SCIENTIFIC OUTREACH:
LINKING ENVIRONMENTAL SCIENCE EDUCATION IN HIGH SCHOOLS WITH SCIENTIFIC RESEARCH
A CASE STUDY OF THE *SCHOOLS ON BOARD* PROGRAM

A THESIS

Submitted to the Faculty of Graduate Studies of the University of Manitoba, in partial fulfilment for the requirements of the degree:

MASTERS OF ENVIRONMENT

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BY

Lucette M.J. Barber

A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirement of the degree

Of

MASTER OF ENVIRONMENT

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ABSTRACT

In 2003 a group of international scientists unanimously supported a scientific outreach program that would take students and teachers onboard their Arctic research expedition. Five years later 'Schools on Board' field program continues to successfully link classroom education with scientific research through authentic science experiences. This is an action research project that utilizes a systematic case study approach to document the planning process and evaluate the 2004 pilot program against a set of three criteria for quality environmental science education programs, determined from the analysis of a literature review on environmental education, science education, and scientific outreach. This project successfully answers the questions "how" and "why" did this program work in 2004? The result is a better understanding of why the program continues to work from both a practical (planning) and theoretical (pedagogical) perspective. Findings of this study include the detailed case description of the steps and key decisions made during the design, planning and implementation of this scientific outreach program, and an evaluation against the criteria identified in the study to reveal recommendations for program improvements.

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I would like to thank the following groups and individuals for their valuable contributions to the creation of this unique outreach program:

Program partners:

- Canadian Arctic Shelf Exchange Study (CASES); ArcticNet Inc.; University of Manitoba (UofM), Centre for Earth Observation Science (CEOS); Natural Sciences and Engineering Research Council (NSERC)

2004 Program sponsors and supporters

- Department of Fisheries and Oceans Canada (DFO)
- University of British Columbia (UBC); Aurora Research Institute (ARI); Bank of Montreal (BMO); all local sponsors who made it possible for students and teachers to participate.
- Dr. Grant Ingram (UBC), accompanying academic, 2004 Schools on Board team
- Schools on Board advisory committee (2004): Dr. David Barber, CEOS (UofM); Bob Hodgson, CEOS (UofM); Andries Blouw, (DFO); Steve Newton, (DFO); Richard Zuk, Springfield Collegiate; Sam Barber, School District #59, BC; Karine Lacoste, Université du Québec à Rimouski (UQAR), QC.
- Participating schools, students and teachers.
- The captain and crew of the *CCGS Amundsen* – Leg 5 of the CASES expedition
- The scientists and researchers from both CASES and ArcticNet networks, for sharing their time, knowledge, and most of all, their passion for science and research with our students and teachers.

The 'Schools on Board' program is administered from the Centre for Earth Observation Science (CEOS), Clayton H. Riddell Faculty of Environment, Earth and Resources at the University of Manitoba and continues to be funded by ArcticNet and NSERC.

This thesis would not be possible without the valuable guidance, support and encouragement of my supervisor and committee members - Drs. Jill Oakes, Barbara McMillan, and Mary Benbow - and funding received from ArcticNet Inc. Project 3.6 People & Environmental Change.

Dedicated to

Dave, Jeremy, Julien, and Jamie Lynne for their unconditional support and encouragement to achieve this personal goal.

And to Waterhen – a place to

re-connect, re-charge, re-think, and re-flect!

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LIST OF ACRONYMS

ARC – Australian Research Council

CASES – Canadian Arctic Shelf Exchange Study

CCGS – Canadian Coast Guard Service

CFL – Circumpolar Flaw Lead system study

CMEC – Councils of Ministers of Education Canada

EE – Environmental Education

EECOM - Canadian Network for Environmental Education and Communication

EOC – Education Outreach and Communication

ESD – Education for Sustainable Development

IEEP – International Environmental Education Programme

IPCC – Intergovernmental Panel on Climate Change

IPY – International Polar Year

NSERC – Natural Sciences and Engineering Research Council (Canada)

NSF – National Science Foundation (USA)

RCUK – Research Council of the United Kingdom

SE – Science Education

SLE – Significant Life Experiences

SO – Scientific Outreach

UNEP – United Nations Environment Programme

UNESCO – United Nations Educational Scientific and Cultural Organization

UNFCCC – United Nations Framework Convention on Climate Change

WCED – World Commission on Environment and Development

CHAPTER ONE - INTRODUCTION

1.1 Background

Colleagues and members of both the science and education communities frequently ask me if I am a scientist or teacher. My answer to this query is, "I am neither. I am a program planner." My formal training is in the area of program planning. I assess the needs of my stakeholders, and I plan programs that attempt to meet or exceed these needs. Although never trained formally in the field of education, my experiences in program planning and my personal relationships to the world of climate change research, have led me to the growing field of scientific outreach and environmental education.

The opportunity to get involved in scientific outreach fell on my lap one summer day. The year was 2002, and Canadian scientists were feeling a renewed optimism as a result of a growing political willingness to support Arctic climate change research in response to a growing concern for climate change by the general public. At the lead of this optimism, was a group of Canadian researchers proposing to purchase and retrofit an icebreaker from the Canadian Coast Guard fleet, into a state-of-the-art research vessel. This icebreaker would become the platform for a unique Arctic ecosystem study called the Canadian Arctic Shelf Exchange Study (CASES). This was an ambitious multidisciplinary program that would be the largest Canadian-led scientific research study conducted in the Arctic to date. It would involve scientists from academic and government research facilities from 11 countries, all aimed at providing their own 'lens' to the examination of the complex Arctic marine ecosystem. This study was of great interest, not only to the scientists but also to the public at large, as it was occurring in the wake of the release of the Third Assessment Report on Climate Change (IPCC, 2001).

All of these factors set the stage for a discussion at a family reunion where two brothers were sharing their latest initiatives, one was an Arctic scientist, the other, was a school administrator in northern British Columbia. Upon hearing about the upcoming CASES study onboard a research icebreaker, the school administrator, asked the scientist, "How do we get high school students on board?" Being present at this discussion, and having a degree and background in program planning, this question became the challenge that launched me into developing Schools on Board (SonB), a national outreach program aimed at getting high schools directly involved in scientific research by providing opportunities for students and teachers to experience an Arctic science expedition.

The successes of the 2004 pilot field program resulted in its growth and development into an integral outreach program of ArcticNet and the International Polar Year (IPY) research project called the Circumpolar Flaw Lead (CFL) system study – two major Canadian-led Arctic climate change research initiatives.

I am part of a growing 'arm' of scientific research called scientific outreach, which is linked to current trends in environmental science education. The current global concern about climate change is resulting in a growing interest in environmental issues and a growing demand for scientists to become involved and engaged with the public and decision-makers (Backstrand, 2003). This increasing need for outreach work especially in the area of environmental research, is in response to a number of influences including, but not limited to: an international recognition of the need for environmental education (UNESCO, 1977, 1992, 1997; WCED, 1987), interest by politicians and policymakers in creating a knowledge economy/society (Gough, 2002) or as Chapman & Pearce (2001) suggest, a 'knowledge culture'; and outreach requirements of research granting agencies such as the Australian Research Council (ARC), the Natural Sciences and Engineering Research Council of Canada (NSERC), the National Science Foundation (NSF) of the USA, and the Research Council of the United Kingdom (RCUK). All of these factors suggest a growing recognition of the role that scientists can play in increasing scientific and environmental literacy, training educators, and inspiring young people to consider future careers in science, engineering, technology, and research (Avery, Trautmann, & Krasney, 2003; Kurdziel & Libarkin, 2002; Trautmann & MaKinster, 2005). This growing rationale for scientific outreach leads to the questions "How do we effectively link research with education?"

The SonB case study looks at the documented successes of the program and asks: How/Why is the program working from both a theoretical perspective (based on educational research) and a practical perspective (based on sound program planning principles)?

1.2 Research Objectives

The objectives of this study are to:

1) Review literature on environmental education, science education, and scientific outreach to gain a better understanding of the criteria for quality environmental science education programs.

2) Apply these criteria to evaluate the SonB program and provide theoretical grounding to our understanding of why the program is successfully creating positive experiences for participating students, teachers and scientists.

3) Examine the planning process and the stakeholder inputs of the 2004 field program to build a detailed case study of the program and determine the key decisions taken during its design and implementation.

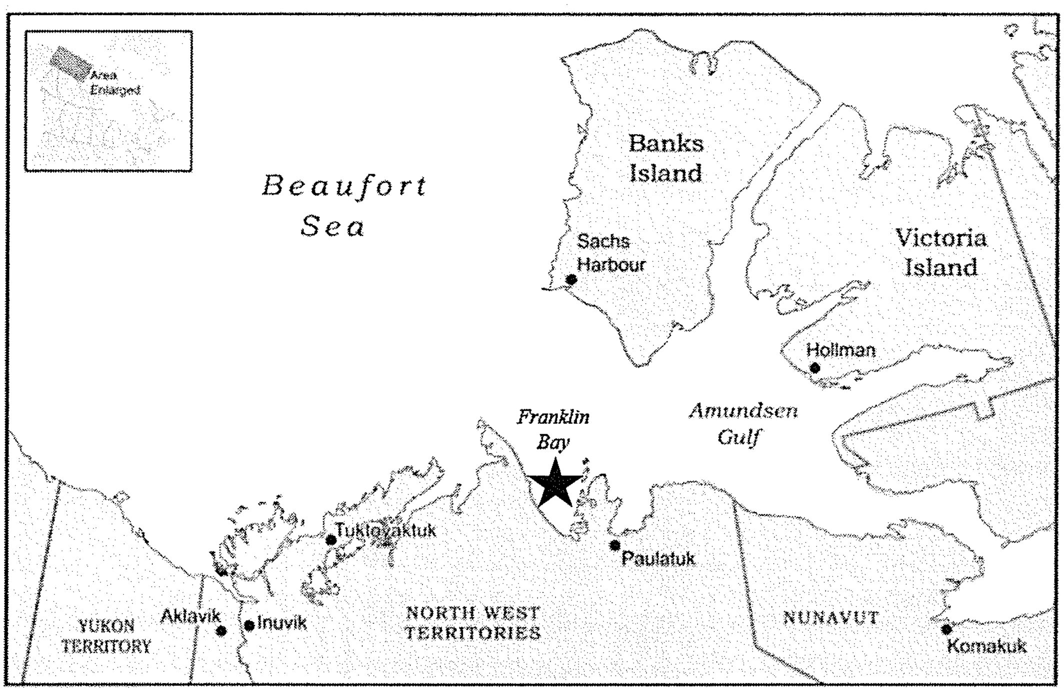
4) Identify recommendations and an action plan for program improvements and future work.

This qualitative research project follows the action research design and sequence described by Stringer (2004) and utilizes the case study method described in Patton (1990) and Yin (2003) to evaluate the program, gain a better understanding of its functions and activities, identify areas for improvement, and develop an action plan for change. The focus of the study is the 2004 SonB field program. This is not a study aimed at developing policies or new curriculum, nor is it an assessment of learning or attitude change in participants. This study is a detailed description of the planning process involved in creating, implementing, and evaluating the 2004 SonB field program based on practical and theoretical findings.

1.3 Description of the case/innovation

The SonB program was developed to answer the initial question: "How do we involve high school students in an Arctic research field program?" The program is now a national outreach program of ArcticNet, a Canadian-led Arctic climate change research program involving a network of scientists and researchers from universities and government agencies across Canada and the world. The SonB program operates out of the University of Manitoba (Winnipeg, Canada) and is currently staffed by one full-time program coordinator and a part-time program assistant. The program was designed and presented to scientists in 2002, introduced to schools in 2003 and piloted in 2004 as an outreach program of the Canadian Arctic Shelf Exchange Study (CASES). The field program was a two-week excursion that included transit to the Arctic, activities in the communities of Inuvik and Tuktoyaktuk (NT), and 7 days onboard the *CCGS Amundsen* during the CASES science expedition in the winter of 2004. Figure 1.1 shows the CASES study area and the two communities visited during the SonB field program.

Figure 1.1 Map of the Canadian Arctic Shelf Exchange Study (CASES) study area.



During the winter season of the research program, the icebreaker was frozen in the ice of Franklin Bay identified by the 'star' in the above map. This is a remote area of the Canadian Arctic only accessible by air, water, or snowmobile. During the winter months, scientists, crewmembers, and SonB participants accessed the icebreaker by chartered twin otter flights departing Inuvik (NT) and landing on a strip of ice near the icebreaker that was cleared by the CCGS crew.

Schools were invited to apply to send a teacher or student to this unique Arctic location, where they would join the scientists on the icebreaker and become integrated into the activities of the various science teams, through a series of lectures, lab activities and fieldwork opportunities. Ten participants, eight students and 2 teachers, were selected from across Canada. The educational program and all travel arrangements were planned and administered by a salaried program coordinator. Scientists from various disciplines participated in the delivery of lectures, fieldwork, and lab activities. In addition to science, the plan included an evening program that addressed the social, political, and historical aspects of climate change. Travel to the Arctic, provided opportunities for participants to learn about northern cultures and northern perceptions of climate change. Visits to two northern communities (Inuvik and Tuktoyaktuk, NT) included presentations at schools, meetings with town leaders, interactions with elders, and activities such as dog sledding and sampling "country" foods.

This case study is an evaluation of the program from a planning perspective, although impacts on participants are discussed with regards to the extent to which the program met the needs of its stakeholders. Further details about the program are described in the case study (Chapter Four).

1.4 Parameters and Limitations

The SonB program has three components: the SonB Network, the SonB Field Program, and the Arctic Climate Change Youth Forum. This study focuses on the field program, specifically, the 2004 pilot program. Information on the other components of the program will be included in the description of the case, but these components will not be evaluated against the criteria identified in this study.

This case study examines the period from the summer of 2002 to the end of 2004. This timeframe includes all planning phases of the program – design, promotion, implementation, evaluation, and reporting. I have since conducted five additional SonB field programs. I acknowledge and recognize that these experiences both bias and inform my examination of the 2004 pilot program. Since the program itself is the unit of analysis of this study, and I designed and implemented the program, I locate myself at the centre of this study as a participant-researcher. This subjectivity is a fact not a flaw. It is, by design, an inherent part of the research, as many details related to the early stages of planning are not known to anyone other than myself. Access to this firsthand information makes me a primary source of data for this study.

A comprehensive review of literature on environmental education, science education and scientific outreach is beyond the scope of this study. The intent of the review of the literature included here is to identify the common threads that link environmental education, science education and scientific outreach. The interpretations of the findings are based on my own perceptions, value judgments and prior experiences, which are informed by my perspective as a program planner, not as an educator or scientist.

I recognize the contextual limitations of a single case study when it comes to transferability of findings. In the case reported here, transferability is limited to scientific outreach programs that utilize field experiences and create authentic science experiences for students and teachers. I recognize the limitations of going back in time to retrieve data from archived documents and personal recollections, which limited my ability to follow strict protocols for collecting data as participants were no longer available for interviewing. Moreover, some of the data was originally collected for purposes of evaluation and not for research, and procedures for collecting observational data in the field were not as rigid as some of the literature on the research methods associated with the case study recommends (Yin, 2003). The research design described in Chapter Three addresses these limitations.

1.5 Relevance

The SonB program represents one example of linking environmental science education in schools to the scientific research activities of an Arctic marine ecosystem study. This case study is of greatest relevance to the stakeholders of the SonB program and its program coordinator. In addition to launching the program into a new stage of development and delivery, the findings of this study will support and justify continued support and allocation of resources to this program. Education, communication, and outreach are important responsibilities of the ArcticNet research program. Their support of this study and their interest in the findings represents their commitment to communicating their work to the public and building capacity in the Canadian research community through quality programming in the area of scientific outreach.

By providing detailed information on program design, planning, and implementation, the findings in this study are relevant to researchers who are interested in initiating similar scientific outreach programs as extensions of their own research programs, and developing similar partnerships with schools. This study is relevant to educators who want to create authentic research and science experiences for students and teachers. Environmental and science educators will see the educational links and the breadth and depth of possibilities for partnerships with the research community, and may be motivated to create their own research partnerships with scientists in a variety of areas. This study provides a sound rationale and an example from which others can learn. The methodology and action research approach to program evaluation will be of interest to other practitioners considering similar approaches to evaluating their own practice.

