to complete the assigned outcomes, and often it is not possible to do this within the given time frame. One participant noted "There's just so many concepts to cover in each course, most of the time you don't finish the curriculum" (Participant 5). Without the inclusion of ocean education in the curriculum outcomes, participants felt that there was not enough additional time to include these concepts. These results are closely aligned with a

separate study within Nova Scotia that focused on the inclusion of environmental education in grade six curricula (Spence, 2011).

In addition to abundant outcomes and restricted time, all outcomes are not weighted equally. Certain concepts are more difficult for students to comprehend and as a result take longer to teach given the complexity of the subject matter. Often teachers will designate more time to difficult curriculum, taking away time from other areas. For example, in the mandatory Science 10 course, students are introduced to chemical reactions for the first time. This material generally presents more challenges to students than the sustainability of ecosystems unit, given the extent of background knowledge. Each unit has an equal weighting, however, in order to efficiently teach the outcomes for student understanding the units are not assigned the same amount of teaching time. As one participant summarized:

You have to spend more time on chemistry, so the kids can understand it. I would like to spend more time talking about biomagnification and eutrophication, but by the time you get there, there's no time left. (Participant 1)

Within the run of a day teachers have additional responsibilities to teaching curriculum outcomes, that include supervising student teachers, assigned student supervision, committee work, volunteer coaching or supervision of extra curricular activities to name a few. These responsibilities take time away from the planning and preparation of new lessons. Given the responsibilities and demands on teacher time, most participants indicated that in addition to the difficulty in connecting ocean education with outcomes, there was little time available to develop resources to help make these connections. While the majority of participants expressed that they would have the

freedom to include ocean concepts, as long as it related to the outcomes, the main deterrent was the amount of time required to develop these connections. For example:

I think it comes down the fact that you feel you have to cover the outcomes, and then you don't have enough time to pull in new ideas. Where do you get the time to plan to do that? (Participant 8).

I have so many outcomes to cover and so much else to do, the thought of adding 1 or 2 more... (Participant 14)

Participants indicated that adding additional concepts into an already packed curriculum, was not only time consuming, but not necessarily effective. Teachers would first have to develop a personal understanding of how ocean content connects to the outcomes, create an engaging way of communicating this to students and ensure that students understand the concepts so that they are able to make the connections to the curriculum. As an add on to the curriculum, the time required to effectively develop student understanding would exceed the available time. Participants felt that in order to include ocean education in a meaningful way and on a consistent basis it needs to be incorporated into the curriculum outcomes.

It would have to be in the outcomes. If the outcomes were specific to oceans, then I would have to teach it. (Participant 2)

If it were included in the outcomes, then I would 100% teach them. It's a way of forcing teachers to cover the material. (Participant 13)

Although the challenge of meeting curriculum outcomes given time constraints is not new for teachers, studies examining the inclusion of environmental education have found the same results (Tan & Pedretti, 2010; Spence, 2011). It does emphasize how difficult it is to implement ocean education into existing curriculum. As long as ocean education remains as an add on to the curriculum outcomes it will continue to be marginalized in the classroom.

4.4.3.2 Resources

Teaching resources, in the form of textbooks, background information for teachers, lesson plans, and hands on activities are very helpful for effective and engaging teaching practices. Within the study, participants identified a lack of knowledge about, or access to, teaching resources devoted to ocean education. While some resources do exist, there are many small, independent, regionally-focused programs, including CaNOE, and COSEE, but they are not widely accessible or publicized to teachers. The presence of multiple small groups can potentially dilute funding capacity and lessen the impact of the overall objective of ocean education (Scully, 2015). Often many of the projects are unable to build momentum, resulting in resources becoming unavailable. Teachers are often unaware of these programs at the onset and as a result may not access these resources at all. Many of the participants in this study indicated that being provided with usable resources that connected to their curriculum in a meaningful way would impact the inclusion of ocean education into their science course(s). For example:

(I need)...good resources at an appropriate level. Something that I can use in the classroom that doesn't require a lot of prep work or background knowledge. If you are teaching a course and oceans isn't your background you need something that is user friendly, so that you can feel confident in teaching the material.
(Participant 17)

I would need some easily accessible resources, you know that I can access and, so it can become part of my conversation then I can include it as part of my lesson.
(Participant 3)

If there were more application type, like labs, that could involve somehow a cross curricular aspect, that would make it easier to implement. But, having the resources. (Participant 4)

On the occasion where participants had received resources on oceans in the past, they indicated that most were not at an appropriate level for high school students. For example:

I find lots of the stuff that we see at the provincial PD (Professional Development) for example is very much geared to younger kids rather than high school levels. Trying to implement these resources often feels forced. (Participant 17)

In addition, participants felt that most resources did not provide the necessary links to deeper thinking or connections to ocean-land systems that are required at the high school level.

When discussing the Oceans 11 course specifically, participants indicated that lack of teaching resources presented a significant challenge. Participants revealed that the course has neither an assigned textbook nor teacher resource book associated with it. Resources for this course are commonly shared by teachers who have taught the course in the past and have created activities on their own or come across materials through research. One participant noted “I got the outcomes and I got the teacher’s binder who used to teach it, and that was it.” (Participant 2). The lack of resources provided to teachers, often with no background in ocean education, created a negative experience in teaching this course for many of the participants. For example:

The thing that I found the hardest was that there was no textbook. There were no resources, so it made it quite hard. I mean there aren’t any books, there’s, there’s nothing. You know it’s terrible to teach the course, because there are no resources. (Participant 5)

There’s no textbook. We don’t have a text book, not even an electronic text book. It’s a pillar to the course.” (Participant 14)

As a teacher with no background in oceans finding engaging material is challenging. With no textbook, it makes it very difficult. (Participant 17)

One participant noted that while resources are difficult to find, there is a significant demand for ocean-related teaching resources. This participant indicated that they had been contacted by several other teachers asking to share their personal activities that they had found online through her website.

I've actually been contacted by probably 5 people or more where I've given my personal resources. There's definitely demand, I had someone come from the valley when I was on mat (maternity) leave! (Participant 6).

Further, participants acknowledged a lack of ability to engage students with the various organizations in the province that could help to provide hands-on and experiential learning about the oceans. Nova Scotia is home to eleven universities and various post-secondary education facilities that offer marine science courses along with the Bedford Institute for Oceanography (BIO), Canada's largest center for ocean research (Province of Nova Scotia, 2011). Despite the abundant resources participants expressed difficulty in acquiring field trip opportunities for students. For example:

I taught two ocean classes last year and tried to get a field trip organized, it was near impossible. I contacted BIO, and they didn't run field trips at that time of year. I contacted Dalhousie, and they couldn't accommodate the number of students we had. I even had a small group contact me who wanted to have students to their facility to do intertidal stuff, we ended up not be able to go due to insurance issues. (Participant 8)

I know we had one teacher at our school years ago and I know she did a lot of field trips took kids to BIO, took them to the ocean, to the beaches, and you know to me it seems like it's much more that type of course where you need that kind of experience. This doesn't happen anymore. (Participant 3)

Access to resources that actively engage students in ocean science and give students a chance to explore potential career opportunities and seek out professionals in the field is

an important aspect of ocean education in Nova Scotia. It is essential that students are given authentic opportunities to engage with local environmental issues to develop a sense of place and value associated with what is important where they live. Without an affiliation for place, many argue that we cannot possibly hope to impart to our students a sense of their own agency and capacity to effect change (Tan & Pedretti, 2010).

4.4.3.3 Teacher Knowledge

One of the key challenges to incorporating ocean education into high school science classrooms identified in this study was the level of knowledge individual teachers had on ocean related concepts. Studies have found that successful inclusion of ocean education and development of ocean literacy is, in part, dependant on the delivery of curriculum by teachers who have a positive attitude towards the marine environment and strong knowledge of ocean concepts (Mogias *et al.*, 2015). While all participants interviewed had a background in science, only two had backgrounds related to ocean education. One had previously taken oceanography courses at the undergraduate level and the other had an undergraduate degree in marine biology. During the interviews, participants were asked to reflect on their level of ocean knowledge. While most participants did feel they had an average understanding of ocean concepts, others indicated that this was not an area of strength as noted by Participant 15 who replied “Limited... and that’s being generous” when asked to describe his/her level of ocean knowledge. These results were not surprising, given that only one participant indicated that they received training specific to ocean education during their Bachelor of Education degree (B.Ed.). The fact that fifteen of the seventeen participants completed their B.Ed. within the Maritime Provinces and received little to no training on ocean education,

highlights a broader concern for the development of ocean literacy. These results align with the other studies that have indicated ocean science is not a focus, and that many pre-service teachers do not receive adequate training during their education degrees (Payne & Zimmerman, 2010; Tan & Pedretti, 2010; Mogias *et al.*, 2015). Bachelor of Education programs are responsible for the training of new teachers and have the potential to implement change into the education system. In addition, these programs have a role in professional development of current teachers, create teacher-education curriculum, and often consult with regional education ministers (Hopkins *et al.*, 2005). A study conducted by the United Nations (Hopkins *et al.*, 2005) on reorienting teacher education towards sustainability indicated that educational material and curriculum should be local and relevant, culturally appropriate, and based on the needs, perceptions and conditions of the local environment (including society and economy). Given the physical proximity of the ocean in all Nova Scotians' lives and the importance of ocean-related activities to the local economy, it would imply that including ocean education within teacher education programs within the province is extremely relevant. It is clear that educators need training and support in the delivery of ocean education, and one way to provide this education is through teacher education programs and by continuing in-service and professional development opportunities (Hopkins *et al.*, 2005).

Participants expressed that in addition to receiving inadequate training on ocean education, their experience (or lack thereof) was another factor that would impact the inclusion of certain oceans topics in their practice:

Well I don't think in my first few years that I would have made any connections to the outside world right. You're panicked to get through it, you're here, here's what you need to know, and all of it is very superficial. Then as you get

experience you know you can try to make those connections and try to you know wiggle that in. (Participant 15)

The first time I taught Oceans [11], it was a learning curve. I followed the lead of another teacher and had the students write notes and do work for the class. The students found it to be a chore, they weren't engaged. But I just didn't have the experience to make it better. (Participant 11)

Further, participants worried that lack of ocean knowledge and experience filters down to the students. As one participant commented:

I would honestly say that most of our kids are graduating high school knowing almost nothing about the ocean (Participant 1).

These results align with the findings of Payne and Zimmermann (2010) who noted while teachers based in Ontario have positive attitudes in teaching these concepts, many feel overwhelmed by the complexity of the content and do not have the skills to appropriately connect the material to potentially controversial global issues. Teaching experience, whether it is the number of years teaching or the number of times teaching the same course, develops confidence and knowledge in the subject material. As knowledge develops, teachers are better able to include extra concepts that are not directly in the curriculum but relate to the subject matter and make learning more meaningful. Given the nature of ocean education and how it relates to global issues, there is the potential as teachers develop knowledge on ocean education for more concepts to make their way into classrooms. While most participants had not received prior training, all indicated that they would be interested in receiving relevant professional development on ocean education in the form of conferences, information sessions and resources.