1.6 Definitions

Action Research (AR) is a cyclical, dynamic, and collaborative research method that is directed at change (action) and understanding (research) at the same time (Tilbury & Cooke, 2005). This is accomplished by initiating an evaluation process that involves cycles of planning, acting, observing, and reflecting. Through this process, the researcher develops new understanding and uses it to changes and improvements to their practice or program, which initiates another cycle of planning, acting, observing, and reflecting. Although AR is often participatory, in that it involves stakeholders in all aspects of the research, the approach used in this study is consistent with a pragmatic and contemporary definition of AR that does not require it to be participatory (Stringer, 2004). Individual stakeholders of the SonB program are transient and change from year to year. For very practical reasons, stakeholders provide input indirectly to this case study through program evaluations and archived documents and files.

Authentic research experiences refers to experiences in a genuine or real research situation, working with experts in a setting where scientific investigation is conducted such as a laboratory or field site, conducting one's own research or contributing to an existing project. These experiences are differentiated from authentic science experiences in that they are more in-depth and involve a greater time commitment from students, teachers and scientists.

Authentic science experiences refer to experiences that include some or all aspects of a scientific investigation. These experiences can occur in a classroom, school laboratory, research facility, or field site, and are led by a more knowledgeable person, which can be a science teacher, a knowledgeable student, or an expert.

Criteria are the standards or expectations by which something can be judged or evaluated. In this thesis, criteria for quality environmental science education identified from a review of literature are used to evaluate the quality of a scientific outreach program from an educational perspective.

Environmental Education (EE) is the teaching and learning of knowledge, processes, and attitudes related to how natural environments function, and how humans can live sustainably on this planet of limited shared resources. In this thesis, environmental education is not limited to education within the formal school system.

For the purpose of this thesis and case study, and for reasons described in the literature review, I include Education for Sustainable Development (ESD) under the umbrella of EE, as I consider EE to be the broader category that includes, but is not limited to, the socio-economic and socio-political characteristics inherent in the terms 'sustainable development'.

Environmental Science Education (ESE) is used in this thesis to refer to the components in the science curriculum that relate to the environment and Earth's ecosystems. Science education is a broad category. In this thesis I use the term ESE to relate to those components in the science curriculum that pertain to the environment and/or climate change. The term is also used to describe programs, such as the SonB program, that combine environmental education and science education.

Key decisions refer to decisions that were made throughout the program's development process that, upon reflection, contributed to the success of the program. Identifying these key decisions in Chapter Four is an important finding of the case study.

Science Education (SE) is the teaching and learning of scientific knowledge, processes, and attitudes related to the physical world. In this thesis, science education refers to the curricular outcomes being taught in formal education (schools). The SonB program specifically targets the secondary or senior high school years.

Scientific Outreach (SO) refers the various initiatives that involve contact with people outside of ones own research group, for the purpose of providing information, resources, or experiences that promote science and technology to the broader community. This can include a wide range of activities. The SonB program focuses on outreach activities between scientists and schools (students and teachers), also referred to in the literature, as 'research partnerships'. 'Research partnerships' are a category of SO programs that are aimed at linking the research activities of scientists to school programs. These partnerships range from email correspondence between scientists and students in a classroom, to scientists bringing students and teachers into their labs or field sites to experience research first-hand. These two terms, outreach and partnership, are used interchangeably, despite the fact that 'scientific outreach' is the broader category under which research partnerships are normally defined.

1.7 Outline of the thesis

This thesis is organized into six chapters. Chapter One is the introduction that describes the background, parameters, and limitations of the study. Chapter Two is a review of the literature related to environmental education, science education and scientific outreach. Chapter Three describes the methodology and case study strategy used for program description and evaluation. Chapter Four is the case study of the 2004 Schools on Board pilot program. It is a systematic and detailed examination that provides the reader with an understanding of, and appreciation for, the planning requirements of this outreach program. Chapter Five describes the findings derived from analysis and interpretation of the case study and literature data, and the evaluation of the program. Chapter Six concludes with a summary and description of an action plan for implementing the recommendations and findings, and includes areas of future work and study.

CHAPTER TWO - LITERATURE REVIEW

This literature review addresses the following key topic areas of my research: Environmental Education (EE), Science Education (SE), and Scientific Outreach (SO). I begin this review with the topic of environmental education (EE) and a description of the political, social, and economic forces that have driven the development of EE and contributed to reforms to science education (SE) such as the inclusion of Science, Technology, Society and the Environment (STSE) as one of the four foundations of the Pan Canadian Science Framework, providing national standards for curriculum development in science education with a focus on the environment (CMEC, 1997). These same socio-political influences help us understand the recent elevated interest by the public in environmental research, especially research related to climate change. Scientists in multiple fields of study from around the world are coming together to understand the complexities of climate change. They are increasingly being asked to inform policy-makers of their findings and to provide the public with the information necessary to understand this complex environmental issue. This growing responsibility to communicate research findings and to contribute to the scientific and environmental literacy of the populace is defined by some, as a civic responsibility of the scientific community (Backstrand, 2003; Clark & Illman, 2001; Merenstein, Bowdy, & Woolley, 2001), and provides strong rationale for scientific outreach.

2.1 Environmental Education (EE)

2.1.1 Evolution of Environmental Education

Environmental education (EE) is a field of study that finds its roots in the nature study movement of the late 1800s and early 1900s and the conservation movement of the

1930s through the 1960s. It has evolved from natural science, ecological, and natural resource conservation interests, to become an important aspect of the formal education of youth and a major focus for international policy-makers. At the core of the contemporary EE movement is the concept of sustainability. The most commonly used definition of sustainability is that of the World Commission on Environment and Development (WCED) defining sustainability as our ability to progress as a human species by "meeting the needs of the present without compromising the ability of future generations to meet their needs" (United Nations General Assembly, 1987 paragraph 27). It is linked to the growing recognition that the Earth's resources, especially those that support life, are finite. The aim of sustainability is to ensure the availability of these resources for future generations. Thus, the interconnections between human health and wellbeing, the environment and the economy are understood. EE, with a focus on learning for sustainability, takes a preventative approach to environmental issues by focusing on thinking and acting that leads to a sustainable future, rather than dwelling on 'doom and gloom' scenarios of environmental problems and disasters. It is this goal toward sustainable living on Earth that drives much of the political influence, locally and globally, that calls for education to play a major role in creating environmentally literate societies whose citizens can critically assess policies, public and government actions, and endorse decisions committed to an environment that sustains human life (Tilbury & Cook, 2005).

Palmer (1998a) provides a thorough description of the historical development of EE. She offers three reasons for including this overview in her text on environmental education in the 21st century that are equally relevant to this thesis. First, a historical overview dispels the notion that EE is new when in reality it has evolved over time on an international level. Second, it recognizes the accomplishments of the 'pioneers of the past' whose efforts have led to the landmark events and milestones shown in Table 2.1. And finally, an understanding of where we have come from will prevent new practitioner in the field of EE from re-inventing the past while planning for the present and the future. Table 2.1 highlights major international initiatives and milestones such as the Keele Conference (1965) that first introduced the term EE on an international stage, and the IUCN/UNESCO 'International Working Meeting on Environmental Education in the School Curriculum' held in Nevada, USA in 1970 that resulted in the 'classical' definition of EE still used today:

> Environmental education is the process of recognizing values and clarifying concepts in order to develop skills and attitudes necessary to understand and appreciate the inter-relatedness among man, his culture, and his biophysical surroundings. Environmental education also entails practice in decision-making and self-formulation of a code of behaviour about issues concerning environmental quality (IUCN, 1970; Palmer, 1998a, pp.7).

The last column of the table lists the key trends in EE as identified by Palmer, demonstrating how these trends correspond with the major events explaining the evolution or development of different aspects of environmental education that have led us to where we are today.

Table 2.1 *Major international and political influences on EE and corresponding trends (source Palmer, 1998a).*

Conference	**Acronym**	**Milestone**	**Trends in EE**
1965 - IUCN Keele Conference	IUCN International Union for the Conservation of Nature & Natural Resources	First use of the term environmental education	1960s Nature studies Fieldwork

Conference	Acronym	Milestone	Trends in EE
1968 - Paris UNESCO Biosphere Conference	UNESCO United Nations Educational, Scientific, and Cultural Organization	Evidence of world wide awareness of EE	
1970 – Nevada IUCN /UNESCO Meeting on Environmental Education in the School Curriculum		Definition of EE Support of key international institutions continue to raise profile of EE	1970s Outdoor education, Field studies centres Conservation education Urban studies
1972 - Stockholm UN Convention on the Human Environment, Stockholm	UN United Nations	International declaration of the need for EE enhances its international status and importance	
1975 – Belgrade UNESCO/UNEP International Workshop on EE	UNEP United Nations Environmental Program IEEP International Environmental Education Programme	Founding of UNEP Founding of IEEP Belgrade Charter – A Global Framework for EE	
1977 – Tbilisi, USSR UNESCO first International inter-governmental conference on EE		Set out goal & objectives for EE Blueprint for developing EE still used today.	
1980's - World Conservation Strategy		Recognize importance of resource conservation Introduce sustainability	1980s Global education – global dimension of EE Development education – political dimension of EE Value education – importance of values through experience Action research – community problem-solving and pupil led problem solving in fieldwork
1987 - 10 year anniversary of Tbilisi conference	WCED World Commission on Environment and Development	Re-visit and re-state commitments from Tbilisi, 1977 Publication of Our Common Future – the Brundtland Report	
1992 – The Earth Summit - Rio de Janeiro	UN Conference on Environment and Development	Agenda 21 – major action program for achieving sustainable development Chapter 36 - promoting education, public awareness and	1990s Empowerment – communication, problem-solving, action, aimed at solutions to socio-economic problems

1995 – Adoption of the Kyoto Protocol		training Rio Declaration – blueprint for sustainable future Publication – Caring for the Earth: a Strategy for Sustainable Living	Education for sustainable development or sustainability 2000s Community Partners? Pupils, students, teachers, politicians, scientists working towards solutions?

Another important initiative not mentioned by Palmer, but relevant to this thesis, is the formation of the Intergovernmental Panel on Climate Change (IPCC) in 1988, a scientific body set up by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) to collect an objective body of information related to global climate change. The IPCC reports (1990, 1992, 1995 and 2001) have provided policymakers from around the world with key information for negotiations such as the 1997 Kyoto Protocol, the Rio Conventions, most recently, the Posnan Climate Change Conference, COP 14, and other negotiations under the United Nations Framework Convention on Climate Change (UNFCCC). In December 2007, the IPCC and Al Gore were jointly awarded the Nobel Peace Prize "for their effort to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change." The fourth and latest report was released in 2007. The reports are all available on line at www.ipcc.ch/index.htm

A recent update to this table is the UNESCO declaration of the United Nations Decade of Education for Sustainable Development (UNDESD) to be held from 2005 to 2014. This declaration encourages governments from around the world to include education for sustainable development in their education and development strategies.

2.1.2 The EE versus ESD debate

A historical overview would not be complete without addressing the growing support for sustainability, sustainable development, and education for sustainable development (Moffatt, 1996; Palmer, 1998b). One by-product of this evolution has been the debate between EE and ESD. Much of the argument seems to focus on the relatively slow progress of EE in achieving changes in behaviours leading to a perceived need to work toward sustainability under a different banner called Education for Sustainable Development (ESD). Discussion and debate are centred on ideology, semantics, ambiguity of terminology, and the continued gap between knowledge (theory) and action (practice) (Chapman, 2004; Fien, 2000; Jickling, 2001; Jickling & Spork, 1998; Stevenson, 1987). Those in support of maintaining a course of action for education under the umbrella of EE point to the lack of agreement on a definition of 'sustainability' and 'sustainable development' which leads to ambiguity and confusion (Chapman, 2004; Jickling, 2001). Orwell (1949) coined the phrase 'double speak' in reference to such terminology that is accepted and utilized for very different, and sometimes opposing purposes. It is used to advocate for development and economic exploitation of resources, and it is used to advocate for the protection and conservation of the same resources.

Other such as McKeown & Hopkins (2005) point out that the goals of EE, as described in the Tbilisi Declaration, and the goals of ESD, as described, in Agenda 21, have much in common (UNESCO, 1977, 1992). They suggest that both are part of the same international movement and that, by working together, the lessons learned in the years of study and practice in EE will be the gain of ESD.

Slow progress and barriers have frustrated many and fuelled much of the debate on the effectiveness of EE, leading to research and discourse into the discrepancy between the intended objectives of EE and its actual teaching (Jickling & Spork, 1998), the discrepancy between environmental knowledge and pro-environmental behaviour (Jensen, 2002; Kollmuss & Agyeman, 2002) and the search for alternative approaches that will build on the ongoing evolution of EE and lead to pro-environmental attitudes, consciousness, and action towards a sustainable society.

Kyburz-Graber and her colleagues (2006) observe that in the midst of this ongoing dialogue, many practitioners use the terms pragmatically, recognizing that in different situations, both are useful for legitimizing programs and providing direction to achieving educational goals, and they concluding that for their purposes, "environmental education is the field that seeks to be educative about environmental issues." (p.201).

2.1.3 Constructing knowledge

Coyle (2005) describes EE as a social construct that is empowering and constructivist in its pedagogy and is consistent with educational theories that recognize the developmental nature of learning. The constructivist perspective on learning is consistent with current pedagogical thinking and is further described in the following science education section (2.2.2 Constructing knowledge, p.33).

The overarching goal of EE is to develop an environmentally or ecologically literate citizenry that demonstrates pro-environmental attitudes and behaviours. This goal can be traced back to the Belgrade Charter –A Global Framework for Environmental Education (1975) and the Tbilisi Declaration (1977) that defined three goals for environmental education. These are: 1) to foster awareness of and concern about economical, social, political and ecological interdependence in urban and rural areas; 2) to provide every person with opportunities to acquire the knowledge, values, attitudes, commitment, and skills needed to protect and empower the environment; and 3) to create new patterns of behaviour of individuals, groups, and society as a whole towards the environment (Palmer, 1998a, p.7-8). These goals are consistent with a social constructivist perspective of knowledge and behaviour, as they acknowledge both the individual and social influences to learning and action and they lead to an international trend to develop strategies for EE that recognize this complexity (Tilbury & Cooke, 2005). The Canadian Framework for Environmental Learning and Sustainability presented by the Government of Canada to the World Summit on Sustainable Development, calls for collaboration from all sectors in society to work towards a more environmentally literate and environmentally responsible society (Government of Canada, 2002).

Towards these ends, in constructing knowledge and environmental literacy, Coyle (2005) makes the important distinction between 'information-giving' and education. He suggests that promoting environmental literacy goes beyond simply passing on facts and concepts to raise awareness - a common approach to outreach, as is evident by the plethora of lectures, displays, posters, and brochures on numerous topics and issues related to the environment. Education on the other hand, involves teaching strategies and techniques aimed at raising awareness <u>and</u> developing skills that will be applied to real life situations. These skills include both practical and cognitive skills such as critical thinking, reflection, decision-making, and problem solving. "What education can do, that other less culturally oriented strategies cannot, is build the foundations for an ecologically sustainable culture at the level of perceptions and practices that transcend generational boundaries" (Saul, 2000, p.5). EE has the capacity to build this knowledge-based culture, which is described by Chapman and Pearce (2001) as one that is critical and reflective, and empowers individuals and communities to change. In order to achieve outcomes such as these, more must occur than the passing on of facts and information and changing 'what' we know. Education must also challenge our perspectives, attitudes, values, and feelings to change 'how' we know and how we construct meaning from what we know. This is the difference between informational learning and transformational learning (Baumgartner, 2001). Outreach providers who identify their programs as EE programs and who endorse change and action in their mission and goal statements, need to consider the distinctions presented by Coyle and Baumgartner to evaluate the extent to which information, education, and/or transformation, drive their programs and initiatives.

2.1.4 Criteria for a quality EE program

A review of the research literature in EE reveals that it is just as diverse and complex as its subject matter. Within the formal education system, EE is found in schools and universities as separate courses, as parts of particular courses, or infused across the curricula of many courses and subjects. It is very contextual, influenced by the teacher, the institution, the social environment, the physical environment, and in some cases, the political environment. Individual programs differ in focus and content, resulting in a wide variety of programs that endorse the philosophy of EE, while adapting the design and implementation to meet the needs of their specific target groups and stakeholders. As such, each EE program demonstrates its own uniqueness.

This contextual nature of EE programs makes it difficult to generate a list of specific criteria for developing quality programs, and explains the growing interest in case studies on specific EE programs to identify common ground, unique ideas, and successful practices (Kyburz-Gaber et al., 2006; Palmer, et al., 1998; Scott & Oulton, 1999; Stevenson, 2004). The common ground rests in the agreement in the EE community, that EE programs have to do more than pass on scientific knowledge 'about' the environment. EE programs need to engage learners in a process of inquiry about multiple paradigms (Gough, 1999; Gough, 2002; O'Riordan, 1988) and ideologies related to the environment so that they can critique, reflect, and develop their own set of environmental beliefs, values and practices. EE programs need to foster sensitivity to the environment, which is identified by Stevenson (2004) as a first priority for all EE program, and they need to empower individuals to act.

Environmental groups and organizations such as Green Street (2005) have produced guidelines and benchmarks for quality EE programs that provide valuable information for designing programs. The critical processes and components for effective EE identified by these groups and educators, converge around three interconnected criteria: 1) educating 'about' the environment; 2) educating 'in' the environment; and 3) educating 'for' the environment. All three are required, in varying degree, to ensure holistic programs that consider all aspects of the environment, include scientific and ecological knowledge, develop a sensitivity and affinity to nature, and provide the skills necessary to increase pro-environmental attitudes and behaviours. By educating 'in' and 'for' the environment, these programs go beyond giving the necessary information 'about' the environment, to produce more transformational learning experiences, as previously suggested by Coyle (2005). The wide spectrum of EE programs is a result of the varying degree to which a program will focus on any individual criterion. These three criteria are described in greater detail in the following three sections.

2.1.4.1 Education about the environment

This criterion requires that EE programs present factual information about the environment with a focus on environmentally significant ecological concepts, scientific information, and knowledge of social issues related to the environment. Although most frequently located in science programs, it is important to consider that knowledge about the environment is no longer limited to scientifically derived knowledge. Gough (2002) firmly asserts that the global nature of environmental issues demands that we start to think globally in order to increase our understanding and develop more effective solutions. He suggests that the contributions of Western science to increase understanding and create solutions to complex, global environmental issues might be enhanced by including local knowledge traditions and recognizing cultural differences in attitudes and practices related to the environment. This is an important aspect to consider when engaging multicultural groups in dealing with environmental issues on a global scale. "We cannot depend on Western science alone because environmental science deals not only with physical reality but also with 'culturally shaped' representations of this reality" (Gough, 2002, p.1228). These culturally shaped representations provide greater options for framing and reframing environmental problems and solutions.

The holistic and systemic nature of the environment, as well as the complexity of environmental issues, requires an interdisciplinary approach to EE that is not limited to any specific discipline or school subject (Caviola & Kyburz-Graber, 2006; Chapman, 2004; Elster, 2006; Fuzne Koszo, 2006; Gustafsson, 2006; Scott & Oulton, 1999). Implementing cross-curricular themes in EE opens doors to new perspectives and entry points for integrating EE and existing school programs (Barab & Landa, 1997; Bereczky, 2006) and makes it easier to make the connections between environment, people, culture and society (Jensen, 2002).

There are numerous sources of information about the environment ranging from factual information found in textbooks and scientific peer-reviewed journals, to editorials, commentaries and essays found in magazines, documentaries, and other popular media that describe many different aspects of environmental problems. Jensen (2002) cautions against focusing on only the factual or scientific knowledge, and suggests that content for EE programs should include action-oriented knowledge that presents four different aspects or dimensions of environmental problems. These include: knowledge about effects (e.g. essential scientific knowledge about the environment); knowledge about root causes, (e.g. the societal factors influencing human behaviour); knowledge about strategies for change, (e.g. the psychological and sociological influences on behaviour such as locus of control and power relations); and knowledge about alternatives and visions (e.g. other world views and possibilities). This approach to educating 'about' the environment is aimed at narrowing the gap between knowledge and behaviours identified by researchers like Kollmuss and Agyeman (2002) who found no apparent correlation between possessing environmental knowledge and displaying pro-environmental behaviours. Jensen (2002) suggests that a broader concept of knowledge is more consistent with the complexity of today's environmental problems.

Since information is the prerequisite for effective decision-making and problem solving, an important aspect of educating 'about' the environment is the development and application of critical thinking and critical reflection skills. These skills are important in processing information, determining its credibility, and identifying related issues. Through a process of critical reflection, individuals are challenged to take ownership or personal responsibility for their own understanding and position on these issues. The result is a working knowledge of concepts, issues, and influences (psychological, sociological, and political) that leads to empowered problem-solving and decision-making that is more likely to lead to action (Hines, Hungerford & Tomera, 1986/87; Hungerford & Volk, 1990).

2.1.4.2 Education in the environment

"If facts are the seeds that later produce knowledge and wisdom, then the emotions and the impressions of the senses are the fertile soil in which the seeds must grow."

- Rachel Carson (biologist, writer, ecologist, 1907-1964).

Providing carefully designed and in-depth opportunities for learners to interact directly with nature and achieve some level of environmental sensitivity promotes environmentally responsible behaviour (Arvai, Campbell, Baird & Rivers, 2004). In studies on 'significant life experiences' (SLE) that examined factors influencing long-term pro-environmental attitudes and behaviours among environmental educators, Palmer and her colleagues (1998) and Chawla (1999, 2001) found that memorable experiences in nature and contact with an adult who taught respect for nature were formative influences in inspiring and developing committed environmental awareness and behaviours. In her 2001 article, Chawla addresses the debate around her research on 'significant life experiences' and acknowledges the impacts of today's changing society on access to natural areas and positive experiences in the environment with parents and other significant individuals. She observes that as "parents and other adults work longer hours, electronic media entertain us indoors, traffic rates increase, neighbourhoods become more dangerous, and the asphalt and buildings cover more and more open spaces" (p.460), we are seeing the 'extinction of experience' with nature. These same ideas supported by more current research, are echoed in the "Last Child in the Woods – Saving our Children from Nature-Deficit Disorder" (Louv, 2008). Louv brings together a growing body of evidence to demonstrate some of the factors influencing the quality of environmental experiences for youth today. He argues that "the child in nature is an endangered species, and the health of children and the health of the Earth are inseparable" (p. 355). This symbiotic relationship between humans and their environment supports the notion that direct experiences in nature are necessary for the health of both humans and the environment.

The rationale for including education 'in' the environment, as a criterion, is reinforced by this fact that individuals in technologically driven societies are spending less time working and playing outdoors, which draws attention to the importance of taking EE outside of the classroom and providing opportunities for individuals to re-connect with nature and the natural environment. In an experiential program on reef studies, Stepath and Whitehouse (2006) brought students into direct contact with reefs through marine field trips that included reef walks, snorkelling, and reef monitoring activities. They found that 'proximity' was an influential factor to student assessments that were unequivocal in attributing the setting of the program to a greater appreciation and understanding of the vulnerability of reefs as well as a greater attitude of caring towards this fragile ecosystem. The qualitative data of the study describes students speaking of "being more connected" to and becoming “more familiar" with coral reefs. They also reported being more sensitive to the need to protect this ecosystem. These researchers found that their students changed as a result of the direct contact with the environment they were exploring and confirmed that education ‘in’ the environment contributes to building or rediscovering connection between humans and the natural world. Sobel (1996) supports this experiential approach to EE that teaches people to love nature before they are expected to fix or heal it.

In a study to measure the effects of research experiences on undergraduate students and K-12 students, Huntoon and colleagues (2001) concluded that the intensive nature of the field program and the exposure to the environment created a learning atmosphere that was conducive to motivated focused learning. Researchers studying ‘interest’ as a factor that influences learning and behaviour, support these findings. They conclude that interest motivates behaviour (Deci, 1992), and that this ‘behaviour-motivating interest’ emerges from an individual’s interactions with his/her environment (Krapp, Hidi & Renninger, 1992).

Literature on landscapes and identity, as well as research on the emotional responses that the environment invokes, add to this section of the literature review and support the decision to take EE programs out of classrooms and into the ‘field’ (Allison & Pomeroy, 2000; Probyn, 2003; Rickinson, 2001). Literature on ‘significant life experiences’ (Chawla, 2001; Gough, 1987; Gough, 1999; Palmer et al., 1998) provides insights on the importance of experiences in the environment in developing lasting changes in attitudes and behaviours toward the environment.

In a frequently cited study on responsible environmental behaviour, Hines and colleagues (1986/87) found that taking ownership or personal responsibility for one's understanding and position on environmental issues, was key to transforming environmental knowledge into pro-environmental action. This position was firmly re-stated by Hungerford & Volk (1990) in a paper prepared for the 1990 UNESCO Round Table on Environment and Education in Jomiten, Thailand. This suggests that, although education 'about' and 'in' the environment predispose an individual towards action by raising awareness and sensitivity, it is not sufficient to create changes in behaviour. Ownership of one's understanding and position on environmental issues requires skills in critical thinking and reflection as well as opportunities to apply these skills in challenging and developing attitudes, values, and personal positions. This is important not only when creating meaning and understanding 'about' the environment but also for making choices and decisions 'for' the environment.

2.1.4.3 Education for the environment

"To think is easy. To act is difficult. To act as one thinks is the most difficult of all."

- Johann Wolfgang Von Goethe (poet 1749-1832).

Environmental issues today come packaged in a number of environmental messages from a variety of information sources that often require sophisticated processing skills for creating meaning. Education 'for' the environment includes components of a program aimed at providing learners with the tools and skills necessary for transforming environmental knowledge or what Kollmuss and Agyeman (2002) coin 'an environmental consciousness,' into action. This is facilitated by teaching a structured decision-making approach that promotes the intention and desire to act, teaches learners specific skills on how to analyze and investigate an issue, challenges learners to question social and individual assumptions, values and attitudes related to these issues, and most importantly, dedicates time needed for learners to practice applying these problem-solving and decision-making skills (Arvai et al., 2004; Hammond, Keeney & Raiffa, 1999; Hungerford & Volk, 1990). Chapman (2004) argues that effective decision-making should empower individuals to act on three different levels:

1. Micro – the individual level that addresses personal values, needs, wants, and interactions with the natural world.
2. Meso – the institutional level that addresses barriers such as curricula, timetables, and professional development.
3. Macro – the political level that addresses social policies related to economic development, social justice, environment, and education.

This approach to teaching decision-making skills considers both internal (personal) and external (social) factors that influence behaviour, and is supported by the ethics approach to educating 'for' the environment that is presented by Jickling, Lotz-Sisitka, O'Donoghue, and Ogbuigwe (2006) in Environmental Education, Ethics, and Action. They suggest that environmental issues such as globalization, climate change, unsustainable use of resources, sustainable development, and the need for environmental action, relate to ethics, and that educators can better prepare students for environmental decision-making and action by incorporating ethics into EE programs.

Kollmuss and Agyeman (2002) describe a complex mix of demographic factors (education, age, gender), internal factors (e.g. motivation, knowledge, awareness, attitudes, locus of control), and external factors (economic, social, political, cultural) that influence and shape our decisions and behaviours on a daily basis and create barriers to pro-environmental behaviours. In their own model of pro-environmental behaviour, they introduce the concept of 'a pro-environmental consciousness' that broadens the definition of knowledge to include emotional involvement, values and attitudes. Consistent with other researchers they do not see a direct relationship between increasing knowledge and increasing behaviour. However, it can be argued that their model only recognizes behaviours that have a direct impact on the environment. Jensen (2002) argues that the concept of pro-environmental behaviour used by researchers (including Kollmuss and Agyeman, 2002) is too narrow, as it focuses too much on direct individual behaviours. He suggests a more inclusive concept of action that recognizes all action targeted at a change. This would include direct (recycling; driving less; using less water; using less chemicals) and indirect action (voting 'green'; political activity; signing petitions; educational outreach) at both the collective (environmental group, classroom) and individual level. There is ongoing debate on how much focus should be placed on action within each level, especially with regards to activism and the age appropriateness of action oriented activities in school programs (Chawla, 1999; Sobel, 1996). Program planners need to consider these issues in the design of their programs. Teaching strategies and activities that encourage critical thinking, critical reflection, problem solving and environmental decision-making are available in relevant curriculum guides (Manitoba Education and Training, 2000/2003b; Manitoba Education, Citizenship and Youth, 2006a/b; Common Framework of Science Learning Outcomes K-12, 1997).

This section has made the case for using education about, in, and for the environment as three criteria for developing quality EE programs capable of meeting the challenges of creating greater awareness, and promoting pro-environmental attitudes and behaviours. EE programs will vary in how much they focus on each criteria depending on their target group and program objectives.

2.1.5 Relevance to this case study

The information emerging from the literature and research on EE is useful in developing criteria for evaluating an environmental scientific outreach program such as the SonB program. These same criteria can also be used to revisit program goals and objectives and help guide program planning, program design, and implementation. Of particular interest to this case study are the areas of convergence between environmental education and the next section on science education.

2.2 Science Education (SE)

Scientific outreach programs can be extensions of science programs in schools. In this sense, science teachers can be partners or collaborators in science outreach programs, as their efforts towards increasing scientific literacy contribute to the existing knowledge base of participants in scientific outreach programs. In return, informed outreach providers can link their programs to existing curricula in the schools, adding to the ongoing construction of knowledge in the formal science education setting. The inclusion of SE in this literature review is intended to produce a greater understanding and appreciation of learning theories and trends in SE that are useful to 'non-educators' designing and evaluating scientific outreach programs aimed directly at schools.

2.2.1 Evolution of Science Education

Unlike EE, SE has a long history within the formal education system, having been introduced in secondary schools in the UK in the late 1800s. Currently, it is firmly established as a core program in most high schools across North America as is manifest by the traditional subjects of general science, biology, chemistry, and physics, and more recently by the curricular headings of life sciences, physical sciences and, Earth and space sciences. The more recent reforms in SE include open-ended and inquiry-based instruction, student engagement in original inquiry and research, and a shift towards making science education relevant to real life (Avery et al., 2003). In a society that is becoming increasingly more knowledge based, this application to real life includes an acknowledgement of the driving influences of technology, and its impacts on society and the environment (CMEC, 1997). Of particular interest to this thesis, is what Barab and Hay (2001) refer to as a 'pedagogical shift' in creating authentic science experiences.

These trends are reflected in changes to science curriculum with increased emphasis on processes such as scientific inquiry, technological problem solving, decision-making, and authenticity. In Canada, these processes are presented in the Pan Canadian science framework as key contributors to scientific literacy (Common Framework of Science Learning Outcomes K-12, 1997). The acknowledgement that scientific fact alone does not develop scientifically literate individuals, has resulted in science curricula that address values, judgments, perceptions, and attitudes, and promote critical thinking about the physical world and within a social context. In the same way that EE has evolved from a focus on knowledge 'about' the environment, SE has evolved from a focus on knowing scientific facts about the physical world, to the recognition of the importance of an interdisciplinary and multi-perspective approach to understanding the physical world and our relationship to it.

2.2.2 Constructing knowledge

Constructivism is a psychological theory of knowledge broadly accepted by the education community that can be used to guide pedagogical approaches and curriculum development. It is based on the study of cognition and revolves around the idea that knowledge is constantly being constructed by the learner who is always in a state of seeking meaning. It assumes that all knowledge has structure, and that learning is a process of sequential knowledge building through interactions with one's environment (both physical and social). Much of the constructivist theory of learning goes back to early studies in child development (Piaget, 1969/70, 1973) and learning theory (Ausubel, 1960, 1968; Bruner, 1960; Ivie, 1998). A core concept of Ausubel's learning theory is the concept of 'meaningful learning' in which new knowledge is not just memorized, but is related to relevant concepts that are already known or familiar. This concept acknowledges that students come to programs with existing knowledge that is organized, structured, and re-constructed into new and meaningful knowledge. Social constructivism goes one step further to suggest that new meanings and understandings grow out of social interactions. According to this theory all learning occurs in social activity (Vygotsky, 1978) adding an emphasis on building new meaning through human interactions, dialogue, negotiation, and collaboration. In this collaborative process of knowledge acquisition or group learning, participation becomes both a process and a goal for learning as knowledge is jointly constructed and distributed amongst everyone involved in the activity (Kyburz-Graber et al., 2006).