4.5 Conclusion

The findings of this study indicate that there are several challenges and barriers to the implementation of ocean education into high school science courses in Nova Scotia. The four most recurring themes in our analysis were in the areas of curriculum outcomes, time, availability of resources, and teacher knowledge of ocean concepts. Gaps existing between participants' expressed positive value of the ocean and the lack of inclusion of ocean education in teaching practices, implies that there is a divide between teacher interest and the Nova Scotia Department of Education. This is reflected through the omission of ocean-related content from most science curriculum. Indeed, even the Oceans 11 curriculum does not reflect all Ocean Literacy Principles or include reference to ocean technology, the largest growing ocean industry in Nova Scotia (Scully, 2015). It appears that the Nova Scotia Department of Education has not fully supported the integration of ocean education through curriculum outcomes that incorporate ocean literacy, development of curriculum-based resources that are widely accessible to all teachers, and appropriate training for teachers in the form of Professional Development and conferences.

It is interesting to note that participants expressed a strong need for better inclusion of ocean concepts into curriculum despite the current barriers. This desire was greatly influenced by their personal connections to the ocean, pride in Maritime heritage and the importance of the ocean regarding global issues and the local economy. The connection to the Maritimes as a sense of place emphasizes the importance of including oceans education in Nova Scotia curriculum, to develop a sense of personal agency and responsibility to create change among students. Despite valuing the ocean, this study

found that most of the participants either did not include ocean education into their science courses or included it on a superficial level. One of the strengths of ocean education is the connection to all Earth systems, by discussing ocean concepts on a superficial level these results indicate that students are not being challenged to think about significant ocean issues.

Based on the results of this study, it is recommended that ocean education be better integrated into the existing curriculum in the form of teaching outcomes. For these concepts to be addressed effectively and on a consistent basis, teachers must be formally directed to teach them. In addition, it is essential that teachers have a strong understanding of ocean knowledge and systems-based thinking. Further recommendations from this study include appropriate training for teachers, specifically those teaching the Oceans 11 course. One suggestion would be to assign an Oceans lead teacher at each school who would receive training and be able to pass along ocean education activities to other teachers to use in various science courses. Given that Nova Scotia relies heavily on the health of the ocean, it is also recommended that teacher education programs offered in Nova Scotia include a mandatory ocean education course for pre-service teachers. If ocean education is going to be successful, appropriate resources need to be developed at the Board of Education level that can be given to all schools, so that all teachers have the appropriate tools available to do their jobs. The growing Ocean industry sector provides opportunities for field trips and guest speakers. For this resource to be used effectively a partnership should exist between industry and the Department of Education to facilitate the development of resources and student engagement.

This research contributes to the limited scholarly research on the subject of ocean education in Nova Scotia and Canada. Building from this study, future research should explore the challenges and barriers to implementing ocean education in all school boards within Nova Scotia to provide a more robust study of the provincial status of ocean education in high school science courses. In addition, similar studies could be completed throughout Canada to examine the status of ocean education with the country and to determine if similarities between the challenges and barriers exist.

Chapter 5: Conclusions

This study sought to answer the following research questions:

- 1) To what extent are the internationally established principles for ocean literacy represented in high school science curriculum in Nova Scotia?
- 2) What are the main challenges and barriers that HRSB high school science teachers experience in implementing concepts related to ocean literacy into established science curriculum?

The findings are encompassed in the two papers intended for publication (Chapters 3 and 4) above, however, the main findings of this thesis as a whole are listed below. In addition, this chapter offers recommendations specifically for the HRSB, and in general for ocean education initiatives in the future. Finally, the chapter ends with suggestions for further research studies that can expand on this work.

5.1 Main Findings

First, this thesis found that explicit references to the Ocean Literacy Principles are largely absent from the high school science curriculum in Nova Scotia. Six of the seven Ocean Literacy Principles are represented within the curriculum as a whole, however, the majority of the supporting Fundamental Concepts (a more detailed breakdown of concepts pertaining to each of the Ocean Literacy Principles) are not. Further, of the eleven science courses reviewed for this study, only three contained specific curriculum outcomes that pertained to the Ocean Literacy Principles. Of the three courses that did address the Ocean Literacy Principles, many of the supporting Fundamental Concepts were omitted. These findings represent a significant concern in the development of ocean

literacy among students in Nova Scotia. The results of this study demonstrate that it is possible for students in Nova Scotia to complete their entire high school education without being exposed to any of the essential Ocean Literacy Principles. Given that the Ocean Literacy Principles were developed to improve understanding of basic ocean processes and the importance of the ocean, the lack of inclusion of these principles in the Nova Scotia curriculum demonstrates that this critical educational opportunity has been missed. In addition, studies have indicated that developing a sense of place has the potential to improve individual citizenship (Ashurst, 2008). Given that all students in Nova Scotia are in close physical proximity to the ocean, studying local environments gives students the opportunity to make relevant connections to their own lives and develop a stronger sense of their personal roles and responsibilities. A lack of focus on the ocean in Nova Scotia impedes the formation of connections between local natural ecosystems and current issues that link to curricular outcomes.

Second, this study found that the Ocean Literacy Principles and Fundamental Concepts that were addressed in the curriculum were focused on knowledge alone (with the exception of the Oceans 11 course which includes curriculum outcomes addressing the STSE and skills categories, such as collecting data and applying ocean knowledge to everyday situations) and did not touch on skills and attitudes which are both considered essential to oceans education as well as the Nova Scotia science curriculum. Due to the complex nature of global issues regarding the ocean, individuals must go beyond factual knowledge and develop an understanding of how the ocean impacts all Earth systems and their personal place in the biogeochemical cycles that sustain all life on Earth. While we acknowledge the importance of the acquisition of knowledge of ocean concepts, we

recognize that knowledge alone does not give students the opportunity to learn about the ocean in a multidisciplinary and systems-way of thinking.

Third, when identifying and examining the challenges and barriers to the implementation of ocean education by high school science teachers within the HRSB, my research shows that most teachers did not include ocean concepts into their classes on a consistent basis. Many of the participants were unaware of the level of inclusion of ocean concepts in the Nova Scotia curriculum as a whole, many assuming that essential ocean concepts were covered through different science courses. It is interesting to note that all of the participants interviewed felt a strong connection to the ocean and that the ocean was a significant factor in the Nova Scotian economy and culture regardless if they incorporated oceans literacy principles into their courses. In addition, the majority of participants felt that the inclusion of ocean education is essential when addressing critical issues for the future. For instance, many of the participants indicated that students need to have a basic understanding of ocean currents and how the ocean impacts climate and to fully understand climate change and the resulting effects such as sea level rise.

Fourth, several challenges and barriers were identified by participants that impeded the inclusion of the Ocean Literacy Principles and ocean education in general into their classrooms. Participants identified a lack of background knowledge of ocean concepts (i.e. they had not received enough oceans education in order to be oceans educators themselves); a lack of access to, or knowledge of appropriate ocean curriculum resources, and a lack of time for developing new lessons related to oceans as their greatest challenges.

5.2 Limitations

As with most research, this study was limited by a number of factors. Primarily, this study was restricted due to time and finances, and as a result focused on a relatively small sample size. Considering the time constraints placed on data collection and completion of a graduate program and given the distances between various school boards in Nova Scotia, the HRSB was chosen as the focus of the study. While the HRSB is the largest school board in Nova Scotia as well as all of Atlantic Canada, the second objective of this study is only reflective of a cohort of teachers within one school board in the province. In addition, within the HRSB there were added time constraints on conducting research. Insights from teachers could only be collected during the months of October, November, and January through to May. It is in the HRSB research policy that no research is to be conducted over the summer months of July and August, when teachers are not accessible, or during the months of September, December and June, where teacher workload is at its' highest. While research is permitted during the months of January and February, at the high school level teachers are involved in exam preparation and beginning new semesters, as a result obtaining interviews during this time was also challenging. Studies with a more flexible timeline should focus on developing a larger sample size, including representatives from other school boards, to contribute to the understanding of the challenges and barriers of implementing the essential Ocean Literacy Principles are included within high school science courses in Nova Scotia.

In terms of interviews, the potential for participant bias in a study such as this was difficult to avoid. During the recruitment process, participants were contacted directly by

the primary researcher, school administrators or referred by other participants. It is possible that the individuals who chose to participate had a previous interest in ocean education. Although no participant stated outright that they had a bias towards ocean education, their reasons for taking part in the study were not questioned and no controls were put in place to avoid a biased selection (Diefenbach, 2009). In addition, researcher bias may also present limitations to the findings of this study. Embedded research offers some benefits, such as facilitating access to participants and gaining insight into the participants lives that other researchers may not be privy to (Vindrola-Padros, Pape, Utley, & Fulop, 2016). However, due to the closeness of the researcher to the study population is it possible for the researcher to unintentionally influence participant responses, and in turn the results. Careful consideration was given to reflexivity in this case as to minimize researcher bias as much as possible.

5.3 Recommendations for Practice

Given the main findings of this thesis, a number of recommendations can be offered to both the HRSB and the Provincial Ministry of Education in terms of practice. These are listed below:

5.3.a. Teacher Training

Only two participants in this study indicated that they had had any previous training in ocean education. This is a concern as studies have demonstrated that low teacher knowledge on ocean concepts reinforces low student knowledge (Mogias *et al.*, 2015). Given that teachers are more effective at teaching topics that they have knowledge of, adequate training centered around ocean education is essential for the delivery of an ocean-based curriculum. As such, it is recommended that teachers receive training and

are offered professional development on ocean education and how to incorporate aspects related to critical ocean issues into science courses and the classroom. In order for training on ocean education to be effective it must be supported through the school board and provided to teachers during in service or conference days. All teachers should be given the opportunity to receive training and it is recommended that any teacher with the Oceans 11 course in their teaching assignment receive mandatory training on ocean education.

Another recommendation would be to require pre-service teachers to take a course based in ocean education and basic ocean processes during their Bachelor of Education program in Nova Scotia. With course assignments changing from year to year often teachers with limited ocean knowledge are teaching science courses, including the Oceans 11 course. While consistency among teachers delivering the material would help to develop more effective ocean education, requiring all pre-service teachers to receive training would improve the level of ocean education incorporated in all courses.

Additionally, it is recommended that one teacher at each school be identified as an ocean team lead, who would be trained through the school board, and who would be responsible for passing the training and information along to other members of the teaching staff when appropriate.

5.3.b. Inclusion of Ocean Literacy Principles within Existing Curriculum Outcomes

The review of the Nova Scotia curriculum enabled a consideration of the potential for the inclusion of the Ocean Literacy Principles within the existing curriculum outcomes. Several of the high school science courses examined in this thesis include outcomes that, if given the appropriate direction and instruction, could address the Ocean

Literacy Principles in a meaningful way. A breakdown of where the specific Ocean Literacy Principles and Fundamental Concepts is provided in Table 6.