A constructivist view of SE acknowledges that science, itself, is constructed by scientists, and that scientific knowledge is embedded in a complex social, political, and cultural environment.

Some of the programming implications of a constructivist framework include the need to: 1) consider the developmental level of the learner; 2) build from prior knowledge; 3) remember that learners come to the program with different views and perspectives on the nature of science; 4) acknowledge that within a group of learners multiple perspectives and interpretations will emerge in inquiry-based activities; 5) provide context to inquiry-based activities by connecting to theory and concepts; 6) provide structure in a curriculum or program plan; 7) provide experiential learning opportunities; 8) value group learning, the important role of group dynamics; and 9) implement different instructional approaches to accommodate many types of learners (Driver, 1983; Libarkin & Kurdziel, 2003; Manitoba Education, Citizenship and Youth, 2006a).

Curriculum resources developed using a constructivist framework provide practitioners with guidance related to content as well as valuable suggestions on instructional approaches that are consistent with this learning theory (see Appendix A for Instructional approaches: roles, purposes and methods).

2.2.3 Criteria for a quality Science Education program

The overriding goal of scientific literacy provides us with a good place to start looking for criteria for a quality SE program. According to Hodson (1986), a scientifically literate person is one who understands the nature of science and scientific knowledge; understands and applies science in interacting with society and the environment; uses processes of science in solving problems and making decisions; and understands and appreciates the relationship between science and technology and their impacts on society and the environment. A focus on scientific literacy draws attention to the fact that SE today does not present only factual, scientifically derived content, nor is not restricted to theories, models, concepts, and principles. The Pan Canadian Science Framework suggests that the development of scientific literacy requires a learning atmosphere that engages students in scientific inquiry, technological problem solving, and decision-making (*CMEC, 1997).* The following sections describe essential science knowledge, scientific inquiry, technological problem solving, and decision-making as criteria for establishing a quality SE program. These four criteria collectively suggest that both content and process considerations related to SE be used to design and evaluate science programs, an approach effectively used by Martin and Howell (2001) when they developed content and process goals for each of the activities related to their web-based scientific outreach program.

2.2.3.1 Essential Science Knowledge

Essential science knowledge relates to the content of a science education program, identified by the Pan Canadian Science Framework as the theories, models, concepts, and principles related to life sciences (biology, microbiology, ecology, biochemistry), physical sciences (chemistry and physics) and, Earth and space science (geology, hydrology, meteorology, astronomy). An important aspect of learning scientific content is learning the philosophy and nature of science that includes an understanding of how science works and how it differs from other ways of knowing.

Contemporary SE programs include more content related to the relationship between science and technology, and the growing impacts these have on society and the environment. This change is evident in the growing number of related curricula such as Current Topics in Science (Manitoba Education, Citizenship and Youth, 2006a), and Education for Sustainability (Manitoba Education and Training, 2000) that have been developed to foster a more interdisciplinary understanding of complex scientific and environmental problems.

It is beyond the scope of this study to go into detail about specific science content and learning outcomes related to curricula. However, the importance of linking scientific outreach to relevant curricula cannot be overstated. Content is the essential and most obvious link between scientific outreach programs and school programs. It will differ with each specific program, but regardless of topic or discipline, programs linked to existing curricula build on existing knowledge and are more likely to be used by teachers for very practical reasons. Lack of time, is often reported by teachers, as the main reason for not integrating new material into an already full curriculum and timetable (Caviola & Kyburz-Graber, 2006; Puk & Behm, 2003).

2.2.3.2 Scientific Inquiry

Driver (1983) suggests that science should be promoted as both a body of knowledge and a place for inquiry and discovery, including the discovery of one's own perception and understanding of the nature of science. This process of discovery is best achieved through scientific inquiry, which is described by Trautmann and MaKinster (2005) as a collaborative learning approach that encourages students and teachers to construct shared meaning and understanding of scientific knowledge by 'doing' science.

'Doing' science entails asking scientifically oriented questions, planning investigations, using appropriate tools and techniques to gather data, interpreting data, formulating explanations, evaluating decisions in light of alternative explanations, and communicating and justifying results and conclusions (National Research Council, 2000). Some of the challenges, reported by teachers, to inquiry-based learning include: getting comfortable working with messy data, uncertain results, and questions that do not have a single correct answer; finding relevant research topics that are appropriate, feasible, and interesting to the students; incorporating the social, economic, and political aspects of science; and lack of direct experience with and training in science inquiry (Trautmann & MaKinster, 2005).

Educators and researchers have suggested the following strategies for overcoming these challenges.

1. Creating opportunities for open-ended research or original experiments designed and conducted by students (Avery et al., 2003).
2. Modifying existing activities or remodelling labs to include inquiry-based approaches (Avery et al., 2003).
3. Including specific lessons on the nature of science that examine how scientists study the natural world; the values, beliefs, and assumptions that underlie the creation of scientific knowledge and foster an appreciation for the complexity and uncertainty of science (Avery et al., 2003; Driver, 1983).
4. Discussing the challenges of data analysis and communication of research (Avery et al., 2003).

5. Using journal publications to discuss the peer review process (Gift & Krasney, 2003) and to critically review published materials (Huntoon, Bluth, & Kennedy, 2001).
6. Engaging students in science discussions and debates similar to those engaged by scientists (Barab & Hay, 2001).
7. Using websites that publish extensive data sets to develop active inquiry exercises that mimic some of the tasks and thought processes that scientists use (Martin & Howell, 2001).
8. Using web-based activities as 'minds-on' activities to complement 'hands-on' activities in the field – focusing on the exploration of questions rather than answers (Martin & Howell, 2001).
9. Designing classrooms to support students reproducing or 'doing science' in the context of the classroom and inviting scientists to work with students and teachers in a classroom or school laboratory (Barab & Hay, 2001).
10. Creating one-on-one mentoring opportunities between student and scientists, and between teachers and scientists (Kurdziel and Libarkin, 2002; Shellito, Shea, Weissman, Mueller-Solger, and Davis 2001).
11. Creating authentic science and research experiences that engage students in 'doing science' with scientists in their labs and at their field sites (Barab & Hay, 2001; Duchovany & Joyce, 2000).
12. Including authentic research experiences in the professional development of teachers (Huntoon et al., 2001; Jarret and Burnley, 2003; Kurdziel and Libarkin, 2002; Trautmann & MaKinster, 2005).

Of interest to this case study is the ability of research partnerships and scientific outreach programs to provide unique and authentic experiences in scientific inquiry. These experiential programs can increase understanding of the scientific process by integrating research and education in a very hands-on/minds on approach (Harnik and Ross, 2003). This experiential approach to learning blends direct experiences with reflection (critical thought, discussion and self-reflection), abstract conceptualization (forming conclusions, interpretations) and active experimentation (application of new knowledge to new cycle of learning, application of technology) placing the learner directly in touch with what is being studied and placing the focus on how something is being learned rather than on what is being learned (Kolb, 1984). Warren and his colleagues (1995) compiled a collection of articles addressing the foundations and benefits of using an experiential process for engaging students in learning. Elster (2006) found that these experiences played an important role in creating what she refers to as the 'aha' experience. According to Elster, these experiences add an emotional quality to content that elevates its perceived value to the learner.

Authentic science or research experiences create 'aha' moments that provide valuable insights to the scientific process that cannot be taught from a textbook. In authentic research experiences, the process of authentic scientific inquiry, or learning at the 'elbows of scientists', allows students to experience the excitement of science and introduces them to the culture of research, which includes the knowledge, skills, language, traditions, behaviour codes, values, social interactions, and passions of the scientific community (Barab & Hay, 2001; Bleicher, 1996).

2.2.3.3 Technological problem solving

Technological problem solving is an active process of learning where students discover how science and technology work hand in hand. It refers to the ability to use existing technology to design new tools and instruments to solve real life human problems. Advances in both science and technology are increasingly changing society in positive and negative ways. A scientifically literate person understands the distinction between science and technology, and is able to critically and creatively think of ways to apply their scientific and technological knowledge to solve very practical problems. Some examples of technological problem solving include the design of prototypes or new products to solve a given problem, the practical application and adaptation of instrumentation to scientific experimentation, and the use of tools including computers and web-based technologies to generate new understanding and solve problems.

2.2.3.4 Decision making

Using Hodson's (1986) definition (p.34), a scientifically literate person is someone who is able to use their scientific knowledge to critically assess and clarify issues, review and evaluate available information, generate possible courses of action, make thoughtful decisions and examine the impacts of these decisions. This developmental process for making relevant and useful decisions involves increasingly demanding contexts. One begins with decisions that are based on limited knowledge and require much guidance, to those that are based on greater knowledge and extensive research and made independently with the intention of making relevant and useful decisions. This decision-making process involves skills in both critical thinking and reflection. Strategies for inclusion of decision-making in programs have already been described in the EE section.

2.2.4 Relevance to this case study

Research partnerships and other scientific outreach programs use their position in the science domain to open doors to schools, students, and teachers and to provide very effective platforms for environmental science education that is 'about', 'in' and 'for' both science and the environment. This focused review of the SE literature provides insights on the nature of science education and a better understanding of the natural connections between science education and scientific outreach. The common ground with EE (i.e., issues, goals, content, and learning strategies) gives credence to Gough's (2002) recognition that the relationship between science education and environmental education is more mutual than competitive (Ashley, 2000; Fien, 2000; Gough, 1999). This mutuality makes it possible to borrow from the criteria of both to develop quality environmental science education and outreach programs that are designed to meet the needs of both.

2.3 Scientific Outreach (SO)

Outreach is, as the name suggests, the process of reaching out and building connections from one person or group to another. Scientific outreach is the effort to communicate science to the public, with the aim of increasing public understanding of scientific research, increasing citizen participation in issues related to science, and providing relevant scientific information to elected officials, civic leaders, and other decision makers in communities.

2.3.1 Evolution of Scientific Outreach

Early outreach efforts were based on a 'diffusion model'. This model viewed the public as passive recipients of information, called for the delivery of scientific and technical information mainly through formal education and mass media, and relied on attempts to persuade the average 'layperson' to have the opinions of the 'experts (Clark & Illman, 2001). Recent models of scientific outreach are more interactive and recognize science communication as a continuum of activities that can deliver a variety of messages. As a result, definitions of outreach are expanding, the rationale for participating in outreach is growing, and best practices for implementing outreach programs are emerging. These changes are manifest in the growing number of case studies in scientific journals that describe a range and diversity of scientific outreach programs (see for example, Journal of Geoscience Education, 51(1) which is dedicated to research partnerships), the increased financial support from research funding agencies such as the Australian Research Council (ARC), the Research Council of the United Kingdom (RCUK), the National Science Foundation (NSF) in the United States, and the Natural Sciences and Engineering Research Council of Canada (NSERC), and the inclusion of dedicated 'Education, Outreach and Communication' (EOC) sessions at major national and international science conferences.

In areas of public concern, such as the environmental degradation and most recently climate change, some argue that it is the civic duty of scientists to become more engaged with public education. The term "civic scientist" suggests that as recipients of public money, scientists have a responsibility to reach out to the public to communicate scientific results, contribute to scientific literacy and become engaged in public discourse

(Clark & Illman, 2001; Merenstein, et al., 2001). This argument provides a strong rationale for developing initiatives that provide scientists with access to the public.

Currently, outreach activities take on many forms and occur at various levels of participation, from basic information sharing to collaborative outreach partnerships. This study will focus on scientific outreach activities that involve research partnerships between schools and scientists and involve authentic science and research opportunities for teachers and students. Case studies of these EE-SE practices are emerging in the literatures of EE and SE (Buck, 2003; Burnley, Evans, & Jarret, 2002; Caviola & Kyburz-Graber, 2006; Elster, 2006; Fuzne Koszo, 2006; Gustafsson, 2006; Harnik and Ross, 2003;Kurdziel & Libarkin, 2002; Kyburz-Graber et al., 2006; Reynolds, 2004; Stevenson, 2004; Tanner, 2000; Trautmann & MaKinster, 2005). Information from the cases cited provides valuable insights on, and rationale for, the practice of scientific outreach. In addition to providing insights into program planning and implementation, findings in this literature also describe specific impacts and benefits of scientific outreach programs on students, teachers, scientists, and society at large.

2.3.2 Benefits of Scientific Outreach

How do collaborative programs between scientists, teachers, and K-12 students influence the learning of science or generate a greater appreciation for the environment? How do they influence perspectives and teaching behaviours of teachers and scientists? How do they impact society at large? These questions are challenging for practitioners and researchers to answer because impacts of scientific outreach programs occur on many levels (individual, professional, institutional, and societal), learning outcomes for participants are specific to each program, and impacts such as knowledge acquisition or attitudinal change are difficult to quantify and attribute to a specific program or experience (Burnley et al., 2002; Harnik & Ross, 2003). That said, assessment is an important component of program planning and delivery, and knowledge of potential impacts, based on research on similar programs, provide valuable insight for designing programs, developing implementation strategies, program goals and objectives, and designing evaluation tools. Educational researchers, Kurziel and Libarkin (2002), anticipate that an increase in programs that promote research partnerships, authentic science experiences and authentic research experiences will result in greater opportunities for systematic assessment of programs and the development of better assessment tools to measure impacts.

The following sections describe some of the impacts found in the reviewed literature that were derived from anecdotal evidence such as testimonials and observations (Duchovany & Joyce, 2000; Harnik & Ross, 2003), findings attained through structured assessments of authentic research partnerships and field-based experiences (Barab & Hay, 2001; Buck, 2003, Burnley et al., 2002; Huntoon et al., 2001; Jarret & Burnley, 2003; Kurdziel & Libarkin, 2002; Lisowski & Dilinger, 1991; Reynolds, 2004; Stepath & Whitehouse, 2006); and teacher/scientist partnerships in the classroom and laboratories (Avery et al., 2003; Bleicher, 1996; Elster, 2006; Trautmann & MaKinster, 2005).

Although these studies are largely based on specific programs with findings that cannot be generalized to all research partnerships, they provide valuable insights into the benefits of the programs studied.

2.3.2.1 Benefits to students

One of the most cited benefits of research partnerships is the connection made between science in the classroom and its application to life outside the classroom and school. The situated nature of practices carried out in authentic research and science experiences, makes science relevant, and creates a greater understanding of scientific content, as measured by Buck, (2003), Huntoon et al., (2001), and Lisowski and Dilinger (1991), and fosters a more sophisticated understanding of the nature of science (Barab & Hay, 2001; Burnley, et al., 2002). These programs create opportunities to include scientific knowledge that is more "in-depth, integrated and authentic than that found in a typical classroom" (Buck, 2003 p.52) and include aspects of scientific inquiry not necessarily found in textbooks, such as engaging in scientific discourse with real scientists (Barab and Hay, 2001). Bleicher (1996) noted that authentic science experiences introduced his students to the 'culture of research' – specifically the language, style of speaking, behaviours, passion, and excitement of scientists. Along these lines, Duchovany and Joyce, (2000) describe the benefit of bringing students and teachers into direct contact with cutting-edge research, state-of-the-art technologies and enthusiastic scientists who serve as excellent role models for those interested in science.

Barab and Hay (2001) found that such authentic science experiences increased interest in research and helped students clarify career goals. They also found that students reported a greater feeling of ownership of the learning and outcomes (results) produced. Using data from field-based outcome surveys collected over three years, Reynolds (2004) claims students demonstrated improved critical thinking skills, an increase in scientific (oceanographic) knowledge, greater confidence in using sophisticated instruments and research technology, and increased interest in field –based projects. Students in a field-based study on reefs (Stepath & Whitehouse, 2006) reported a greater sense of proximity to nature that reconnected them to the natural world and created a greater sense of caring towards the environment.

In addition to direct benefits to students, Kurdziel and Libarkin (2002) point out that students benefit indirectly from research partnerships that involve teachers, as these teachers bring the benefits of their experiences back to the classroom and enrich the science education program. Some of these benefits to teachers and educators are described in the following section.