Table 6: Potential Areas for the Incorporation of Ocean Literacy Principles into Existing Curriculum

Ocean Literacy Principles	Fundamental Concept (FC)	Science 10	Geology 12	Biology 11	Biology 12	Chemistry 11	Physics 11
1. The earth has one big ocean with many features	A						
	B		✓				
	C						
	D						
	E						
	F						
	G						
	H						
2. The ocean and life in the ocean shape the features of earth	A		✓				
	B						
	C						
	D						
	E						✓
3. The ocean is a major influence on weather and climate.	A						
	B						
	C						
	D						
	E					✓	
	F						
	G						
4. The ocean made earth habitable	A			✓	✓		
	B				✓		
	C						
5. The ocean supports a great diversity of life and ecosystems	A						
	B			✓			
	C	✓		✓			
	D			✓			
	E			✓			
	F	✓					
	G						
	H						
	I						
6. The ocean and humans are inextricably interconnected	A						
	B						
	C						
	D	✓		✓		✓	
	E	✓					
	F			✓			
	G	✓					
7. The ocean is largely unexplored.	A						
	B						
	C						
	D						
	E						
	F						

The following are suggestions of where resources could be made available and/or outcomes could be clarified to include oceans literacy principles:

1. The Science 10 curriculum includes multiple references to Principle 3 (The ocean is a major influence on weather and climate) within the “weather dynamics” unit, yet there is ample room to include additional principles. For example, Fundamental Concept D (Condensation of water that evaporated from warm seas provides the energy for hurricanes and cyclones, and that most rain that falls on land originally evaporated from the tropical ocean, FC 3D) makes connections between the water cycle and the formation of severe storms such as hurricanes. Given appropriate direction FC 3D could be directly linked to outcomes within the weather dynamics unit on how the weather forecasting of severe storms impacts society in terms of preparedness and damage reduction.
2. The Science 10 curriculum has a unit on the sustainability of ecosystems. This unit has multiple areas where the Ocean Literacy Principles could be implemented:
 - a. Ocean Literacy Principle 5 (The ocean supports a great diversity of life and ecosystems) Fundamental Concept C states that most of the major groups existing on Earth are found exclusively in the ocean and the diversity of major groups of organisms is much greater in the ocean than on land (FC 5C). Students in this unit are asked to compare similar ecosystems in different geographical areas. Given that the ocean is a prominent ecosystem in many parts of Canada, FC 5C could

easily be incorporated in comparing ocean ecosystems in various locations within Canada. A theme within this unit is the concept of a paradigm shift towards sustainability and how this impacts society (Nova Scotia Department of Education, 2012, p.58). Considering the impact of the ocean on our society and current economic well being, it is important that ocean health be considered when discussing this outcome.

- b. Principle 6 (the ocean supports a great diversity of life and ecosystems), focuses primarily on human impacts on the ocean and making shifts to more sustainable practices. Fundamental Concept D (Humans affect the ocean in a variety of ways, with laws, regulations, and resource management decision-making affecting what is taken out and put into the ocean. Human development and activity leads to pollution, changes to ocean chemistry, and physical modifications, FC 6D) highlights the importance of sustainable practices, a theme throughout the unit. Fundamental Concept G (Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all, FC 6G) reflects on the impacts of human activities and responsibility for sustaining this resource and could be easily incorporated into this unit.
- c. In this unit, students are asked to “distinguish between biotic and abiotic factors determining the impact on the consumers at all trophic

levels due to bioaccumulation, variability, and diversity” (Nova Scotia Department of Education, 2012, p. 58). Bioaccumulation is a topic easily addressed using marine food webs and would also provide the opportunity for educators to discuss real world examples, such as heightened levels of mercury in fish stocks (Scheuhammer *et al.*, 2015). This outcome directly relates to Ocean Literacy Principle 5 (the ocean supports a great diversity of life and ecosystems), Fundamental Concept F (Ocean ecosystems are defined by environmental factors and the community of organisms living there. Ocean life is not evenly distributed due to differences in physical and chemical requirements, FC 5F), addressing how marine life is affected by abiotic factors, as well as Ocean Literacy Principle 6, Fundamental Concept E (Changes in ocean temperature and pH due to human activities can affect the survival of some organisms and impact biological diversity, FC 6E), which discusses the effect of human activities on abiotic factors, such as temperature and pH, and how this impacts biological activity.

- d. Students are also asked to analyze an ecosystem’s response to short-term stress and long-term changes, which can easily be achieved through the discussion of critical current issues such as climate change and ocean acidification. These examples also align with Ocean Literacy Principle 6, Fundamental Concept E (FC 6E), and develop

student understanding of issues that are essential to the sustainability of all ecosystems.

3. Geology 12 is another course that includes some direct references to the Ocean Literacy Principles. In addition to the direct references there are other outcomes within the “nature of geology” and “internal processes” units that could include Principle 1 and Principle 2.
 - a. Outcomes within the nature of geology unit express how “knowledge of geology might influence our decisions about how we use earth resources” (Nova Scotia Department of Education, 2003, p. 25) and asks students to “identify sources and types of geological information needed to examine issues of a societal/environmental nature” (Nova Scotia Department of Education, 2003, p. 25). Given that tectonic activity in the crust adjacent to the ocean has an impact on geological features on land, and that new rock develops in the ocean through tectonic movement, students could develop an understanding of geological features in the ocean, which are addressed in Principle 1 (the Earth has one big ocean), Fundamental Concept B (Ocean basins are composed of the seafloor and all of its geological features. They vary in size, shape and features due to the movement of Earth’s crust, FC 1B).
 - b. The outcomes from the internal processes unit further details the impacts of tectonic activity, asking students to explain the theory of plate tectonics, to connect the rock cycle to the movement of plate

boundaries and to describe how through these movements mountains are formed (Nova Scotia Department of Education, 2003, p. 51).

Principle 2 (The ocean and life in the ocean shape the features of the earth), Fundamental Concept A (Many earth materials and biogeochemical cycles originate in the ocean, and many of the sedimentary rocks now exposed on land were formed in the ocean, FC 2A), connects the ocean to the formation of several types of rocks. Much of the sedimentary rock on land originated in the ocean (Ocean Literacy, 2013), as such it is essential for students to make this ocean connection in order to understand the rock cycle. Fundamental Concept E (Tectonic activity, sea level changes, and the force of waves influence the physical structure and landforms of the coast, FC 2E) also relates to the outcomes within this unit, discussing how tectonic activity and wave action impacts the physical formation of landforms along the coast.

4. In the life science courses, Biology 11 and Biology 12, there is no direct inclusion of the Ocean Literacy Principles within the curriculum outcomes. However, given the nature of each course there is the potential for Ocean Literacy Principles to be addressed in many of the units of study. Ocean Literacy Principle 4 could be addressed in both the Biology 11 and 12 curricula, in the “matter and energy” and “evolution” units, in addition Ocean Literacy Principles 5 and 6 could be well represented within the Biology 11 units on “biodiversity” and “interactions among living things”.

- a. Within a Biology 12, students are asked to “outline evidence and arguments pertaining to the origin, development and diversity of living things” (Nova Scotia Department of Education, 2003, p. 155). Ocean Literacy Principle 4 (The ocean made the Earth habitable), Fundamental Concept A (Most of the oxygen in the atmosphere originally came from the activities of photosynthetic organisms in the ocean, FC 4A) highlights the critical role of the ocean in establishing an environment that could support life through the production of oxygen. The connection of life originating in the ocean is also expressed by Fundamental Concept B (The ocean is the cradle of life; the earliest evidence of life is found in the ocean. The millions of different species of organisms on Earth today are related by descent from common ancestors that evolved in the ocean and continue to evolve today, FC 4B) and connects to the Biology 12 outcome that asks students to “explain the roles of evidence, theories and paradigms in the development of evolutionary knowledge” (Nova Scotia Department of Education, 2003, p. 155).
- b. Ocean Literacy Principle 4 Fundamental Concept A (FC 4A) could also be included in the Biology 11 curriculum when the processes of photosynthesis and respiration are discussed. The connection between atmospheric oxygen and the ocean is one that students should be able to make given that the ocean provides approximately 50% (Maribus, 2010) of the current oxygen as a result of photosynthesis from marine

plants. In discussing the process of photosynthesis students should understand the significance of the ocean. It has been well documented that youth struggle to make these connections (Ballantyne, 2004; Guest *et al.*, 2015).

- c. The biodiversity unit of Biology 11 focuses on the classification and diversity among living organisms. Given the diversity of many ocean ecosystems, these outcomes could be addressed by including references to Principle 5 (The ocean supports a great diversity of life and ecosystems). Fundamental Concepts B (Most of the organisms and biomass in the ocean are microbes, which are the basis of all ocean food webs. Microbes are the most important primary producers in the ocean and fix a huge amount of the carbon and release a large fraction of atmospheric oxygen on Earth, FC 5B), C (Most of the major groups that exist on Earth are found exclusively in the ocean and the diversity of major groups of organisms is much greater in the ocean than on land, FC 5C), D (Ocean biology provides many unique examples of life cycles, adaptations, and important relationships among organisms that do not occur on land, FC 5D), and E (The ocean provides a vast living space with diverse and unique ecosystems from the surface through the water column and down to, and below, the seafloor, FC 5E), could easily be addressed by the outcomes within this unit. Multiple outcomes within this unit include a “representative organism from each kingdom” (Nova Scotia Department of Education, 2003, p.

49), whether it is discussing the physiology or explaining the life cycle (FC 5B). All major taxonomic groups can be found within the ocean, and as a country that is completely surrounded by ocean, considering ocean ecosystems when making connections to Canadian biomes, which is specifically stated in the outcomes is essential. In looking at FC 5D, individuals who are ocean literate recognize that there are “unique examples of life cycles, adaptations, and important relationships among organisms (symbiosis, predator-prey dynamics, and energy transfer) that do not occur on land” (Ocean Literacy, 2013). The interactions among living organisms unit addresses these relationships within the outcomes and as a result it is important that the ocean environment be examined. In addition, students are expected to “explain energy flow in the production, distribution and use of food resources” (Nova Scotia Department of Education, 2003, p. 85), connections to these Fundamental Concepts could help to connect learning to real examples and improve understanding.

- d. Within the interactions among living things unit of Biology 11 Ocean Literacy Principle 6 (The ocean supports a great diversity of life and ecosystems) could be included in multiple ways. Within this unit students are required to consider social issues related to the natural balance of ecosystems and the impact that human population growth has on resources. Fundamental Concepts D (Humans affect the ocean in a variety of ways, with laws, regulations, and resource management

affect what is taken out and put into the ocean. Human development and activity leads to pollution changes to ocean chemistry, and physical modifications, and changes to the food web, FC 6D) and F (Much of the world's population lives in coastal areas which are susceptible to natural hazards, FC 6F) address human impacts on the ocean in terms of pollution, sea level rise, development, and resource depletion, and as a result, outcomes in this unit could be achieved through the inclusion of this ocean literacy principle. Developing connections to the ocean and an awareness of the impact of individual actions has been linked to improved marine citizenship (McKinley & Fletcher, 2012). Including the Ocean Literacy Principles within the life science courses would help to develop and strengthen these connections.