2.3.2.2 Benefits to teachers and educators

Piaget's law of interest states that true interest appears when the 'self' identifies itself with ideas or objects, and finds meaning of expression that is necessary to fuel intellectual activity or action (Piaget, 1969/70). Contemporary research on interest suggests that interest is: 1) a phenomenon that emerges from an individual's interaction with his or her environment, 2) is an enduring disposition, and, 3) motivates behaviour (Deci, 1992; Krapp, et al., 1992). Jarret and Burnley (2003) speculate that if the above connections are accurate, the following might be said about interest in science:

> If science interest can be developed through interaction with fascinating phenomena, once an interest in science is developed, people make the effort to seek out additional scientific information and science related experiences, thus further deepening science interest. If students increase interest in scientific research through involvement in real research projects, they may be more interested in careers in research. Teachers who enjoy and appreciate scientific research may be more motivated to do inquiry science with their students. If this hypothesized connection between interest and action is accurate, a key to effective science education may be to ensure that those who teach science have experiences that make them interested in research (p.86).

One of the most cited benefits of research partnerships for teachers is that these arrangements create opportunities for testing new practices and for professional development of educators, especially that of educators with little or no first-hand experience in scientific inquiry (Avery et al., 2003). Through practice with scientists, teachers' develop more confidence and become better skilled at 'doing' open-ended inquiry, which increases the likelihood that they will implement inquiry-based activities in their classrooms (Buck 2003; Jarret and Burnley, 2003). Fuzne Koszo (2006) found that teachers in their program had very little experience implementing lessons in the field (outdoors). Such experiences, however, are opportunities for teachers to try new methods and take risks (Huntoon et al., 2001; Trautmann and MaKinster, 2005). They provide teachers with access to current research and creative options for addressing aspects of their curriculum in a very real context (Duchovany & Joyce, 2000). They also provide opportunities for mentoring relationships and friendships to develop between teachers and scientists, resulting in what Trautmann and Makinster (2005) call a 'supportive learning community' between these two professions.

It is important to note that in many situations, while working next to scientists, teachers are both educators and learners. They report many of the same benefits identified for students in the previous section such as increased content knowledge (Buck, 2003; Reynolds, 2004), increased interest in research (Jarret & Burnley, 2003), and increased confidence in 'doing' science inquiry (Avery et al., 2003; Jarret and Burnley, 2003; Buck, 2003; Huntoon et al., 2001; Trautmann & MaKinster, 2005).

2.3.2.3 Benefits to scientists

Outreach potentials of programs can only be achieved if partnerships are evaluated from both pedagogical and scientific perspectives (Harnik & Ross, 2003). Creating win-win situations ensures that scientists are also benefiting from the relationship. Tanner (2000) describes some benefits experienced by scientists in a study where faculty, graduate students and postdoctoral research fellows were interviewed to determine the benefits they obtained from their collaborations with K-12 students and teachers. Tanner found that the benefits were diverse but could be categorized into 3 classes:

1. Benefits to them as scientists:
   - Their enthusiasm for science was rekindled by working with youth.
   - Their interactions with students made them think of their own science more broadly.
2. Benefits to them as educators:
   - They developed the ability to explain science in simpler terms.
   - They developed a new appreciation for the challenges that teachers face and felt the experience improved their skills for teaching.
3. Benefits to them as individuals:
   - They experienced personal satisfaction from working with youth.
   - They appreciated the opportunity to think outside of their own research specialty.

These findings concur with similar findings by Barab and Hay (2001) and Kurdziel and Libarkin (2002). Benefits directly related to scientists' research include assistance in data collection and data analysis (Buck, 2003; Duchovany & Joyce, 2000), and given proper protocols, assistance in generating high quality data (Shellito, et al., 2001). Additional findings from Trautmann and MaKinster (2005) elaborate on the relationships that develop and the learning that occurs from working with teachers and educators. Partnerships create an environment where scientists learn pedagogical knowledge and skills such as, planning curriculum, age appropriate lesson planning, student assessment and curricular links to research. In this shared process of teaching and learning, friendships often emerge.

2.3.2.4 Benefits to society

According to Duchovany and Joyce, (2000), "doing science" or conducting actual research along side researchers is one of the best ways to achieve scientific literacy. The benefits of scientific outreach are becoming evident not only to scientists and educators but also to research granting agencies who share the goal of increasing scientific literacy in society, and who recognize the 'civic' responsibility of scientists to share their knowledge and expertise. National research funding agencies in Canada, the USA, the United Kingdom, and Australia, all endorse scientific outreach (ARC; NSERC; NSF; RCUK) and strongly encourage scientists to become more engaged with the public. In Canada, the Natural Sciences and Engineering Research Council (NSERC) has created funding programs specifically aimed at promoting scientific literacy. These include the PromoScience and CRYSTAL (Centres for Research on Youth, Science Teaching, and Learning) programs (NSERC, 2007).

Communicating science to the public has the obvious benefit of raising awareness of science and research. Increasing environmental, ecological and scientific literacy has far-reaching societal benefits that are consistent with the goals of both environmental education and science education as previously discussed.

2.3.3 Relevance to this study

The SonB program is an outreach program that integrates the needs of scientists, teachers, and students, to create meaningful authentic research experiences that link environmental science education to scientific research. Planning experiences that are mutually meaningful for schools (students and teachers) and scientists increases the likelihood that the SonB program will meet or exceed its goals. Examining the literature for examples of similar scientific outreach programs contributes to a greater understanding of how these authentic experiences are delivered and assessed by others.

This review of literature demonstrates that authentic research experiences and research partnerships are good vehicles for linking environmental science education to scientific research, and that carefully designed programs can have impacts on individuals (students, teachers, and scientists) and the public's attitudes and perceptions toward science and the environment (Kurdziel & Libarkin, 2002).

2.4 Discussion

The literature reviewed for this chapter provides background and context for this research and provides clues to where the study fits in the growing body of literature related to scientific outreach and research partnerships.

The 'program planning' field has much to offer in terms of theory and practice to those interested in designing quality environmental science education programs. These programs range from commercial enterprises such as ecotourism to scientific outreach programs and research partnerships between scientists and educators. Regardless of the program, planners will have to consider the various interests of its stakeholders.

Program providers and scientists interested in developing programs with schools need to work collaboratively with teachers and school administrators to become familiar with the realities of working in these environments (i.e., curriculum demands, teacher workloads, and the like) and to ensure that programs are developed to meet the needs of teachers and students, not just the needs of the program (McKeown, 2003). The following is a quote from a school administrator interviewed in McKeown (2003).

> In all my years as a principal and superintendent, not one person came to me and asked what I needed help with. Most groups approached us with a solution to a problem we did not have. Few groups were willing to develop an idea with us. Most viewed us as a cheap delivery system for their package, message, and solution (p. 874).

Fennell (2002) insists that practitioners (program planners) must be motivated to explore the rich theoretical offerings of other disciplines in order to be more knowledgeable and better prepared to address the many challenges of providing quality programs that meet the needs of all stakeholders. This literature review has been an attempt to do just that. In order for the SonB program to improve, a theoretical understanding of science education, environmental education, and scientific outreach programs was necessary.

In addition to providing context, the literature reviewed in this chapter contributes to the research as a primary source of data for this study. The next chapter describes how a separate database was created from this literature, and used as one of the multiple sources of data for the case study in Chapter Four. This database was also analyzed to identify the three criteria for environmental science education programs that were used to evaluate the SonB program in Chapter Five.

CHAPTER THREE – METHODOLOGY AND METHODS

Research in environmental education has undergone changes in orientation as well as paradigm shifts that are summarized by Robottom (2005) as periods of 'norming', 'storming', and 'performing' in research. Borrowed from Tuckman's (1965) model on group dynamics, these terms refer to stages of cohesion, conflict, and "role relatedness" in the development of functional groups. Robottom (2005) applies 'norming' to the period of the 1970s and early 1980s when research in EE was most visible in studies of applied science in nature and closely aligned with applied science approaches to research. In the late 1980s and early 1990s, researchers in EE started challenging established research practices. This 'storming' period was marked by intense debate of EE research and critical reflection of assumptions and practices, which resulted in a range of new approaches to research and growing support for qualitative inquiry. This set the stage in the 2000's for a shift to a performing period in research that encourages reflective research on practice, such as action research.

Evidence of this evolution can be found in the growing number of research papers presented at national and international EE conferences, and the similar growth in the number of refereed academic journals focused on EE research (The Journal of Environmental Education; Australian Journal of Environmental Education; Environmental Education Research; Canadian Journal of Environmental Education*)*. One of the historical trends identified by Palmer (1998b) has been the increasing emphasis on linking empirical research to the improvement of practice.

This study is part of the trend to improve practice through research. It is situated within the qualitative research paradigm and follows an action research sequence (Figure 3.1) presented by Stringer (2004). This design demonstrates the systematic nature of an action research approach to inquiry. The distinguishing feature of an action research study is the action phase that aims for immediate practical results informed by the research. This phase is illustrated in the last column of Figure 3.1.

Figure 3.1 Schools on Board case study design (adapted from Stringer, 2004).

DESIGN RESEARCH	**GATHER DATA**	**ANALYZE DATA**	**COMMUNICATE**	**ACT**
Initiate the case study	Capture stakeholder experiences & perspectives	Identify key features	Writing thesis	Make plans
Scope & focus	Observations	Categorize and code data	Reports	Make changes
Literature review	Documents print & electronic archives	Identify emergent themes	Conferences	Improve practices
Sources of data	Literature review	Identify relationships	Presentations	
Ethics		Make inferences & conclusions	Journals	
Validity				

The linear direction of the arrow emphasizes the importance of the action phase in this research design. It is important to note that typical of an action research project, new understandings and actions produced through this process have the potential for feeding back into an ongoing cyclical and dynamic process of reflective practice and program improvement. The purpose of this study is to systematically document and evaluate the 2004 SonB pilot program using a case study approach (Patton 1990; Yin, 2003) within this research design.

3.1 Rationale for using a case study design

Case studies have been identified by leaders in qualitative research methods, (Denzin & Lincoln, 2005; Patton, 1990; Stake, 2005; Yin, 2003) as effective tools for evaluating and improving practices through action research studies. According to Yin, the case study is a preferred research strategy when dealing with "how" or "why" questions. These types of questions are at the heart of this study: How/Why is the program working from both a theoretical perspective (based on educational research) and a practical perspective (based on sound program planning principles)?

Schön (1987) recommends the case study as an effective tool for reflective research of one's own practice. This examination of the 2004 field program from a practitioner's perspective considers reflections 'in' and 'on' the program's early stages of development, subsequent implementation, and evaluation. Critical reflection is considered an important objective and outcome of this study.

More over, a review of research in environmental education revealed a growing number of case studies and support for this method of communicating information on program designs, approaches to implementation, and impacts on participants. A recent publication of fourteen case studies on environmental education programs supports the case study approach as a means to study and share good practices (Kyburz-Graber, 2006).

3.2 Case study design

The 2004 SonB field program was a pilot study to determine how best to integrate high school students and teachers into an active Arctic research program. The 2004 pilot program was purposefully selected for its known characteristics and successes. This is a holistic case study involving a single unit of analysis, which is identified as the 2004 field program. The rationale for using a single case study (the 2004 field program) rather than a multiple case study of two or more past field programs (2004-2008) lies primarily with the intended purpose of the study, but also takes into account a concern about the size and scope of the study, and the lack of resources to complete such an in-depth examination. It was important to document the pilot program in a systematic and detailed manner focusing on how this particular program was conceived, designed, planned and implemented. Subsequent field programs using the same program model have generated similar feedback from participants year after year. Thus greater interest was in the need to document the 2004 planning process and gain a better understanding of why this program design continues to generate successful experiences and determine how the SonB program can be improved.

To be consistent with Yin's (2003) documented case study design suggesting that theoretical propositions provide clearer links between the objectives and the data, guide data collection, and facilitate interpretation of the findings, the following propositions were developed:

Proposition #1: There is enough common ground between EE and SE to develop criteria or guidelines for environmental science education programs that will assist the development and evaluation of the SonB program to ensure that it is based on current theories of learning and current pedagogical approaches.

Proposition #2: A systematic examination of the SonB program (design, planning and implementation stages) will reveal the key decisions that contributed to the program's success in the 2004 pilot year (and all subsequent years), and will contribute to future program development and ongoing evaluation of the program.

3.3 Research Objectives

As previously stated in the introduction, the objectives of this study are to:

1. Review the literature on environmental education, science education, and scientific outreach to gain a better understanding of the criteria for quality environmental science education programs (linked to Proposition #1).
2. Apply these criteria to the SonB program to evaluate the program from a pedagogical perspective and ensure future program planning that is consistent with current educational research (linked to Proposition #1).
3. Examine stakeholder inputs and the planning process of the 2004 field program to build a detailed case study of the program and determine the key decisions taken during its design and implementation (linked to Proposition #2).
4. Identify recommendations for effective planning based on findings in the literature, documents, and experiences of the participants and program leader (linked to Proposition #2).
5. Identify an action plan for program improvements and future work (linked to Propositions #1 and #2).

3.4 Data collection

3.4.1 Sources

This study follows Yin's (2003) three principles of data collection for case study research: 1) use of multiple data sources, 2) creation of a case study database, and 3) maintenance of a chain of evidence. One of the benefits of a case study approach is the admissibility of numerous sources of data. Although cumbersome to manage, multiple sources result in a rich description of the case, and ensure that the claims made in the research are not those of a single person (the researcher).

The three sources of data for this case study include:

1. Participant-researcher observations and critical reflections based on experiences in all stages of program design, program planning, and program implementation. These observations and reflections also include responses to findings in the literature.
2. Secondary sources of data including program documents, curriculum documents, field notes, newspaper clippings, conference papers, testimonials, grant applications, reports, 2004 program evaluations (completed by participants, schools and scientists), electronic materials such as websites and expedition logbooks, and all emails sent and received from 2002-2006 that are relevant to the 2004 field program.
3. Reviewed literature on environmental education, science education, and scientific outreach.

An Excel file, described in the next section, was created to collect, organize and manage the large amount of data generated for this study. A 'chain of evidence' in

Appendix B outlines how each of the data sources addressed the fundamental questions of this study: 1) How did the program work? 2) Why did it work? And 3) How can the program be improved?

3.4.2 Perspectives

As participant-researcher in this study, I am centrally located in this research, providing observations, reflections and interpretations from a personal and professional perspective. The multiple sources of data required for a case study, ensures that more than one perspective is included in this study. The table below demonstrates the diversity of perspectives sought through various sources of data.

Table 3.1 *Perspectives represented through multiple sources of data.*

Perspective	Sources of data
Program coordinator/researcher	Observations – log/planning book Field notes Personal experiences and reflections Critical reflections on literature SonB files and documents (files, reports, manuals) Schools on Board website Media interviews Email correspondence – 2002-2006 Executive summary and Final report
Participating teachers and students	Program evaluations – recommendations (Appendix K) & testimonials (Appendix L) Emails Expedition Logbook Outputs – presentations; lesson plans

	School evaluations Website – success stories
Participating scientists	Email correspondence Expedition logbook Scientist evaluations Science meetings
Participating schools	School evaluations – recommendations and testimonials Email correspondence
Funding partners CASES/ArcticNet CEOS DFO NSERC	Outreach award – UofM Reports Letters of support & testimonials CASES & ArcticNet Science meetings Congratulatory emails re: awards CASES website and expedition reports ArcticNet newsletter Grant proposals
Advisory committee	Electronic – email interactions; meeting notes 2004 Field Program – itinerary; handbook; handout; brochure
Canadian Coast Guard Service	Letters of support Letter/certificate to schools Liability issues – waivers DFO Familiarization Guide
Theoretical perspectives Environmental educator Science educators Other outreach providers	Literature reviewed – all cited literature Curriculum documents and websites Electronic - websites

All of the perspectives included in this table represent the stakeholders of the Schools on Board program – the program coordinator, teachers, students, schools, scientists, funding agencies, and program partners.

3.4.3 Collection Process

A letter of permission was received from ArcticNet to access all files, including participant evaluations (see Appendix C for letter of permission from ArcticNet). Ethics approval was not necessary for this thesis, as all participant input was done through secondary sources and anonymity and confidentiality were maintained.

Initially, colour-coded index cards were used to collect data from both the SonB program and the literature. The reviewed literature was managed using a computer program called EndNote 9.0. The colours of the cards corresponded to the four main categories – Environmental Education (EE), Science Education (SE), Schools on Board (SonB), and Scientific Outreach (SO). Documents and the reviewed literature were analysed, and content related to the study's objectives and propositions was added to a growing database. The coloured cards made it easier to visually identify structure and relationships as data was being collected.

As the database grew and themes emerged, the index cards were replaced with a number-coding system and managed within an Excel spreadsheet. The database was organized around the following column headings: row, data type, category, finding, theme, source, already doing, to consider. The options for data type include: literature, documents, electronic, emails, observations, and reflections. Table 3.2 shows the different headings and codes used during initial data collection. Data types and categories remained unchanged. The numbering system for themes evolved as subthemes emerged during data collection and data analysis.

Table 3.2 *Headings and codes used for data collection*

Row	Data type	Category	Finding	Theme	Source	Doing	To Do
	Literature	EE		100's	Detailed		
	Documents	SE		200's			
	Electronic	SO		300's			
	Emails	PP		400's			
	Observations	SonB		500's			
	Reflections						

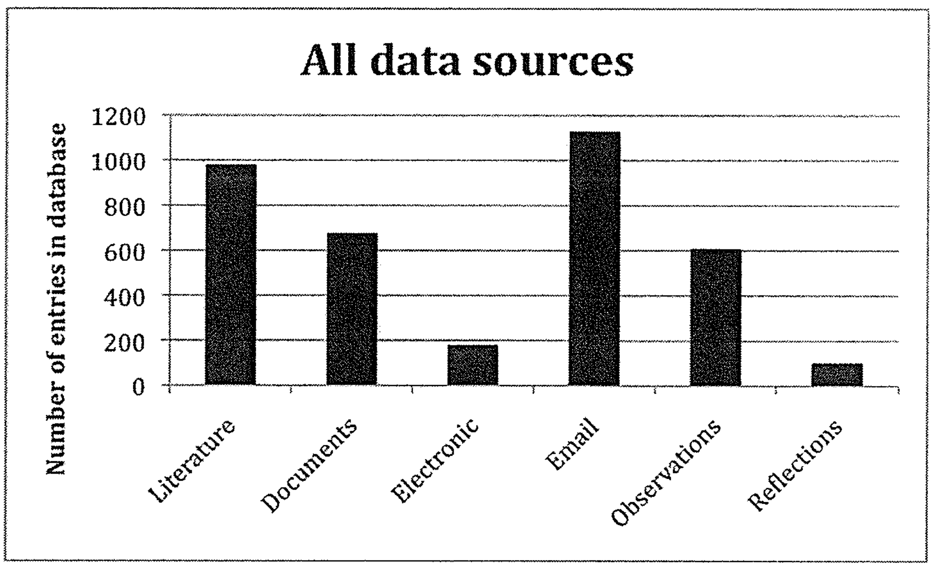
Although time consuming, including all of these headings allowed for ongoing and random data entry and created many options for sorting data during analysis and interpretation (i.e., sorting by type, by category, by theme, by items already doing, or by items to consider (recommendations). Table 3.3 is a sample of data entries taken from the database.

Table 3.3 *Sample of data entries taken from database*

Row	Data	Cat.	Finding	Theme	Source	Doing	To Do
4	Lit	EE	Curricula should be age and maturity sensitive	100	Sobel, 1996	*	*
131	Lit	SE	Goals of science course - broken into content goals and skills goals	102	Martin & Howell, 2001		*
109	Obs	SonB	Need a presentation for orientation day of field program that describes and discusses 'nature of science'	210	LB researcher)	*	

Each of the findings was assessed with regards to its relevance to the program. Ongoing reflection during data collection considered each finding as an item we were already doing, or one that we should consider, as indicated by an * in one of the two last columns in Table 3.3. This Excel spreadsheet became a tool for organizing and managing the large amount of data that was generated. An ongoing process of data collection generated 3672 lines of data that breaks down into 2516 entries from SonB data sources, and 1156 entries from literature and electronic sources (combined). Figure 3.2 shows the distribution of the data sources by data type.

Figure 3.2 Distribution of data sources.



'Literature' refers to reviewed literature in EE, SE, and SO. 'Documents' include all program documents, field notes, newspaper clippings, conference papers and posters, reports, grant applications and program evaluations. 'Electronic' sources refer to data retrieved from the Internet, such as information on curriculum documents and other programs. 'Emails' included all emails received and sent from 2003 to 2006 that were relevant to the 2004 field program. This became a major source of SonB data, providing an important trail to early communications related to the program, dating back to 2003.

Other tools for collecting data included note taking and an ongoing logbook of ideas, meetings, presentations, discussions, and thoughts related to the thesis, as well as documenting emerging themes and relationships from the data.

3.5 Analysis and Interpretation

Data analysis and interpretation involved a process of qualitative content analysis (Miles and Huberman, 1994). The conclusions drawn in the latter stages of analysis involved a process of triangulation (Patton, 1990) described in section 3.5.2 and 3.5.3.

3.5.1 Qualitative content analysis

Qualitative content analysis, as defined by Miles and Huberman (1994), involves the following systematic procedure that guided this study:

Step 1: Arranging data for qualitative content analysis.

Step 2: Deciding the unit of analysis.

- The single unit of analysis for the case study was the 2004 SonB field program.
- The units of analysis for the literature were EE, SE, and SO, as defined in the introduction.

Step 3: Moving from unit of analysis to categories.

- Identifying categories within the data was an ongoing process.
- A coding scheme was adjusted to adapt to emerging themes in the data. As themes emerged, colour index cards were replaced with a number coding scheme.
- An Excel spreadsheet was used to organize data.

- Step 4: Identifying emergent themes
    - Initial themes emerging from the data on EE and SE included content (education about), setting (education in), and context (educating for).
    - Initial themes emerging from the data on SO and research partnerships included rationale, considerations for program planning, and implementation, impacts on students, impacts on teachers, impacts on scientists, and impacts on society.
    - Initial themes emerging from SonB materials included content, setting, rationale, program planning consideration, program implementation consideration, program processes such as social interactions, group dynamics, reflection, happenstance, outreach, and impacts.

Step 5: Code data

- Major reoccurring themes within the database were assigned numerical sub-codes. The table in Appendix D describes the numbering system used to code the data in response to emerging themes during the data collection process. In the initial stages of data collection, sub-codes were added as themes emerged.
- Early classification for EE was influenced by literature related to environmental literacy (ABOUT, IN and FOR).
- Early classification of SE data was influenced by literature related to scientific literacy (content, scientific inquiry, technological problem-solving, learning by expert, and decision-making).
- Early classification of SO data was based on literature related to other scientific outreach programs that focused on research partnerships, field-based

programs, and authentic science experiences. Themes in this category included rationale for outreach and benefits to students, teachers, scientists and society. These themes remained consistent throughout the study.

- Data related to program planning and implementation was found in all categories (EE, SE, SO, and SonB).

Step 6: Recheck consistency of coding data

- Working back and forth between the data and the classification system to verify the meaningfulness and accuracy of the categories and placement of the data, resulted in the re-classification of the data (see tables in Appendix E/F).
- During this re-classification, the database was sorted by data type to create two separate datasets: 1) a literature dataset including all entries coded 'Literature' or 'Electronic' under the 'data type' column and 2) a SonB dataset including all entries coded as: 'Documents', 'Emails', 'Observations', or 'Reflections'.
- The numbering system used to code categories in the literature dataset used units and the SonB dataset used the order of 'tens' to identify subcodes (e.g. 101, 102, 103 in the literature dataset correspond to 110, 120, 130 in SonB dataset). This numbering system extended the sorting options and made it possible to later compare the data collected for the SonB program to the criteria derived from the data in the literature database (see figure 3.3. on the following page).

Figure 3.3 Initial and re-classification of data leading to recoding based on converging themes. The re-classification process led to the creation of two datasets from the main database.

Re-classification

Theme	Description	Sub	Description of emerging themes
100's	Environmental Education	101	EE – about (physical; cultural, socio-political)
		102	EE – in (physical; research culture)
		103	EE for (decision making; action)
200's	Science Education	201	SE – about (general; scientific inquiry; technology; TEK)
		202	SE – in (research culture; learning by expert)
		203	SE – decision making; reflection; action
300's	Scientific Outreach	300	SO – general – rational
		301	SO – impacts – students
		302	SO – impacts – teachers
		303	SO – impacts – scientists
		304	SO – impacts – society
		305	SO – other programs
400's	Program Planning	400	Planning consideration
		401	Ecosystem thinking
		402	Implementation consideration
		403	Evaluation
		404	Strategies to maximize impacts

Literature Dataset
1156 entries

Initial classification

Theme	Description	Sub-code	Description of emerging themes
100's	Environmental Education	100	EE – about (physical)
		102	EE – about (cultural)
		103	EE – in (physical)
		104	EE – for (decision making)
		105	EE – (for) action
		106	EE – in (research culture)
200's	Science Education	200	SE – general
		201	SE – scientific inquiry
		202	SE – technological problem-solving
		203	SE – decision making
		204	SE – traditional knowledge
		205	SE - learning by expert
300's	Scientific Outreach	300	SO – general – rational
		301	SO – impacts – students
		302	SO – impacts – teachers
		303	SO – impacts – scientists
		304	SO – impacts – society
		305	SO – other programs
400's	Program Planning	400	Planning consideration
		401	Ecosystem thinking
		402	Implementation consideration
		403	Evaluation
		404	Strategies to maximize impacts
500's	Program processes	500	Knowledge construction – reflection
		501	Instructional strategies
		502	Experiential
		503	Group dynamics

Re-classification

Theme	Categories	Sub	Description of emerging themes
100's	Environmental Education	110	SonB – content – About
		120	SonB – In
		130	SonB – For
200's	Science Education	210	SonB – content – About
		220	SonB –design – In
		230	SonB – For
300's	Scientific Outreach	300	SonB – rational
		310	SonB – impacts – students
		320	SonB – impacts – teachers
		330	SonB – impacts – scientists
		340	SonB - outreach
*400's	Program Planning		
	410 – Stakeholders – input; needs and resources		
	410 – Network		
	410 – Operations - administration		
	410 – Funding		
	410 - Public Relations		
	410 – Risk management		
	410 - Communication		
	410 – Program design – goals, objectives, rationale, key features		
	410 – Program structure – specific to field program		
	410 – Logistics – selection; criteria; travel; social & cultural components		
	410 – Program processes – reflection; group dynamics; experiential; informal interactions; social processes; happenstance		
	410 – Evaluation - process		
	410 – Ecosystems planning		

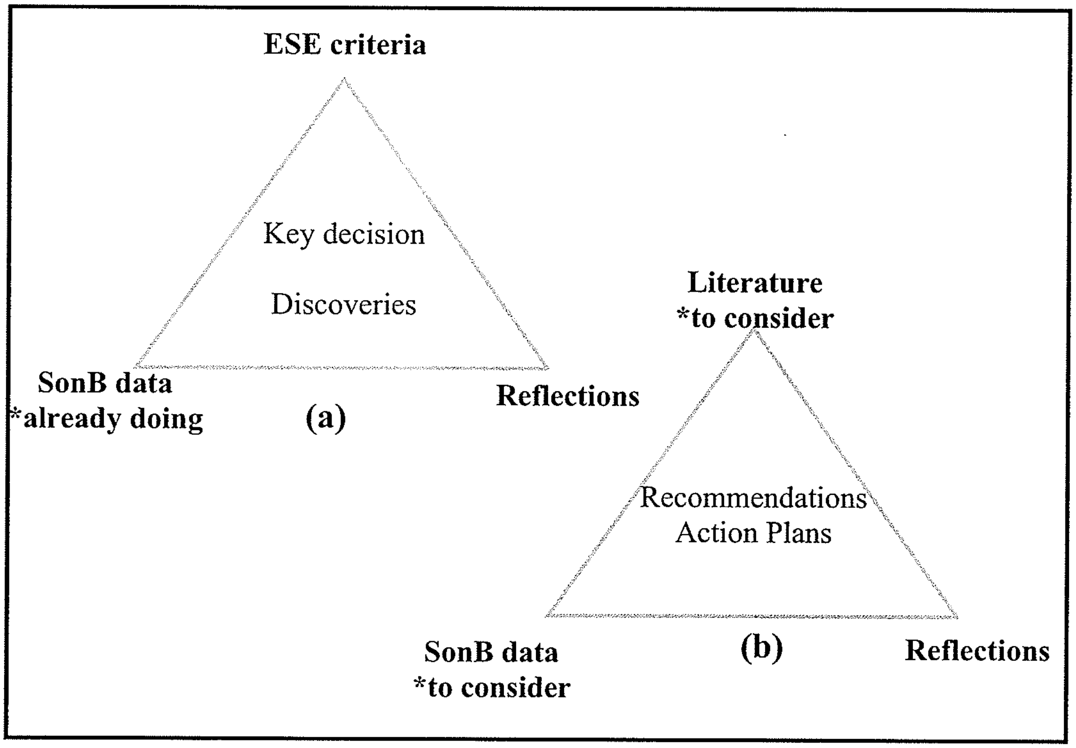
SonB Dataset
2516 entries

Step 7: Drawing conclusions from the coded data. This is a process of making sense of the generated categories, making inferences and exploring dimensions of categories, identifying relationships between categories, uncovering patterns and themes

- The sorting and filtering capabilities of the Excel program assisted in identifying convergence between the SonB data and the literature. It also provided a mechanism to see emerging patterns and relationships between EE, SE, SO, and SonB.
- The spreadsheet provided the option to sort by data and theme within each category (EE, SE, SO, and SonB) and facilitated the re-coding of themes during the collection process.
- Triangulation of the SonB data, described in Figure 3.5 (p.71) strengthens the interpretation of the themes and information used to describe the SonB program presented in Chapter Four.
- The interpretation of themes that emerged in the planning category (410's) of the SonB dataset was influenced by the professional experiences of the researcher/practitioner. The planning themes were useful in providing structure to the case description. The headings in Chapter Four correspond with the themes found in this dataset.
- Triangulation of the literature data, in Figure 3.6 (p.72), strengthened the inductive interpretation of patterns and relationships used to determine the criteria for a quality environmental science education program.

- Key decisions and discoveries about the SonB program were interpreted by comparing the two datasets. The 'already doing' and 'to consider' columns of the datasets provided the option to evaluate the SonB program on an ongoing basis throughout the data collection process. Each data entry was considered to be an item that was already present in the program ('already doing'), something to be considered for future development ('to consider') or important but not relevant to this particular program ('dismiss'). Each entry was marked with a * in the appropriate column.
- The results of this ongoing reflection during the process of data collection are revealed in the findings (key decision, evaluation, discoveries, recommendations, and action plan) in Chapter Five.
- Figure 3.4 (a) on the following page shows how the criteria from the literature, the 'already doing' entries in the SonB dataset, and reflections resulted in an evaluation of the program determining to what extent it met the criteria, key decisions that were made during the all stages of program planning, and discoveries about the program not previously noted.
- Figure 3.4 (b) shows how the 'to consider' items of the literature, the 'to consider' items of the SonB data, and reflection resulted in determining a set of recommendations and an action plan for program improvements.
- SonB data sorted by 'already doing' column include data from program evaluations submitted by participants, teachers, schools, and scientists.
- All conclusions were reached using an inductive approach to analysis, and are therefore shaped by assumptions and experiences of the researcher.