5. While the potential for the inclusion of Ocean Literacy Principles in the physical science courses is less obvious, there are some areas where their inclusion might make learning relevant and meaningful with regard to the ocean:
 - a. In the wave unit in Physics 11, one outcome requires students to “apply the laws of reflection and the laws of refraction to predict wave behaviour” (Nova Scotia Department of Education, 2002, p. 73). Many students have experience with the power of ocean waves, in using examples from Principle 2 (The ocean and life in the ocean shape the features of the earth), Fundamental Concept E (Tectonic

activity, sea level changes, and the force of waves influence the physical structure and landforms of the coast, FC 2E), involving wave driven processes such as erosion and deposition, students could examine the impacts of wave reflection and refraction through the connection to real world phenomenon.

- b. One of the key focuses of the organic chemistry unit in Chemistry 11 is to examine the influence of organic compounds on society. Ocean Literacy Principle 3 (The ocean is a major influence on weather and climate), Fundamental Concept E (The ocean absorbs roughly half of all carbon dioxide and methane that are added to the atmosphere) discusses the role of the ocean in the carbon cycle, acting as a carbon sink. In addition, one outcome in the organic chemistry unit directs students to “write and balance chemical equations to predict reactions of selected organic compounds” (Nova Scotia Department of Education, 2003, p. 79). Ocean acidification, lowering of the pH of the ocean, occurs as a result of a chemical reaction between carbon dioxide, water and carbonate ions as carbon dioxide is absorbed into the ocean (The Royal Society, 2005). This process has a significant impact on the ocean as well as society and can be used to achieve this outcome using examples from a critical global issue. Discussing chemical changes within the ocean directly relates to Ocean Literacy Principle 6 (The ocean supports a great diversity of life and ecosystems), Fundamental Concept D (Human development and

activity leads to pollution, changes to ocean chemistry (ocean acidification), and physical modifications).

Results from this study have the potential to influence a more robust inclusion of the essential Ocean Literacy Principles in Science curriculum as a whole in Nova Scotia. In addition to the implementation of ocean education into the existing curriculum it is recommended that changes to the curriculum also occur. The changes include; implementing direct references to the Ocean Literacy Principles within the specific curriculum outcomes as well as realigning the Oceans 11 course specifically to reflect more of the Ocean Literacy Principles and include all Fundamental Concepts.

5.4 Recommendations for Future Research

While this thesis offers insights into the inclusion of the Ocean Literacy Principles into the Nova Scotia high school science curriculum and the challenges and barriers to the incorporation of these principles into practice within the classroom, there are a number of additional questions that have developed as a result of the thesis, and a number of potential research studies that could result.

First, future studies could broaden the catchment area and explore the challenges and barriers experienced by teachers in all school boards within Nova Scotia in order to provide a more robust and statistically representative study of the provincial status of ocean education in high school science courses. In addition, similar studies could be completed in each of the provinces and territories of Canada to examine how the Ocean Literacy Principles within high school science courses are incorporated into curriculum outcomes throughout the country. Such a study could give a better idea of how the nation

as a whole treats ocean literacy and could be useful for developing recommendations to the Canadian Council of Education Ministers.

Finally, future studies could examine the inclusion of the Ocean Literacy Principles in non-science disciplines, such as social sciences, and at other grade levels, including elementary and junior high school students. Developing ocean literacy should begin at a young age where youth are excited and curious about the ocean and marine organisms. Ocean concepts introduced at the Elementary school age enables students to build on their knowledge as they grow and learn. At the junior high school level students are starting to form opinions around careers and life paths. It is important to expose students at this level to the importance of the Ocean Literacy Principles and opportunities that exist in career fields related to the ocean. Additionally, it is important for all individuals to be ocean literate in order to be able to make informed decisions regarding the health of the ocean and the impacts on Earth. Not all students will take science courses throughout high school as such it is important to include the Ocean Literacy Principles throughout additional non-science disciplined courses.

5.5 Implications

As anthropogenic stressors continue to threaten the health of ocean ecosystems and marine life, individuals need to develop a deeper understanding of the connectivity between humans and the ocean environment. Studies have indicated that public perception and understanding of ocean knowledge and marine processes is low (Steel, Lovrich *et al.*, 2005; Plankis & Marrero, 2010). This research offers insight into the current state of ocean education in Nova Scotia and suggests ways to improve ocean literacy among Nova Scotia youth within the Nova Scotia science curriculum. This

research contributes to the understanding of the quantity of ocean education included within high school science curriculum and to what extent the Oceans Literacy Principles have been incorporated into oceans education in the province. In addition, this research also contributes to the better understanding of the difficulties associated with implementing ocean education in the classroom. As this study focuses on teachers and their experiences in the classroom, this study contributes to the limited academic research in this area.

This research provides the Nova Scotia Department of Education with an understanding of the current state of ocean education within the high school science curriculum and offers solutions to improve inclusion. The practical breakdown of outcomes that reference the essential Ocean Literacy Principles could serve as a starting point on where ocean education could be implemented.

The documented challenges and barriers experienced by teachers in the classroom offer insight into where supports and additional training are needed in order to improve ocean literacy among Nova Scotian youth. This research could also be used to inform and alter practices of active teachers within Nova Scotia by identifying the quantity of Ocean Literacy Principles that are included within high school science courses and providing them with possible outcomes that could be linked to the essential Principles in a meaningful way.

References

- Amineh, R., Asl, H. (2015). Review of Constructivism and Social Constructivism. *Journal of Social Science, Literature and Languages*, 1(1), 9-16.
- APEF (Atlantic Provinces Education Foundation). (1998). *Foundation for the Atlantic Canada science curriculum*. Halifax, Nova Scotia: Department of Education.
- Ardoin, N., Clark, C., Kelsey, E. (2012): An exploration of future trends in environmental education research, *Environmental Education Research*, 1-22.
- Ashurst, D. (2008). *Promoting a Sense of Place and Culture in Science: A Study of the Effectiveness of a Cross-Cultural, Marine Science Curriculum through Experiential Exploration*. (Master's thesis). University of Victoria. British Columbia, Canada.
- Assaraf, O, Orion, N. (2005). Development of System Thinking Skills in the Context of Earth System Education. *Journal of Research in Science Teaching*, 42(5), 518-560.
- Ateweberhan, M., Feary, D., Keshavmurthy, S., Chen, A., Schleyer, M. (2013). Climate change impacts on coral reefs: Synergies with local effects, possibilities for acclimation and management implications. *Marine Pollution Bulletin*, 74 (2), 526 – 529.
- Atkinson, R., Flint, F. (2001). *Accessing Hidden and Hard-to-Reach Populations: Snowball Research Strategies*. *Social Research Update*. University of Surrey, 33.
- Ausubel, D., Ausubel, P. (1966). Cognitive Development in Adolescence. *Review of Educational Research*, 36(4), 403-413.
- Ballantyne, R. (2004). Young students' conceptions of the marine environment and their role in the development of aquaria exhibits. *GeoJournal*, 60(2), 159–63.
- Belden N, Russonello J. Stewart & American Viewpoint (1999) *Communicating About Oceans: Results of a National Survey*. National survey conducted for The OCEANS Project. Washington DC: Belden, Russonello & Stewart Research and Communications. <http://www.brspoll.com/uploads/files/Oceans%20summary.Pdf>
- Berchez, F.A.S., Ghilardi-Lopes, N.P., Correia, M.D., Sovierzoski, H.H., de Pedrini, A.G., Ursi, S., Kremer, L.P., de Almeida, R., Schaeffer-Novelli, Y., Marques, V., Brotto, D.S. (2016). Marine and coastal environmental education in the context of global climate changes – synthesis and subsidies for RioBentos (Coastal Benthic Habitats Monitoring Network). *Brazil Journal of Oceanography*, 64(2), 137–156.
- Biernacki, P., Waldorf, D. (1981). Snowball Sampling: Problems and Techniques of Chain Referral Sampling. *Sociological Methods & Research*, 10(2), 141-163.
- Bijma, J., Pörtner, H.O., Yesson, C., Rogers, A.D. (2013). Climate change and the oceans--what does the future hold? *Marine Pollution Bulletin*, 74(2), 495-505.

- Blackburn, A. (1983). Steps Along the Path: UNESCO/UNEP International Environmental Programme. *The Environmentalist*, 3, 269-276.
- Boyce, C, Neale, P. (2006) Conducting In-Depth Interview: A Guide for Designing and Conducting In-Depth Interviews for Evaluation Input. Pathfinder International Tool Series, Monitoring and Evaluation-2.
- Brody, M.J., Koch, H. (1990). An assessment of 4th-, 8th-, and 11th-grade students' knowledge related to marine science and natural resource issues. *Journal of Environmental Education*, 21(2), 16–26.
- Canadian Network for Ocean Education (2014). What is CaNOE? (Retrieved from). <http://oceanliteracy.ca/about/>
- Carter, R., Simmons, B (2010). The History and Philosophy of Environmental Education. In: Bodzin A., Shiner Klein B., Weaver S. *The Inclusion of Environmental Education in Science Teacher Education*. Springer, Dordrecht.
- Castle, Z., Fletcher, S., McKinley, E., (2010). Coastal and Marine Education in Schools: constraints and opportunities created by the curriculum, schools and teachers in England. In: *Ocean Yearbook*. 24, 425–444.
- Cava, F., Schoedinger, S., Strang, C., and Tuddenham, P. (2005). Science Content and Standards for Ocean Literacy: A Report on Ocean Literacy. http://www.coexploration.org/oceanliteracy/documents/OLit200405_Final_Report.pdf.
- CDIAC (1998). The International Year of the Ocean, (Retrieved from). <http://cdiac.ess-dive.lbl.gov/newsletr/fall98/yoto.htm>
- Chatzifotiou, A. (2006). Environmental Education, National Curriculum and Primary School Teachers. Findings of a research study in England and possible implications upon education for sustainable development. *The Curriculum Journal*, 17(4), 367-381.
- Chawla, L., Cushing, D. (2007) Education for strategic environmental behaviour. *Environmental Education Research*, 13(4), 437-452.
- Cheung, W., Lam, V., Sarmiento, J., Kearney, K., Watson, R., Pauly, D. (2009). Projecting Global Marine Biodiversity Impacts under Climate Change Scenarios. *Fish and Fisheries*, 10, 235-251.
- Cheung, W., Pinnegar, J., Merino, G., Jones, Barange, M. (2012). Review of climate change impacts on marine fisheries in the UK and Ireland. *Aquatic Conservation. Marine and Freshwater Ecosystems*, 22(3), 368-388.
- CMEC (Council of Ministers of Education, Canada). (1997). Common framework of science learning outcomes K-12. Toronto, Ontario: Council of Ministers of Education, Canada.

CMEC (Council of Ministers of Education, Canada). (2001). The Development of Education in Canada. In response to the International Survey in Preparation for the Forty-Sixth Session of the International Conference on Education Geneva September 5-8, 2001.

CMEC (Council of Ministers of Education, Canada). (2014). Canada's response to UNESCO questionnaires on the UN Decade of Education for Sustainable Development, 2005–2014: Education for Sustainable Development after 2014 and UN Decade of ESD final report. Prepared by the Council of Ministers of Education, Canada, in collaboration with The Canadian Commission for UNESCO, February 2014. (Retrieved from). <http://www.cmec.ca/Publications/Lists/Publications/Attachments/335/Canada-Response-UNESCO-DESD-2014-Questionnaire-s-1-and-2-EN.pdf>

CMEC (Council of Ministers of Education, Canada). (2012) Education for sustainable development in Canadian faculties of education. (Retrieved from), http://www.cmec.ca/Publications/Lists/Publications/Attachments/279/ESD_Dean_reportEN.pdf.

Cope, M. (2010). Coding Qualitative Data. In I. Hay (Ed.), *Qualitative Research Methods in Human Geography* (3rd ed), pp. 281–294). Don Mills, Ontario: Oxford University Press.

Cool Australia (2014). Ocean Conservation. (Retrieved from). <http://www.coolaustralia.org>.

Cresswell, J. (2014). *Research Design: Qualitative, Quantitative, and Mixed Method Approaches*. (4th ed). Thousand Oaks, CA: Sage Publications, Inc.

Cudaback, C. What do college students know about the ocean? *Eos, Transactions, American Geophysical Union*, 87(40), 418–21. (Retrieved from). <http://dx.doi.org/10.1029/2006EO400003>.

Cummins, S., Snively, G. (2000). The Effect of Instruction on Children's Knowledge of Marine Ecology, Attitudes toward the Ocean, and Stances toward Marine Resource Issues. *Canadian Journal of Environmental Education*, 5(1), 305-326.

Cvijanovic, I., Caldeira, K. (2015). Atmospheric impacts of sea ice decline in CO₂ induced global warming. *Climate Dynamics*, 44, 1173–1186, DOI: <https://doi.org/10.1007/s00382-015-2489-1>.

DeBoer, G. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science Teaching*, 37(6), 582-601.

Derraik, J. (2002). The Pollution of the Marine Environment by Plastic Debris: a review. *Marine Pollution Bulletin*, 44, 842-852.

Diefenbach, T. (2009). Are Case Studies More Than Sophisticated Storytelling?: Methodological problems of qualitative empirical research mainly based on semi-structured interviews. *Quality and Quantity*, 43, 875-894.

- Dikko, M. (2016). Establishing Construct Validity and Reliability: Pilot Testing of a Qualitative Interview for Research in Takaful (Islamic Insurance). *The Qualitative Report*, 21(3), 521-528. Retrieved from <http://nsuworks.nova.edu/tqr/vol21/iss3/6>
- Donert, K., Fauville, G., Gotensparre, S., Mäkitalo, A., Van Medegael, L., Zwartjes, L., (2015) 'Review of Marine Formal Education' EU Sea Change Project. (Retrieved from). (<http://www.seachangeproject.eu>)
- Eddy, T. (2014). One Hundred-fold Difference between Perceived and Actual Levels of Marine Protection in New Zealand. *Marine Policy*, 61-67.
- Fabry, V., Seibel, B., Feely, R., Orr, J. (2008). Impacts of Ocean Acidification on Marine Fauna and Ecosystem Processes. *ICES Journal of Marine Science*, 65(3), 414-432.
- FAO (Food and Agriculture Organization of the United Nations). (2007). Communication and Sustainable Development. Selected papers from the 9th UN roundtable on communication for development. Rome.
- FAO (Food and Agriculture Organization of the United Nations). (2016). The State of World Fisheries and Aquaculture. Contributing to food security and nutrition for all. Rome. 200 pp.
- Fereday, J., Muir-Cochrane, E. (2006). Demonstrating Rigor Using Thematic Analysis: A Hybrid Approach of Inductive and Deductive Coding and Theme Development. *International Journal of Qualitative Methods*, 5(1), 80-92.
- Filho, W. L. (2000). Communicating Sustainability: Some International Considerations and Challenges. In W. L. Filho (Ed.), *Communicating sustainability* (pp. 11-23). Frankfurt: Peter Lang.
- Fletcher, S., Potts, J. (2007). Ocean Citizenship: An emergent Geographical Concept. *Coastal Management*, 35, 511-524.
- Fletcher, S., Potts, J., Heeps, C., Pike, K. (2009). Public Awareness of Marine Environmental Issues in the UK. *Marine Policy*, 33(2), 370-5.
- GCS Marine. (2014). GCS Marine Project 1600. (Retrieved from). <http://www.ceeaustralia.org>
- Gettelman, A, Rood, R. (2016). *Demystifying Climate Models. A Users Guide to Earth System Models*. Springer-Verlag Berlin Heidelberg.
- Great Barrier Reef Marine Park Authority. (GBRMPA). (2016). Learn About the Reef. (Retrieved from). <http://www.gbrmpa.gov.au/learn-about-the-reef/resources-bytheme>.
- Greene, J. (2007). *Mixed Methods in Social Inquiry*. California: Jossey-Bass & Wiley.
- Grossman, P. L. (1995). Teachers' Knowledge. In L. W. Anderson (Ed.) *International encyclopedia of teaching and teacher education*. New York, NY: Pergamon.

- Gough, A. (2017). Educating for the Marine Environment: Challenges for Schools and Scientists. *Marine Pollution Bulletin*, 124(2), 633-638.
- Government of Canada (1996). The Oceans Act. Minister of Justice. (Retrieved from). <http://laws-lois.justice.gc.ca/PDF/O-2.4.pdf>
- Guest, H., Lotze, H., Wallace, D. (2015). Youth and the Sea: Ocean Literacy in Nova Scotia, Canada. *Marine Policy*, 58, 98-107.
- HRSB (Halifax Regional School Board). (2012). Assessment, Evaluation, and Communication of Student Learning Policy. (Retrieved from). <https://www.hrsb.ca/sites/default/files/hrsb/Downloads/pdf/board/policy/sectionC/C.007-student-assessment.pdf>
- HRSB (Halifax Regional School Board). (2017). About Our Schools. (Retrieved from). <https://www.hrsb.ca/about-hrsb/about-us>
- Handl, G. (2012). Declaration of the United Nations Conference on the Human Environment (Stockholm Declaration), 1972 and the Rio Declaration on Environment and Development, 1992. United Nations. (Retrieved from). <http://legal.un.org/avl/ha/dunche/dunche.html>
- Harley, C. (2011). Climate Change, Keystone Predation, and Biodiversity Loss. *Science*, 334, 1124-1127.
- Hawthorne, M., Alabaster, T. (1999). Citizen 2000: Development of a Model of Environmental Citizenship. *Global Environmental Change*, 9, 25-43.
- Hoffman, M., Barstow, D. (2007). Revolutionizing Earth System Science Education for the 21st Century, Report and Recommendations from a 50-State Analysis of Earth Science Education Standards. TERC, Cambridge MA.
- Hooper, D., Chapin, F., Ewel, J., Hector, A., Inchausti, P., Lavorel, S., Lawton, J., Lodge, D., Loreau, M., Naeem, S., Schmid, B., Setälä, H., Symstad, A., Vandermeer, J. and Wardle, D. (2005), Effects of Biodiversity on Ecosystem Functioning: A Consensus of Current Knowledge. *Ecological Monographs*, 75, 3-35.
- Hopkins, C., Mckeown, R., the International Network. (2005). Guidelines and Recommendation for Reorienting Teacher Education to Address Sustainability, Education for Sustainable Development in action technical paper no. 2 (Paris, UNESCO). <http://unesdoc.unesco.org/images/0014/001433/143370E.pdf>
- Houghton C., Casey, D., Shaw D., Murphy, K. (2013). Rigour in Qualitative Case-study Research. *Nurse Researcher*. 20(4), 12-17.
- IPSO. (2017). The State of the Ocean Report 2013. Retrieved from: <http://www.stateoftheocean.org/science/state-of-the-ocean-report/>

- Jóhannesson, I., Norðdahl, K., Óskarsdóttir, G., Pálsdóttir, A., Pétursdóttir, B. (2011). Curriculum Analysis and Education for Sustainable Development in Iceland. *Environmental Education Research*, 17(3), 375-391.
- Kalpana T. (2014). A Constructivist Perspective on Teaching and Learning: A Conceptual Framework. *International Research Journal of Social Sciences*. ISSN 2319–3565. Vol. 3(1), 27-29.
- Kulnieks, A., Young, K., Longboat, D. (2013). Indigenizing Environmental Education: Conceptualizing Curriculum that Fosters Educational Leadership. *First Nations Perspectives*, 5, 65-81.
- Lambert, J. (2005). Students' Conceptual Understandings of Science after Participating in a High School Marine Science Course. *Journal of Geoscience Education*, 53(5), 531-539.
- Lambert, J. (2006). High School Marine Science and Scientific Literacy: The Promise of an Integrated Science Course, *International Journal of Science Education*, 28(6), 633-654.
- Lodico, M., Spaulding, D., Voegtler, V. (2010). *Methods in Educational Research. From Theory to Practice*. California: Jossey-Bass & Wiley.
- Lotze, H., Milewski, I. (2004). Two Centuries of Multiple Human Impacts and Successive Changes in a North Atlantic Food Web. *Ecological Applications*, 4(5), 1428-1447.
- Maier S., Monahan, B. (2009). How Close is Too Close? Balancing Closeness and Detachment in Qualitative Research. *Deviant Behaviour*, 31(1), 1 -32.
- Maribus (2010). *World Ocean Review: Living with the Oceans*. Mareverlag, Hamburg.
- Markos, A., Boubonari, T., Mogais, A., Kevrekidis, T. ((2017) Measuring Ocean Literacy in Pre-service Teachers: Psychometric Properties of the Greek version of the Survey of Ocean Literacy and Experience (SOLE), *Environmental Education Research*, 23:2, 231-251
- Mayring, P. (2014) *Qualitative Content Analysis: Theoretical Foundation, Basic Procedures and Software Solution*. Klagenfurt, 2014. URN: <http://nbn-resolving.de/urn:nbn:de:0168-ssoar-395173>
- McCammon, B. (2017). Semi-structured Interviews. *Design Research Techniques*. (Retrieved from). <http://designresearchtechniques.com/casestudies/semi-structured-interviews/>
- McKinley, E., Fletcher, S. (2010). Individual Responsibility for the Oceans? An Evaluation of Marine Citizenship by UK Marine Practitioners. *Ocean and Coastal Management*, 53, 379-384.