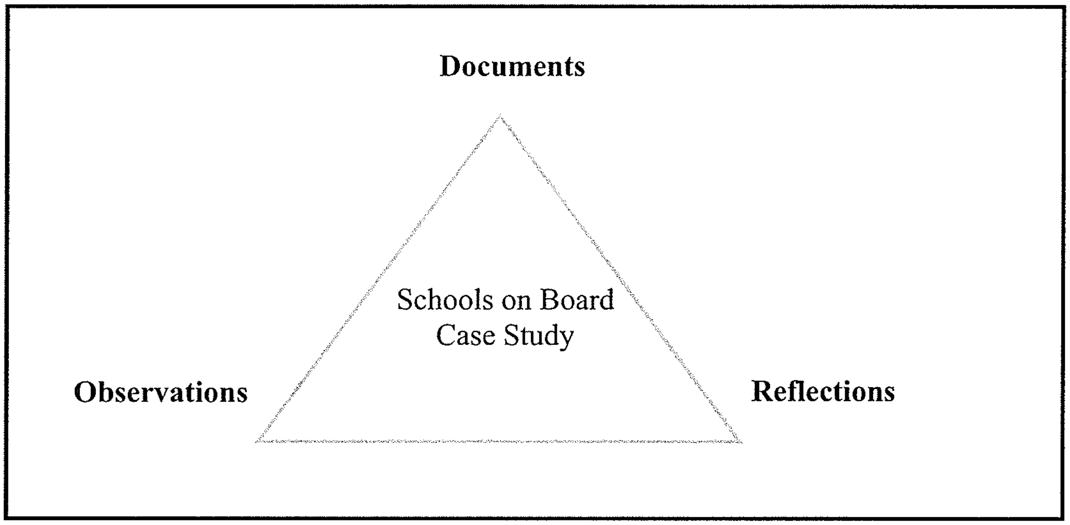
Figure 3.4 Triangulation of all data sources and findings from the literature for program evaluation using a) ESE criteria and SonB data to identify key planning decisions and discoveries about the program, and b) using literature and SonB datasets to produce recommendations and an action plan.



3.5.2 Triangulation

The triangulation process described above, calls for using multiple data sources to confirm the interpretation of findings. Patton (1990) suggests that triangulation can be done using multiple sources of data (triangulation of data) and by looking at multiple perspectives (triangulation of theory). Figure 3.5 identifies the three main types of data used in this study to generate the SonB dataset, construct the case description of the 2004 field program presented in Chapter Four, and evaluate the program for Chapter Five.

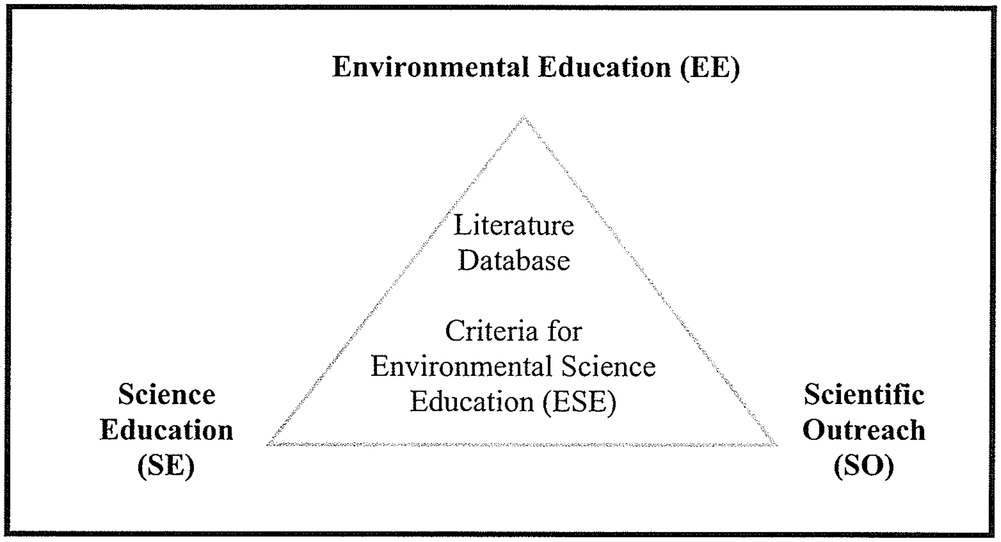
Figure 3.5 Triangulation of data for Schools on Board case study.



In this figure, 'documents, refer to all program documents (handbooks, program itineraries, files), emails, field notes, testimonials, and program evaluations; "observations' are those of the program coordinator (researcher) that occurred in the field and noted in files, field notes and final reports, as well as observation based on recollections of specific events, occurrences and interactions related to the 2004 field program; and 'reflections' are those of the program coordinator (researcher) used to re-trace steps and re-call experiences related to the timelines of the 2004 field program (2003-2006).

Triangulation of theory was achieved by comparing theoretical findings from the reviewed literature of three interconnected fields of study. Figure 3.6 is a schematic representation of the three theoretical perspectives that contributed to the literature database and the identification of criteria for a quality environmental science education program presented in Chapter Five.

Figure 3.6 Triangulation of theory for the Schools on Board case study



The three interconnected fields of study shown in this figure represent the perspectives of educators, educational researchers, and practitioners of environmental education (EE), science education (SE) and scientific outreach (SO).

Step 8: Reporting.

- The final step in this procedure is the communication of findings. This is achieved through the completion of the thesis and its distribution to the major program partners of this program (ArcticNet, Centre for Earth Observation Sciences, University of Manitoba).
- Chapter Four is the documentation and case description of the 2004 Schools on Board program.
- Chapter Five includes the findings related to program evaluation.
- Consistent with the design of action research, Chapter Six takes this step further to present an action plan for implementing change and making program improvements, as well as identifying 'future work' and other

opportunities to share the results of this study with all program stakeholders and other practitioners.

3.6 Parameters and Limitations

Although the SonB program has three components and is not limited to activities with schools, this study focused on the 2004 field program with an emphasis on links to formal education. Information on the other components of the program were included in the description of the case in Chapter Four, but these components were not systematically evaluated within the context of this study.

This research is a single case study of the 2004 pilot field program. It examines the period from the summer of 2002 to the end of 2004. This timeframe includes all planning stages of the program – design, promotion, implementation, evaluation, reporting. Email correspondence relevant to the field program continued into 2006. These were included in the SonB dataset due to their relevance to understanding the long-term impacts of the 2004 field program and its contribution to future programs. I recognize the limitations of going back in time and including data based on recollection and memory. I have since conducted subsequent SonB field programs and acknowledge that these experiences and knowledge bias my examination of the 2004 pilot program and interpretations of the data and findings. I locate myself at the centre of the research. In this study I am the participant researcher. The program is the unit of analysis and I designed and implemented the program. This subjectivity is a fact not a flaw. By design, it is an inherent part of the research. I designed the program and am currently the Program Coordinator. Much of the detail related to the early stages of planning is not known to anyone other than myself. This firsthand information is a direct result of my position in the program.

The literature review on environmental education, science education, scientific outreach and program planning is not comprehensive. A comprehensive review is beyond the scope of this study. My purpose was to identify the common threads that link environmental science education and scientific outreach. My analysis of the literature is based on my own perceptions (value judgment & prior experiences) and frame of reference as an informal educator, not a formally trained teacher. My interpretations are influenced by my experiences as a program planner, scientific outreach coordinator, and program leader.

I identify the contextual limitations of a single case when it comes to transferability of findings, which, in this case, may be limited to scientific outreach programs that utilize field experiences to meet their goals and objectives. The data collection and research design described in this chapter have attempted to address these limitations.

3.6 Issues of Validity

The bias of the researcher and the limitations explicitly and fully described in the previous section are important factors affecting the validity of this study. Triangulation of multiple sources of data was employed as a tactic to prevent a one-sided interpretation of the data, and a modified protocol for data collection and data analysis was used to address credibility and confirm-ability of results. In addition, key informants reviewed a draft of this thesis and concurred with interpretations and conclusions relevant to their experiences with the program.

Lincoln and Guba (1985) propose four criteria to evaluate validity in qualitative research studies. These include credibility, transferability, dependability, and confirm-ability. The following table illustrates measures taken at different phases of this research, to address each of these criteria.

Table 3.4 *Steps taken to address criteria for validity.*

CRITERIA FOR VALIDITY	TACTIC USED TO ADDRESS VALIDITY	PHASE OF RESEARCH
Confirm-ability	Use of multiple sources of data	Data collection
	Establish a chain of evidence	Composition/reporting
	Record of sources	
	Maintain a database	Data analysis & interpretation
	Triangulation	
Credibility	Multiple perspectives	Data collection
	Stakeholder input & testimonials	
	Triangulation	Data analysis & interpretation
	Key informants review draft	Reporting
Transferability	Detailed descriptions of the case.	Research design
	Contextual nature of the study is clearly defined.	
	Applicability of findings is left with the reader to determine.	Reporting
Dependability	Use case study protocol	Research design
	Develop case study data base	Data collection
	Chain of evidence	Data collection & analysis

In addition to the criteria indentified in the table above, Schön, (1987) claims that for reflective projects aimed at making practice useful and relevant, such as this action research study, validity (truth) is not enough. He suggests that these studies must be concerned with, both validity and utility. The test for utility is the extent to which findings focus on recommendations rather than contributions to a body of knowledge. The following three chapters reveal the utility of this study to the practitioner (researcher), the host organization and all of the program's major stakeholders.

CHAPTER FOUR – CASE STUDY

This chapter provides a detailed description of the 2004 field program based on the data collected, analyzed and interpreted. The following case description was built from data sorted in the SonB dataset. As previously described, data were classified and sorted by themes that related specifically to program planning, program design and program implementation (400's). Emerging sub-themes were consistent with basic textbook program planning principles (Edington, Hanson, Edington & Hudson, 1998; Fennell, 2002) and included categories consistent with Fennell's (2002) steps on ecotourism planning emphasizing field preparations and risk management. These themes helped to structure the case study and organize findings into the following sections.

4.1 Background & rationale

Schools on Board (SonB) was launched in 2002 in response to the need to provide the public with information on the scientific research conducted by the scientists associated with the Canadian Arctic Shelf Exchange Study (CASES) and a desire to create unique educational experiences for high school students and teachers. SonB was initiated using a ten thousand dollar grant received from Fisheries and Oceans Canada. This seed funding was used to develop a program that would be piloted in the 2003-2004 school year. The program was presented to the CASES scientists at a planning meeting in Montreal, January 2003 and received strong support to move forward with the planning, promotion, and delivery of the program. Twelve berths were granted onboard Leg 5 of the CASES science expedition (www.cases.quebec-ocean.ulaval.ca), and on February 25th, 2004, the first SonB participants boarded the *Canadian Coast Guard Ship*

(CCGS), Amundsen, while it was frozen in the sea ice in Franklin Bay, in the Western Canadian High Arctic.

The success of the pilot program resulted in SonB becoming an important means of connecting the ArcticNet science program (www.arcticnet.ulaval.ca) and the IPY-Circumpolar Flaw Lead (IPY-CFL) system study (www.ipy-cfl.ca) to schools across Canada and abroad. The 2004 field program continues to guide program design and implementation today. This chapter describes in detail, the SonB program, the planning process used to develop and implement the first field program in 2004, and an evaluation to determine if the program goals were achieved.

4.2 Description of Schools on Board

'Schools on Board' was created to promote Arctic marine sciences in high schools across Canada. The program targets high school students (15-18 years old) and teachers interested in science and the environment, and their extended communities. The program revolves around an experiential field program that takes students and teachers onboard the *CCGS Amundsen*, where they are integrated into the activities of the science teams conducting research in the Arctic. The field program is designed to introduce participating students and teachers to the breadth of science activities involved in Arctic research. Face-to-face interactions with scientists at all levels (Masters, PhD's, researchers, Canada Research Chairs), and access to state-of-the-art scientific instrumentations onboard the icebreaker combine to create numerous unique field experiences for teachers interested in integrating Arctic sciences in their programs, for students interested in pursuing related careers, and for scientists interested in sharing their work.

The 2004 field program proposed to take 8 high school students and 2 science teachers on board the research icebreaker during a scientific expedition. Participants would board the *CCGS Amundsen* while it was in full research mode, and they would become integrated into the life and activities of the ship. The onboard program would include lectures, fieldwork, and lab activities delivered and overseen by scientists. In addition to science, participants would be introduced to the social, political, and cultural dimensions of conducting research in the Arctic. Community visits and tours in two northern communities would provide participants with the northern perspective of climate change.

4.2.1 Goals and objectives

One of the first steps in planning this program was to identify goals and objectives. The goals of the program were identified as: 1) to increase awareness of climate change research and the environmental importance of the Canadian Arctic; and 2) to inspire the next generation of scientists, resource managers, and policy-makers. These goals led to the following objectives:

- To promote the Arctic marine sciences and climate change research in schools across Canada;
- To create unique opportunities for high school students and teachers to meet and interact with scientists in the field;
- To create opportunities for schools to develop lasting relationships with researchers and their institutions; and
- To provide teachers with tools and experiences that will facilitate the integration of Arctic sciences and climate change research into their existing programs.

Key decision: From the very beginning it was apparent that in order to meet our stated goals and objectives the program would have to be broader than a field program. Therefore, the concept plan for the program included three components: a network, a field program, and a student forum. The three components allow us to extend our outreach beyond the few students, teachers, schools, and scientists participating in the field programs.

4.2.2 Program components

1) *Schools on Board Network*: The network was created to permit identification of educators, (formal and informal), scientists, and outreach agencies interested in Arctic sciences. It was born out of necessity as an inexpensive and reliable means to disseminate information, with the intention that it would become the main means of communication for sharing information on educational materials and resources, field opportunities, and new initiatives. The network began with 10 educators from the participating schools, the advisory committee, and the estimated 200 scientists in the CASES network. In 2009, the network consisted of 165 educators, more than 400 Arctic Net, CASES, and IPY-CFL scientists, 125 agencies, 30 media representatives, 65 international contacts, and 70 SonB alumni (teachers and students who have participated in a field program or organized a youth forum).

2) *Student Forum*: A follow-up activity involving a broader audience was considered important and necessary. It was believed that a forum, focused on the SonB objectives, would benefit the program by allowing a greater number of students, teachers, schools and scientists to be involved, as it would not be limited to space and resources on the ship. Due to limited resources, particularly time and money, this component of the

program was postponed for future development, pending a successful field program. In 2006, the first Arctic Climate Change Youth Forum was successfully piloted. This component of the SonB program is now scheduled to occur every two years and in conjunction with a major science meeting or conference.

3) *Schools on Board Field Program*: The field component was identified as the central component to the SonB program. The field program would provide unique opportunities for students and teachers to join scientists in the Canadian High Arctic onboard a research icebreaker, where they would become completely integrated into life on the ship and in the research activities of the science teams. The onboard program would be planned by a coordinator, but would be delivered by participating scientists. It would include a blend of lectures, lab activities, and fieldwork in the science disciplines represented on the ship. In 2005 and 2006, SonB offered field programs in conjunction with the ArcticNet Scientific Expeditions and three international programs associated with the 2008 IPY-Circumpolar Flaw Lead system study.

Key decision: The three components of the program would be implemented in stages. Prioritizing program components allowed energy and limited resources to be focused on developing and piloting the field program in the first year. The network was seen as a work in progress that would evolve at the rate of the program, and the forum was tabled for future development.

4.2.3 Target group and scope

Once we decided 'what' we wanted to do and 'why', the next decision concerned identifying our target group. In making this decision, the following factors were considered: the geographical scope of the CASES project; the level of scientific knowledge that would be required to appreciate and anchor the experience; the remoteness of the field program; and program logistics, primarily risk management. The result was a national program, reflecting the national scope of the research team, targeting high school students and teachers from across Canada. Naming the program 'Schools on Board' was a significant decision, as it identified schools as the primary targets for the field program. Knowing that space would be limited to only 12 participants, the decision to accept applications from schools rather than individuals established the expectation that the outreach and impacts would occur at three levels: the individual, the school, and its broader community. It also established a collaborative relationship between SonB and all participating schools. This relationship of shared responsibilities and shared vested interests allowed the creation of significant experiences for the individuals selected, while maximizing the outreach potential of the program.

Key decision: Targeting schools rather than individuals established a more collaborative and supportive relationship with schools, and extended the outreach potential of the program from a single individual to the wider school population and its extended community (staff, alumni, sponsors, administrators, parents, and families). Targeting schools across Canada provided more diversity and extended the outreach on a national scale. This, however, required more flexibility to accommodate different jurisdictions, school systems, curricula, languages, and cultures.