- McKinley, E., Fletcher, S. (2012). Improving Marine Environmental Health through Marine Citizenship: A call for debate. *Marine Policy*, 36, 839-843.
- Mimura, N. (2013). Sea-level Rise Caused by Climate Change and its Implications for Society. *Proceedings of the Japan Academy, Series B, Physical and Biological Sciences*, 89(7), 281-301.
- Mogias, A., Boubonari, T., Markos, A., Kevrekidis, T. (2015). Greek Pre-Service Teachers' Knowledge of Ocean Sciences Issues and Attitudes toward Ocean Stewardship. *The Journal of Environmental Education*, 46(4), 251-270.
- Moran, M., Kujawinski, E., Stubbins, A., Fatland, R., Aluwihare, L., Buchan, A., Crump, B., Dorrestein, P., Dyhrman, S., Hess, N., Howe, B., Longnecker, K., Medeiros, P., Niggemann, J., Obernosterer, I., Repeta, D., Waldbauer, J. (2016). Deciphering Ocean Carbon in a Changing World. *PNAS*, 113(12), 3143-3151.
- NOAA (National Oceanic and Atmospheric Administration). (2017). Ocean Explorer Education. (Retrieved from). <http://www.oceanexplorer.noaa.gov>
- Nova Scotia Department of Education. (1998). Foundation for the Atlantic Canada Science Curriculum. (Retrieved from). <https://www.ednet.ns.ca/files/curriculum/camet/foundations-science.pdf>
- Nova Scotia Department of Education. (2003). Atlantic Canada Science Curriculum: Geology 12. Nova Scotia. Department of Education.
- Nova Scotia Department of Education. (2012). Atlantic Canada Science Curriculum: Oceans 11. Nova Scotia. Department of Education.
- Nova Scotia Department of Education. (2012). Atlantic Canada Science Curriculum: Science 10. Nova Scotia. Department of Education. (Retrieved from). <https://www.ednet.ns.ca/files/curriculum/Science10-2012.pdf>
- NSCBNE (Nova Scotia Commission on Building our New Economy). (2014). Now or Never: An Urgent Call to Action for Nova Scotians. (Retrieved from). <http://onens.ca/wp-content/uploads/Now-or-Never-Nova-Scotia-Final-Report-with-Research-Engagement-Documentation.pdf>
- Ocean Health Index (2015). (Retrieved from). <http://www.oceanhealthindex.org>
- Ocean Learning Partnership (2016). Coastal Explorers Field School. (Retrieved from). <http://www.coastalexplorers.net>
- Ocean Literacy Network. (2013). Ocean Literacy: The Essential Principles and Fundamental Concepts of Ocean Sciences for Learners of All Ages Version 2. First published June 2005, revised March 2013. Washington, DC: National Oceanic and Atmospheric Administration. (Retrieved from). www.oceanliteracy.net.

- Ocean Networks Canada. (2016). Educator Opportunities. (Retrieved from). <http://www.oceannetworks.ca/learning/get-involved/educators>
- OECD (2015). Education at a Glance 2015: OECD Indicators. OECD Publishing, Paris. (Retrieved from). <http://dx.doi.org/10.1787/eag-2015-en>.
- Oepen, M. (2000). Environmental Communication for Sustainable Development. In M. Oepen, & W. Hamacher (Eds.), *Communicating the environment: Environmental communication for sustainable development* (pp. 32-37). Frankfurt: Peter Lang.
- Ornetzeder, M., Rohrer, H. (2005). Social learning, Innovation and Sustainable Technology. In W. L. Filho (Ed.), *Handbook of sustainability research* (PP. 147-176), Frankfurt/M.: Peter Lang.
- Orr, D. (1992). *Ecological literacy: Education and Transition to a Post- modern world*. Albany: State University of New York Press.
- Payne, D.L., Zimmerman, T.D. (2010). Beyond Terra *firma*: Bringing Ocean and Aquatic Sciences to Environmental and Science Teacher Education. In: Bodzin A., Shiner Klein B., Weaver S. (eds) *The Inclusion of Environmental Education in Science Teacher Education*. Springer, Dordrecht.
- Plankis, B., Marrero, M. (2010). Recent Ocean Literacy Research in United States Public Schools: Results and Implications. *International Electronic Journal of Environmental Education*, 1(1), 21-46.
- Province of Nova Scotia. *Defined by the Sea: Nova Scotia's Oceans Technology Sector Present and Future*. Halifax, Nova Scotia, Canada: Department of Economic and Rural Development and Tourism. http://novascotia.ca/econ/sectors/docs/Defined_by_the_sea-NS_Oceans_Technology_Sector.pdf; 2011.
- Puk, T., Makin, D. (2006). Ecological Consciousness in Ontario Elementary Schools: The truant curriculum and the consequences. *Applied Environmental Education and Communication*, 5:4, 269-276.
- QSR International (2017). What is Qualitative Research? (Retrieved from). <http://www.qsrinternational.com/what-is-qualitative-research.aspx>
- Ramirez, F., Afan, I., Davis, L., Chiaradia, A. (2017). Climate Impacts on Global Hot Spots of Marine Biodiversity. *Science Advances*, 3(2), DOI: 10.1126/sciadv.1601198.
- Richmond, B. (1993). Systems Thinking: Critical Thinking Skills for the 1990s and Beyond. *System Dynamics Review* 9(2): 113-133.
- Saldaña, J. (2013). *The Coding Manual for Qualitative Researchers* (2nd ed.). Thousand Oaks, CA: Sage Publications, Inc.

Scheuhammer, A., Braune, B., Chan, H., Frouin, H., Krey, A., Letcher, R., Losetol, L., Noel, M., Ostertag, S., Ross, P., Wayland, M. (2015). Recent Progress on our Understanding of the Biological Effects of Mercury in Fish and Wildlife in the Canadian Arctic. *Science of the Total Environment*, 509-510, 91-103.

Schoedinger, S., Cava, F., Jewell, B. (2006). The Need for Ocean Literacy in the Classroom. *The Science Teacher*, 73(6), 44-47

Schoedinger, S., Tran, L. U., Whitley, L. (2010). From the Principles to the Scope and Sequence: A Brief History of the Ocean Literacy Campaign. NMEA Special Report #3.

Scully, S. (2015). Marine People Partnership: The Challenges Needs and Opportunities for Strategic Workforce Development in the Greater Marine Industry. Halifax, NS: Institute for Ocean Research Enterprise (IORE)

Scully, S. (2016). Marine People Partnership: Student Intentions and Perceptions Survey. Report of Findings, Analysis and Recommendations. Halifax, NS: Institute for Ocean Research Enterprise (IORE)

Shenton, A. (2004). Strategies for ensuring Trustworthiness in Qualitative Research Projects. *Education for Information*, 22, 63-75.

Snellgrove, P.V.R (1999). Getting to the Bottom of Marine Biodiversity: Sedimentary Habitats: Ocean bottoms are the most widespread habitat on Earth and support high biodiversity and key ecosystem services. *BioScience*, 49(2), 129-138.

Spence, E. (2011). Unearthing Environmental Education: A Study of Sixth Grade Curriculum and Teachers' Experiences in the x Regional Municipality, Nova Scotia. (Master's thesis). Dalhousie University. Nova Scotia, Canada.

Spence, E., Wright, T., Castleden, H. (2013). Present, Absent, or Tardy? A study of the barriers, bridges, and beliefs concerning environmental education among a cohort of sixth grade teachers in Nova Scotia. *Applied Environmental Education and Communication*, 12(3), 197-206.

Steel, B., Lovrich, N., Lach, D., Fomenko, V. (2005). Correlates and Consequences of Public Knowledge Concerning Ocean Fisheries Management. *Coastal Management*, 33, 37-51.

Steel, B., Smith, C., Opsommer, L., Curiel, S., Warner-Steel, R. (2005). Public Ocean Literacy in the United States. *Ocean and Coastal Management*, 48, 97-114.

Sterling, S. (2001). *Sustainable Education: Reinvisioning Learning and Change*. Bristol, UK: Green Books.

Strang, C., DeCharon, A., Schoedinger, S. (2007). Can You Be Science Literate Without Being Ocean Literate? *The Journal of Marine Education*, 23(1), 7-9.

- Strang, C. (2008). Education for Ocean Literacy and Sustainability: Learning from Elders, Listening to Youth. *Journal of Marine Education*, 24(3), 6-10.
- Strauss, A., Corbin, J. (1990). *Basics of Qualitative Research*. Newbury Park: Sage.
- Stroeve, J., Holland, M., Meier, W., Scambos, T., Serreze, M. (2007). Arctic Sea Ice Decline: Faster than Forecast. *Geophysical Research Letters*, 34(9), DOI: 10.1029/2007GL029703.
- Surfers Against Sewage (2014). Seas for Life: North Devon Schools Programme. (Retrieved from). <http://www.sas.org.uk/news/sas-news/seas-for-life-northern-devon-schools-programme/>
- Tan, M., Pedretti, E. (2010). Negotiating the Complexities of Environmental Education: A study of Ontario teachers. *Canadian Journal of Science, Mathematics, and Technology Education*, 10:1, 61-78.
- Tanaka, K., Hideshige, T., Rei, Y., Kaoruko, M., Masi-aki, F., Yutaka, W. (2013). Accumulation of Plastic-derived Chemicals in Tissues of Seabirds Ingesting Marine Plastics. *Marine Pollution Bulletin*, 69, 219-222.
- Tran, L. U., Payne, D., Whitley, L. (2010). *Research on Learning and Teaching Ocean and Aquatic Sciences*. NMEA Special Report #3.
- The Royal Society (2005). *Ocean Acidification due to Increasing Atmospheric Carbon Dioxide*. The Clyvedon Press Ltd, Cardiff, UK.
- UNESCO (1998). *World Science Report 1998*. UNESCO, Paris. (Retrieved from). <http://www.unesco.org/new/en/natural-sciences/science-technology/prospective-studies/unesco-science-report/world-science-report-1998/>
- UNESCO. (2005). *United Nations Decade of Education for Sustainable Development (2005–2014): international implementation scheme*. (Retrieved from). unesdoc.unesco.org/images/0014/001486/148654e.pdf.
- UNESCO. (2014). *Roadmap for Implementing the Global Action Programme on Education for Sustainable Development*. UNESCO, Paris (Retrieved from). <http://unesdoc.unesco.org/images/0023/002305/230514e.pdf>.
- UNESCO (2015). *UNESCO Science Report: Towards 2030*. UNESCO, Paris (Retrieved from). <http://unesdoc.unesco.org/images/0023/002354/235406e.pdf>
- United Nations (1972). *Declaration of the United Nations Conference on the Human Environment*. (Retrieved from). www.unep.org/Documents/Multilingual/Default.asp?documentid=97&articleid=1503.

United Nations (2017). The Sustainable Development Goals Report 2017. (Retrieved from).
<https://unstats.un.org/sdgs/files/report/2017/TheSustainableDevelopmentGoalsReport2017.pdf>

United Nations (2016). Ocean and Law of the Sea. Chapter 54: Overall Assessment of Human Impact on the Oceans.
http://www.un.org/depts/los/global_reporting/WOA_RegProcess.htm

UNEP (2006). Our Precious Coasts. Nelleman C. and Corcoran E (Eds). GRID Adrendal Norway.

UNEP (2016). Kids against Marine Litter. (Retrieved from).
<http://www.unep.org/regionalseas/marinelitter/kids/default.asp>

Uyarra, M. C., Borja, A. (2016). Ocean Literacy a “new” socio-ecological concept for a sustainable use of the seas. *Marine Pollution Bulletin*, 104(1-2), 1-2.

Van Wijk, E., Harrison, T. (2013). Managing Ethical Problems Involving Vulnerable Populations, Using a Pilot Study. *International Journal of Qualitative Methods*, 12(1), 570-586.

Vindrola-Padros, C., Pape, T., Utley, M., Fulop, N. (2017). The Role of Embedded Research in Quality Improvement: A narrative review. *BJM Quality and Safety*, 26(1), 70-80.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Walter, H., Lien, J. (1985). Attitudes of Canadian Students and Teachers toward the Marine Environment and Marine Education. *Marine Parks and Conservation: Challenge and Promise*. Volume 1. National and Provincial Parks Association of Canada.

Weinrib, J., Jones, G. (2014). Largely Matter of Degrees: Quality assurance and Canadian Universities. *Policy and Society*, 33(3), 225-236.

White, J (2008). Canada’s Ocean Playground: The Tourism Industry in Nova Scotia 1870 – 1970. *Nova Scotia Archives*. (Retrieved from).
<http://novascotia.ca/archives/virtual/tourism/early.asp?Language=English>

Williams, S. (2013). Sea-level rise implications for coastal regions. *In*: Brock, J.C.; Barras, J.A., and Williams, S.J. (eds.), *Understanding and Predicting Change in the Coastal Ecosystems of the Northern Gulf of Mexico*, *Journal of Coastal Research*, Special Issue No. 63, 184–196.

Wilcox, C., Van Sebille, E., Hardesty, B. (2015). Threat of Plastic Pollution to Seabirds is Global, Pervasive, and Increasing. *PNAS*, 112(38), 11899-11904.

Worm, B., Barbier, E., Beaumont, N., Duffy, J., Folke, C., Halpern, B., Jackson, J., Lotze, H., Micheli, F., Palumbi, S., Sala, E., Selkoe, K., Stachowicz, J., Watson, R. (2006). Impacts of Biodiversity Loss on Ocean Ecosystem Services. *Science*, 314(5800), 787-790.

Zickfield, K., Levermann, A., Granger Morgan, M., Kuhlbrodt, T., Rahmstorf, S., Keith, D. (2007). Expert Judgements on the Response of the Atlantic Meridional Overturning Circulation to Climate Change. *Climate Change*, 82, 235-265.

Appendix A: Dalhousie University Ethics Approval



Social Sciences and Humanities Research Ethics Board Letter of Approval

July 07, 2015

Ms Kerri McPherson
Management\Resource & Environmental Studies

Dear Kerri,

REB #: 2015-3537
Project Title: Development of Ocean Literacy in Nova Scotia's High School Curriculum
Effective Date: July 07, 2015
Expiry Date: July 07, 2016

The Social Sciences & Humanities Research Ethics Board has reviewed your application for research involving humans and found the proposed research to be in accordance with the Tri-Council Policy Statement on *Ethical Conduct for Research Involving Humans*. This approval will be in effect for 12 months as indicated above. This approval is subject to the conditions listed below which constitute your on-going responsibilities with respect to the ethical conduct of this research.

Sincerely,

Sharon Gomes

Appendix B: HRSB Ethics Approval



November 25, 2015

Dear Ms. McPherson:

"Development of Ocean Literacy in Nova Scotia's High School Curriculum"

Approved Project Duration: November 25, 2015 to May 31, 2016

I am writing in response to your application to conduct research in the Halifax Regional School Board and to advise that your project is **approved**.

It is the Committee's requirement that all projects with student participation have signed parental/guardian consent. Further to that requirement, it is the request of the Committee that the parental/guardian consent form clearly outlines the information to be collected.

You are required to seek school's permission from the principal regarding the school's participation in the project. As noted in the Halifax Regional School Board's Research Application, the participation of a school or an individual in your research is voluntary. Our approval does not compromise a school's or an individual's right to decline participation in external research projects.

You are reminded that the personal identity of all participants must remain confidential and may not be included in any publication or communication describing the research; nor released to any other party. Any media publicity regarding the project must be reviewed and discussed fully with the Halifax Regional School Board's Communications Unit prior to publication.

Researchers are required to request, in writing or by email to cjennex@hrsb.ca, approval of any changes or extensions to the research application.

Your approved project duration is noted above. All research in the school/s must be concluded by the end of May 31, 2016. Please keep in mind that due to the large number of activities that take place during the early and final weeks of school, external research activities are not permitted during the months of September or June.

Should you have any questions regarding this approval, please contact Charmaine Jennex at 464-2000, extension 2567.

We wish you every success with this effort and look forward to reading your final report.

Sincerely,

Alison (Leverman) King
Director, Program

Appendix C: Information Letter for Teachers



Title of Research Study:

Inclusion of Ocean Literacy Principles in Nova Scotia's High School Science Curriculum.

Principal Investigator:

Kerri McPherson, Masters of Environmental Studies, Dalhousie University.
kmcpherson@hrsb.ca, Telephone: (902) 209-1594

Academic Supervisor:

Dr. Tarah Wright, Department of Environmental Science, Dalhousie University.

Thesis Committee member:

Dr. Peter Tyedmers, School for Resource and Environmental Studies, Dalhousie University.

Hello,

I would like to invite you to take part in a research study that I am conducting as a part of my Masters of Environmental Studies degree at Dalhousie University. My name is Kerri McPherson and I am the Principal Investigator for this study, I will be the contact person for this research. Participation in this research project is volunteer, and if for any reason you decide to no longer be involved in the study you may withdraw at any time. My research is outlined below; including a description of the study, the purpose and goals, methods, confidentiality and outcomes. If you have any questions pertaining to the study or my research please do not hesitate to contact me through the contact information provided.

The purpose of this research study is to gain insight into the inclusion of ocean concepts into the curriculum and classrooms of high school science courses within Nova Scotia. This study will focus on how educators perceive oceans education and will investigate the challenges and barriers, if any, that teachers face in the implementation of ocean concepts into high school science curriculum. Insight gained from this study will help to determine the level of inclusion of ocean concepts in high school science curriculum and classrooms.

This research study will involve an in depth review of scholarly literature in the area of oceans education and an analysis of the curriculum outcomes for high school science courses including; Science 10, Biology 11, 12 and IB, Chemistry 11, 12 and IB, Physics 11, 12, and IB, IB Environmental Systems Studies, and Human Biology 11. I plan to conduct individual one hour interviews with high school science teachers employed with the Halifax Regional School Board. With permission from participants, each interview

will be recorded and transcribed. Analysis of the interviews and transcripts will be completed to identify common themes among the interviews. The transcripts will be made available to participants for review and participants will be contacted if one of their quotes is intended to be used directly in the study. Participant names will not be used in the study, in order to protect the privacy of the participants they will be assigned a pseudonym. Participants will have access to a working copy of my thesis so that they may review to see how their information is being used. Recording of the interviews will only be heard by myself and my thesis committee members, Dr. Tarah Wright and Dr. Peter Tyedmers from Dalhousie University. Audio files will be destroyed once they are transcribed and written transcripts will be kept in a locked filing cabinet in the office of Dr. Tarah Wright in the Environmental Science Department at Dalhousie University for 5 years upon which they will be destroyed as required by the Dalhousie University Policy on Research Integrity.

The results of this study will be presented in an academic thesis and may be communicated in academic articles and at academic conferences.

If you have any questions or would like more information please do not hesitate to contact me. I look forward to hearing from you.

Kind Regards,

Kerri McPherson

Appendix D: Interview Script

Thank you for agreeing to participate in this study on the inclusion of ocean concepts in high school science curriculum in Nova Scotia. Before the interview begins I wanted to remind you that I will be recording our conversation. The interview should last for approximately 1 hour and the questions will pertain to the inclusion of ocean concepts in high school science courses. During the interview I will be asking questions regarding how ocean concepts are included in your high school science course curriculum along with how and if they are included in your classroom practices. There are no right or wrong answers, I am simply interested in hearing your opinions on the quantity and quality of oceans education offered. If there are questions you do not wish to answer, that is fine, we can simply move on to the next question. If there is a comment you wish to make but do not want it recorded simply indicate that to me and the comment can be removed. If at any point you wish to terminate the interview or withdraw from the study, just let me know, this includes after the interview is completed. The information collected during this interview will be kept confidential. At the end of this study I will be producing a completed thesis, and any information that you provide or comments that are used will be identified using a pseudonym. Do you have any questions before we begin?

I would like to start by asking a few general questions:

1. What institution did you get your Bachelor's of Education from?
2. What are your first and second teaching subjects?
3. In what discipline (or disciplines) is your science background in?
4. How long have you been teaching with the Halifax Regional School Board?
Have you taught with any other school board? (Have you taught outside of the province?)
5. How long have you been teaching at your current school?
6. How long have you been teaching high school science courses?
7. Which science courses are you currently teaching?
8. At any point during your B.Ed. did you receive any education or specific training on the ocean or ocean concepts?
9. Do you feel that having training in ocean concepts would be (or would have been) helpful to you in your teaching career? Why or why not?

Now I would like to ask you a few more specific questions regarding your experience with the ocean and oceans education.

10. Did you grow up here in Nova Scotia?
11. How would you describe your knowledge of the ocean?
12. What are your personal feelings/attachments to the ocean? (Did you grow up near the ocean, family history with the ocean, etc.?)
13. Do you feel that it is important for our youth to have a connection to the ocean? Why or why not?

I would like at this point to talk a little bit about how oceans are included in high school science courses.

14. a) Have you previously taught the Oceans 11 course?
b) What is your overall impression of the course in terms of the level of oceans education?
c) Do you feel that this is enough time/resources devoted to oceans education?
15. Do you think that ocean concepts should be covered to a greater extent in the NS high school science curriculum?
16. Being here in Nova Scotia, “Canada’s Ocean Playground” do you think it is important that students receive a higher level of oceans education?
17. In your opinion do your students show an interest in ocean concepts? Why do you think this is?
18. Have you ever incorporated ocean concepts into a current science course that you are teaching? If yes, what was the overall response?
19. As a teacher are you aware of any ocean related teaching resources that are available to you?
20. a) What do you feel are the greatest challenges to incorporating ocean concepts into your science courses and your classroom?
b) What would influence you to incorporate more ocean concepts into your teaching?
21. The ocean industry sector in Nova Scotia is responsible for over 5 billion dollars in revenue each year. Do you as a teacher feel that you have a responsibility in providing education for our students in this area? Or is there a responsibility?

Finally, I would like to ask a few questions on ocean education and the education system as a whole.

22. As a teacher how much freedom do you have in incorporating ocean concepts into your course? How much control do you have over the curriculum outcomes?
23. Do you feel the school board is supportive of ocean concepts being addressed in a variety of high school science courses? Do you feel you have the freedom to do this if you chose to?
24. Would you be open to receiving training on oceans education in the form of Conferences, PD session, resources and lesson plans?
25. Would you be willing to attend PD sessions and/or conferences to improve your own knowledge on ocean education? Why or why not?

Thank-you for taking the time to speak with me. I will be in touch with you with a copy of your transcript if you wish to review it. It was wonderful to meet with you, enjoy your day.

Appendix E: Interview Consent Form



Consent Form

Title of Research Study: Inclusion of Ocean Literacy Principles in Nova Scotia's High School Science Curriculum.

1. Do you consent to being audio taped? Yes ___ No ___
2. Do you wish to receive a copy of the transcript? Yes ___ No ___
3. Do you wish to receive a working copy of the thesis to review how you information and/or quotes will be used? Yes ___ No ___

I have read the outline and explanation of the research study. I have been given the opportunity to ask questions pertaining to the study and my questions have been answered to my satisfaction. I am aware that participation in this study is voluntary and that I may withdraw from this study at any time. I agree to take part in this study.

Signature: _____

Printed Name: _____

Date: _____

Thank-you for your participation!

Appendix F: Ocean Literacy Principles and Fundamental Concepts
(Cava *et al.*, 2005)

Ocean Literacy Principles	Fundamental Concepts
1. The Earth has one big ocean	A: The ocean is the defining physical feature on our planet Earth—covering approximately 70% of the planet’s surface. There is one ocean with many ocean basins, such as the North Pacific, South Pacific, North Atlantic, South Atlantic, Indian, Southern, and Arctic.
	B: Ocean basins are composed of the seafloor and all of its geological features (such as islands, trenches, mid-ocean ridges, and rift valleys) and vary in size, shape and features due to the movement of Earth’s crust (lithosphere). Earth’s highest peaks, deepest valleys and flattest plains are all in the ocean.
	C: Throughout the ocean there is one interconnected circulation system powered by wind, tides, the force of Earth’s rotation (Coriolis effect), the Sun and water density differences. The shape of ocean basins and adjacent land masses influence the path of circulation. This “global ocean conveyor belt” moves water throughout all of the ocean basins, transporting energy (heat), matter, and organisms around the ocean. Changes in ocean circulation have a large impact on the climate and cause changes in ecosystems.
	D: Sea level is the average height of the ocean relative to the land, taking into account the differences caused by tides. Sea level changes as plate tectonics cause the volume of ocean basins and the height of the land to change. It changes as ice caps on land melt or grow. It also changes as sea water expands and contracts when ocean water warms and cools.
	E: Most of Earth’s water (97%) is in the ocean. Seawater has unique properties. It is salty, its freezing point is slightly lower than fresh water, its density is slightly higher, its electrical conductivity is much higher, and it is slightly basic. Balance of pH is vital for the health of marine ecosystems, and important in controlling the rate at which the ocean will absorb and buffer changes in atmospheric carbon dioxide.
	F: The ocean is an integral part of the water cycle and is connected to all of Earth’s water reservoirs via evaporation and precipitation processes.
	G: The ocean is connected to major lakes, watersheds, and waterways because all major watersheds on Earth drain to the ocean. Rivers and streams transport nutrients, salts, sediments, and pollutants from watersheds to coastal estuaries and to the

	ocean.
	H: Although the ocean is large, it is finite, and resources are limited.
2. The ocean and life in the ocean shape the features of the earth.	A: Many earth materials and biogeochemical cycles originate in the ocean. Many of the sedimentary rocks now exposed on land were formed in the ocean. Ocean life laid down the vast volume of siliceous and carbonate rocks.
	B: Sea level changes over time have expanded and contracted continental shelves, created and destroyed inland seas, and shaped the surface of land.
	C: Erosion—the wearing away of rock, soil and other biotic and abiotic earth materials—occurs in coastal areas as wind, waves, and currents in rivers and the ocean, and the processes associated with plate tectonics move sediments. Most beach sand (tiny bits of animals, plants, rocks, and minerals) is eroded from land sources and carried to the coast by rivers; sand is also eroded from coastal sources by surf. Sand is redistributed seasonally by waves and coastal currents.
	D: The ocean is the largest reservoir of rapidly cycling carbon on Earth. Many organisms use carbon dissolved in the ocean to form shells, other skeletal parts, and coral reefs.
	E: Tectonic activity, sea level changes, and the force of waves influence the physical structure and landforms of the coast.
3. The ocean is a major influence on weather and climate.	A: The interaction of oceanic and atmospheric processes controls weather and climate by dominating the Earth’s energy, water, and carbon systems.
	B: The ocean moderates global weather and climate by absorbing most of the solar radiation reaching Earth. Heat exchange between the ocean and atmosphere drives the water cycle and oceanic and atmospheric circulation.
	C: Heat exchange between the ocean and atmosphere can result in dramatic global and regional weather phenomena, impacting patterns of rain and drought. Significant examples include the El Niño Southern Oscillation and La Niña, which cause important changes in global weather patterns because they alter the sea surface temperature patterns in the Pacific.
	D: Condensation of water that evaporated from warm seas provides the energy for hurricanes and cyclones. Most rain that falls on land originally evaporated from the tropical ocean.
	E: The ocean dominates Earth’s carbon cycle. Half of the primary productivity on Earth takes place in the sunlit layers of the ocean. The ocean absorbs roughly half of all carbon dioxide and methane that are added to the atmosphere.

	<p>F: The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon, and water. Changes in the ocean's circulation have produced large, abrupt changes in climate during the last 50,000 years.</p>
	<p>G: Changes in the ocean-atmosphere system can result in changes to the climate that in turn, cause further changes to the ocean and atmosphere. These interactions have dramatic physical, chemical, biological, economic, and social consequences.</p>
<p>4. The ocean made Earth habitable.</p>	<p>A: Most of the oxygen in the atmosphere originally came from the activities of photosynthetic organisms in the ocean. This accumulation of oxygen in Earth's atmosphere was necessary for life to develop and be sustained on land.</p>
	<p>B: The ocean is the cradle of life; the earliest evidence of life is found in the ocean. The millions of different species of organisms on Earth today are related by descent from common ancestors that evolved in the ocean and continue to evolve today.</p>
	<p>C: The ocean provided and continues to provide water, oxygen, and nutrients, and moderates the climate needed for life to exist on Earth (Essential Principles 1, 3, and 5).</p>
<p>5. The ocean supports a great diversity of life and ecosystems.</p>	<p>A: Ocean life ranges in size from the smallest living things, microbes, to the largest animal on Earth, blue whales.</p>
	<p>B: Most of the organisms and biomass in the ocean are microbes, which are the basis of all ocean food webs. Microbes are the most important primary producers in the ocean. They have extremely fast growth rates and life cycles and produce a huge amount of the carbon and oxygen on Earth.</p>
	<p>C: Most of the major groups that exist on Earth are found exclusively in the ocean and the diversity of major groups of organisms is much greater in the ocean than on land.</p>
	<p>D: Ocean biology provides many unique examples of life cycles, adaptations, and important relationships among organisms (symbiosis, predator-prey dynamics, and energy transfer) that do not occur on land.</p>
	<p>E: The ocean provides a vast living space with diverse and unique ecosystems from the surface through the water column and down to, and below, the seafloor. Most of the living space on Earth is in the ocean.</p>
	<p>F: Ocean ecosystems are defined by environmental factors and the community of organisms living there. Ocean life is not evenly distributed through time or space due to differences in</p>

	<p>abiotic factors such as oxygen, salinity, temperature, pH, light, nutrients, pressure, substrate, and circulation. A few regions of the ocean support the most abundant life on Earth, while most of the ocean does not support much life.</p>
	<p>G: There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps, rely only on chemical energy and chemosynthetic organisms to support life.</p>
	<p>H: Tides, waves, predation, substrate, and/or other factors cause vertical zonation patterns along the coast; density, pressure, and light levels cause vertical zonation patterns in the open ocean. Zonation patterns influence organisms' distribution and diversity.</p>
	<p>I: Estuaries provide important and productive nursery areas for many marine and aquatic species.</p>
<p>6. The ocean supports a great diversity of life and ecosystems.</p>	<p>A: The ocean affects every human life. It supplies freshwater (most rain comes from the ocean) and nearly all Earth's oxygen. The ocean moderates the Earth's climate, influences our weather, and affects human health.</p>
	<p>B: The ocean provides food, medicines, and mineral and energy resources. It supports jobs and national economies, serves as a highway for transportation of goods and people, and plays a role in national security.</p>
	<p>C: The ocean is a source of inspiration, recreation, rejuvenation, and discovery. It is also an important element in the heritage of many cultures.</p>
	<p>D: Humans affect the ocean in a variety of ways. Laws, regulations, and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (point source, nonpoint source, and noise pollution), changes to ocean chemistry (ocean acidification), and physical modifications (changes to beaches, shores, and rivers). In addition, humans have removed most of the large vertebrates from the ocean</p>
	<p>E: Changes in ocean temperature and pH due to human activities can affect the survival of some organisms and impact biological diversity (coral bleaching due to increased temperature and inhibition of shell formation due to ocean acidification).</p>
	<p>F: Much of the world's population lives in coastal areas. Coastal regions are susceptible to natural hazards (tsunamis, hurricanes, cyclones, sea level change, and storm surges).</p>

	<p>G: Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.</p>
<p>7. The ocean supports a great diversity of life and ecosystems.</p>	<p>A: The ocean is the largest unexplored place on Earth—less than 5% of it has been explored. The next generation of explorers and researchers will find great opportunities for discovery, innovation, and investigation.</p> <p>B: Understanding the ocean is more than a matter of curiosity. Exploration, experimentation, and discovery are required to better understand ocean systems and processes. Our very survival hinges upon it.</p> <p>C: Over the last 50 years, use of ocean resources has increased significantly; the future sustainability of ocean resources depends on our understanding of those resources and their potential.</p> <p>D: New technologies, sensors, and tools are expanding our ability to explore the ocean. Scientists are relying more and more on satellites, drifters, buoys, subsea observatories, and unmanned submersibles.</p> <p>E: Use of mathematical models is an essential part of understanding the ocean system. Models help us understand the complexity of the ocean and its interactions with Earth’s interior, atmosphere, climate, and land masses</p> <p>F: Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, physicists, animators, and illustrators. And these interactions foster new ideas and new perspectives for inquiries.</p>