4.3 Needs and Resources – Stakeholders

In planning a SonB program that would meet or exceed the needs of stakeholders, it was discovered that stakeholders represented a valuable pool of resources. Participants, in particular, were very resourceful and could be expected to assist the program developers in fulfilling the education, communication and outreach goals of SonB.

An advisory committee composed of an educator, two scientists, a school administrator, and two representatives from a federal research agency (Department of Fisheries and Oceans Canada) provided guidance and support. Their input was invaluable in determining needs, resources, and reasonable expectations of stakeholders. The committee met by conference call on a regular basis during the program design stage. Individual members were called upon periodically to provide input based on their area of expertise.

The following table identifies the stakeholders of the SonB program, their needs specific to the role each played, and the resources that they could bring to the program.

Table 4.1 *Inventory of Schools on Board stakeholders, needs, and resources*

STAKEHOLDERS	NEEDS	RESOURCES
PARTICIPANTS **STUDENTS** Role: learner; active participant; evaluator	Meaningful experiences Current information about climate change Situations to apply knowledge and education Contacts (professional) Social interaction Guidance & Supervision Recognition for their contributions Safe learning environments Clear communication Clear expectations Career options	Prior knowledge Communication skills Diversity in perspectives Interpersonal skills Contacts (personal) Enthusiasm Appetite for knowledge and authentic science experiences

PARTICIPANTS **TEACHERS** Role: Learner first; educator second; facilitator; supervisor; evaluator	Meaningful experiences Professional development Knowledge Experiences in science inquiry Contacts (professional) Recognition of their contribution Safe learning environment Clear communication Clear expectations	Knowledge of curriculum links Teaching strategies Understanding of knowledge acquisition Training in science education and environmental education Skills in communicating science Enthusiasm
SCHOOLS Role: Collaboration; administration; selection of participants; risk management; outreach; evaluation; facilitate school visits	Resources Meaningful experiences Capacity building - teachers Affordability Accountability Risk management Efficient time management Clear communication Clear expectations	School community Alumni Parent councils Schools boards Support for the student Support for the teacher Facilities Administrative skills
SCIENTISTS Role: Delivery of the onboard program; role model; mentor; Outreach; school visits; participation in youth forums and science fairs.	Vehicle for outreach Efficient time management Meaningful exchanges with students and teachers Meaningful partnerships with schools Flexibility to accommodate research commitments Risk management Clear communication Clear expectations Recognition for contributions	Knowledge and expertise Passion for science and research Experience in scientific inquiry Contacts (professional) Berths on the ship Research icebreaker Access to technology Partnerships with schools Outreach – access to science meetings and conferences
CANADIAN COAST GUARD SERVICE Role: Safety; risk	Communication and outreach related to the function and role of the coast guard Assurance of proper supervision	Knowledgeable crew Logistical support Create opportunities for students & teachers

management; logistics; program delivery	and preparations Accountability Risk management Forms and waivers Protocol and codes of conduct Recognition for contributions	Technological support Contacts Safety orientation High safety standards Protocol and codes of conduct Support for the field program Access to icebreaker
PARTNERS AND SPONSORS Role: Funder; supporter	Accountability Affordability Results re: impacts and outreach Proper recording and reporting Recognition	Funding Website support Gear & field support Assist with community visits in the North Networks Office & administrative support Legal services Liability insurance Credibility Outreach to new audiences Promotion
PUBLIC Role: Funder and supporter	Public education Scientifically literate citizenry Environmentally literate citizenry Exciting opportunities for youth Inspiration to pursue post-secondary education Increased awareness of climate change Staying current with global affairs and concerns	Support education and research through voting Interest through media Communication and outreach Financial support Volunteering Attending presentations Advocacy
PROGRAM COORDINATOR Role: Program planning and	Meaningful employment Support from science teams Office space Administrative support	Dedicated salaried employee for outreach Program planning skills Administration skills

implementation; communication with stakeholders; public relations; risk management; evaluation	Funding Feedback and input Professional development Success & recognition	Communication skills Networks Partnerships

The inclusion of the Program Coordinator as a stakeholder recognizes that the person designing, planning and implementing the program brings his/her own needs and resources to the planning table. The above inventory of stakeholders is developed on the assumption that each stakeholder played a role in the program, had a vested interest based on their needs, and was willing and able to contribute to the program. The Schools on Board program was created and piloted on very limited resources. This collaborative approach amongst the stakeholders was instrumental in the successful implementation of the program.

Key decision: Identifying both the needs and resources of stakeholders expanded our resource base and our ability to meet their needs and expectations. Establishing an advisory committee at the design stage of the planning process helped ensure that the program was addressing the needs of each stakeholder and that all available resources were assessed. This step was critical in creating a program that would be mutually beneficial and meaningful to participating students, teachers, schools, and scientists. Keeping the advisory committee up-to-date with program developments kept them involved and committed.

4.4 Administration

The Schools on Board program was created in the home office of the program coordinator. Administrative responsibilities required for the successful operation of the SonB program included financial, promotion and public relations, risk management, and networking.

4.4.1 Financial

It was important to distinguish between two levels of funding required for the SonB program. These were the operations of the whole program and the specific field program.

4.4.1.1 Funding operations

Operation of the SonB program included staffing, office space, office support (mailing, photocopy, email, phone), promotions (posters, brochures, web-support), travel and professional development. In 2003 the program received funding from ArcticNet. This was to ensure continuous programming into the ArcticNet project. Funding for the salary and travel expenses of the program coordinator was used to leverage support, from Centre for Earth Observation Science (CEOS) at the University of Manitoba, for office space and administrative assistance. A fully funded program coordinator and administrative support are unique features of the SonB program. This level of support from the science program and its partners demonstrated a strong commitment towards scientific outreach and was critical in leveraging support from schools and other funding agencies.

4.4.1.2 Funding for the field program

The field program was completely self-funding. All costs were estimated in a working budget to determine a registration fee that was charged to the participants. The costs did not include the stay on the ship, which was sponsored by the science program. The location and duration of the field program were determining factors in this fee. Schools agreed to collect the fee and assist participants in raising funds. For each field program a list of sponsors was generated from the School Evaluation. These sponsors were identified and recognized on the SonB website. It is important to note here, that the sponsors became stakeholders in the program and new audiences with vested interests in sharing the experiences of the participants. The fee included a 10% buffer for unexpected costs and replacement of inventory. Any surplus was re-invested in the field program. Since cost was an important consideration for schools, every effort was made to keep the fee down by securing funding and in-kind support from outside sources. The SonB program offered schools a flexible payment schedule to accommodate their needs. This schedule required that 75% of the registration fee be paid before airline tickets were booked. Once booked, there was no refund, as most of the registration fee was used to cover airfares to and from our northern destination.

The administration of funds for both operations and the field program required good recordkeeping and reporting back to stakeholders and funding agencies. As this program was the product of partnerships, reporting in-kind support was important for leveraging support and determining the true value of the program. This was especially true for the field program, as the registration fee reflected only a portion of the real costs.

Key decision: Charging a fee for the program and making the schools responsible for the registration fee secured greater commitment to the program, and ensured participants got support and assistance in fundraising. Schools were invoiced directly for the fee, and they raised the funds through a variety of methods including support from school boards, parent councils and teachers' associations, letter campaigns to alumni and sponsors, cost sharing with participants, and the like. Every letter written for support, served to inform new audiences about the SonB program and a school's involvement in this unique program.

4.4.2 Promotion & Public relations

Developing an image and logo was seen as an important first step in promoting the program to schools. A brochure with basic program information was created for distribution to schools and the general public. The national scope of our program required that this basic program information be translated in three languages (English, French, and Inuktitut). A commercial graphic artist was hired to develop the logo (Figure 4.1). This logo was added to all communication and program materials.

Figure 4.1 Schools on Board logo, designed by Hydesmith Communications.

It was important that the logo represent the research program (icebreaker and helicopter) the Arctic setting (Inukshuk, polar bear and ice) and schools (title on the ship and people on the deck). The red maple leaf and shape of the Canadian Coast Guard ship, gave the program its Canadian identity.

The main public relations tools used to promote the program included conferences and meetings (both educational and scientific), word of mouth referrals by scientists and others, and the media (interviews in print and broadcast on radio and television). The CASES website provided SonB with a home for its webpage, and CASES provided a skilled webpage designer who would create a professional looking webpage consistent with the science team's website. The SonB page was geared to school administrators, teachers, and potential sponsors, rather than students, and required a professional approach to design and content. It provided participating schools with easy access to all information related to the program and demonstrated the connection between SonB and the CASES expedition. This site became the main tool for communicating information to schools and other interested individuals.

Key decision: Specific schools were targeted to pilot the program before promoting the program to every school across the country. As such, promotion was initially limited, but was gradually stepped up to keep pace with the development of the program. Full-scale promotion did not occur until it became clear that a successful program could be sustained.

4.4.3 Risk Management

Risk management was an aspect of planning most relevant for the field program. It is included in this section as it directly affected the administration of the program and influenced the decision by schools and research institutions to participate. Risk management required seeking legal advice, keeping accurate records, dealing with issues of confidentiality, and taking preventive measures. A reality for schools and other institutions today is that most have policies regarding risk. Some institutions have risk managers who will assess the risks before granting permission to participate in programs. Steps taken by SonB to manage risks included:

- Creating an informed consent/waiver form with assistance of a lawyer;
- Complying with the safety procedures of the Canadian Coast Guard;
- Adding a section on safety in the Participant Handbook;
- Dealing only with licensed commercial operators;
- Providing a suggested packing list and Arctic gear (on loan) to ensure all participants are adequately prepared to work in Arctic conditions;
- Creating a code of conduct outlining program and behavioural expectations (signed by parents and participating students);
- Ensuring a minimum ratio of 3 students to 1 adult during fieldwork;
- Identifying activities that required third party waiver forms (i.e., dog sledding) as optional;
- Providing schools with clear criteria for student and teacher selection and charging them with the selection process to ensure proper selection of participants;
- Conducting a safety tour and practicing emergency procedures on the ship;
- Providing participants with the opportunity to opt out of any activity considered too risky;
- Identifying proper channels of communications and providing participants with more than one person to whom they could express concerns;
- Conducting exit interviews on the final day of the field program.

Exit Interviews are one-on-one, face-to-face interviews between the participant and the program coordinator or an accompanying teacher. They provide participants with a final opportunity to express any concern or describe any problem that might have occurred during their participation in the program. This precautionary measure provided the ability to identify and deal with any unexpected issue prior to the end of the program. If a problem was identified, appropriate action could then be taken, recorded, and documented. All forms were filed with other confidential documents. Accident and incident reports were also created to ensure proper recording for such unexpected events.

The school application required school administrators to accept the risks inherent in the program. It was critical to demonstrate that safety was a high priority and that risks associated with the program were manageable. The national scope of the program required a standard procedure for dealing with issues related to risk and required that all schools follow the same procedures and formalities. Operating the program through an institution like a university provided the necessary liability insurance, access to legal services, and existing policies for dealing with such matters. A feature that distinguishes the SonB program from similar programs is the extended (overnight) involvement of minors on an active research program. This involves potential risks not associated with offering the same programs to adults.

Key decision: Risk management was an important issue for schools, participants, and families. Leveraging support to operate SonB at the University of Manitoba provided institutional and legal support for managing risks. Allocating spaces to schools rather than individuals and requiring an application from the school and their acceptance of the risks inherent to the program ensured their collaboration in the management of risk. Using exit interviews was especially important since participants are minors.

4.4.4 Networking & Partnerships

Networking and building partnerships involved identifying and fostering linkages between SonB and other agencies and institutions. SonB sought out partnerships with educators, scientists, northern communities, related outreach agencies, and the media. The following table (Table 4.2) identifies each of these networks, their contributions to the program, and system linkages that provided access to other groups within each network.

Table 4.2 *Schools on Board network and partnership building.*

Networks	Contributions	System linkages
Educators	Sponsorship of participants Educational resources Communication networks Feedback and advise on developing the educational program Distribution of printed material Participants Outreach Funding	Government Departments of Education School boards/councils School administrators Science consultants Parent councils Teachers – science, environmental, geography Teachers' associations Professional Development Workshops Students
Scientists	Berths on the ship Access to national and international network of scientists Volunteers to deliver field program Referrals to schools in their area National and international	Universities Government research agencies – Fisheries & Oceans Canada; Environment Canada Websites Annual meetings and conferences National research council - NSERC

	promotion of scientific outreach at conferences Classroom visits Mentoring opportunities for students – employment, student placement Access to funding and gear	
Northern Agencies	Advise on making program culturally sensitive Advise on including traditional knowledge Communication networks to schools and communities. Logistics for community visits Access to elders and community leaders Follow up opportunities for students – employment, student placement Sponsorship of participants Funding	Agencies representing northern communities – Inuit Tapiriit Kanatami (ITK); Inuit Circumpolar Council (ICC); Inuvialuit Regional Corporation (Inuvik) Northern colleges and research centres – Aurora Research Institute Hunters and Trappers organizations Game councils Youth organizations Schools Town offices
Related Agencies Parks Canada IISD EECOM CMOS Nassivik Centre	Curriculum materials Sponsorship of participants Access to their networks Referral of schools Promotion of SonB Access to resources Collaboration on projects In-kind support Leverage funding Letters of support for grant applications Joint use agreements Recognition - Awards of	Programs officers Educational consultants Outreach coordinators Education specialists Project managers Communications officers

	Excellence Validation	

Successful networks and partnerships with educators, scientists and other agencies were those that were able to establish a mutual relationship based on shared goals. The SonB program was able to assist other agencies fulfil at least one of the following: training teachers; providing interesting and unique learning experiences; providing scientific outreach to the public; sharing traditional knowledge; promoting an interest in science and research; creating greater awareness of climate change; developing and piloting educational materials; sharing resources; creating learning opportunities for northern youth; and promoting pro-environmental attitudes and behaviours.

Key decision: Including a SonB Network as a program component in the design stage enabled the building of a network and the identification of potential partnerships that facilitated the planning and implementation stages of the program.

4.5 Field Program (2004)

A detailed description of the 2004 field program provides insights into the planning considerations and steps taken to implement the first field program. Although summarized in the program itinerary (Appendix G) included in the Participant Handbook, the program is best described by the participants themselves in their dispatches to the *CCGS* Amundsen's Expedition Logbook available at: (http://www.cases.quebec-ocean.ulaval.ca/trip/log_feb.asp).

4.5.1 Setting

The program took place in a variety of settings starting and ending in each participant's home community. Southern participants met in Edmonton where they connected to a northbound flight to Inuvik (NWT). Upon arrival in Inuvik, they were introduced to the four participants from Inuvik and Tuktoyaktuk. The group boarded a twin otter aircraft and headed to a location (70°03'N: 126°18'W) in the Franklin Bay of the Beaufort Sea, which is located in the Western Canadian High Arctic. The plane landed on an icy landing strip, next to the Class 1200 Coast Guard Ship *Amundsen*, in the early evening of February 23rd, 2004.

The group boarded the icebreaker and immediately became integrated in the activities of the CASES science teams. Participants had access to all areas of the ship except the engine rooms. The conference room became the meeting place and location of all lectures and evening activities. The physical setting of the ship included the various laboratories (wet, dry, cold, paleoceanography, dry instruments, satellite reception, and computer labs), the microscopy room, the moonpool, as well as the bridge, the outside decks, and all of the living spaces. Each participant was assigned to a shared room that included two beds, space for storing their belongings, and two workstations (desk, office chair, and electrical service for laptops and other electronics). Everyone had access to email and phones. The use of telecommunications was limited due to cost and priority was given to science and coast guard operations.

All meals were eaten in a cafeteria except for the Sunday dinner when the group was invited to dine at the Captain's table. Students also had access to the recreational spaces (two lounges with television, computer, and game boards). This was truly a unique learning environment, quite different from any classroom or school setting.

Figure 4.2 Photos of the learning environment of the 2004 SonB Field Program. The photo on the left shows the *CCGS Amundsen* frozen in the ice of Franklin Bay (NT) during the winter months of the CASES scientific expedition. In the photo on the right a scientist demonstrates to students sampling techniques using plankton nets in the moonpool (a hole in the hull of the ship that allows scientists to sample through the ice during the winter season.

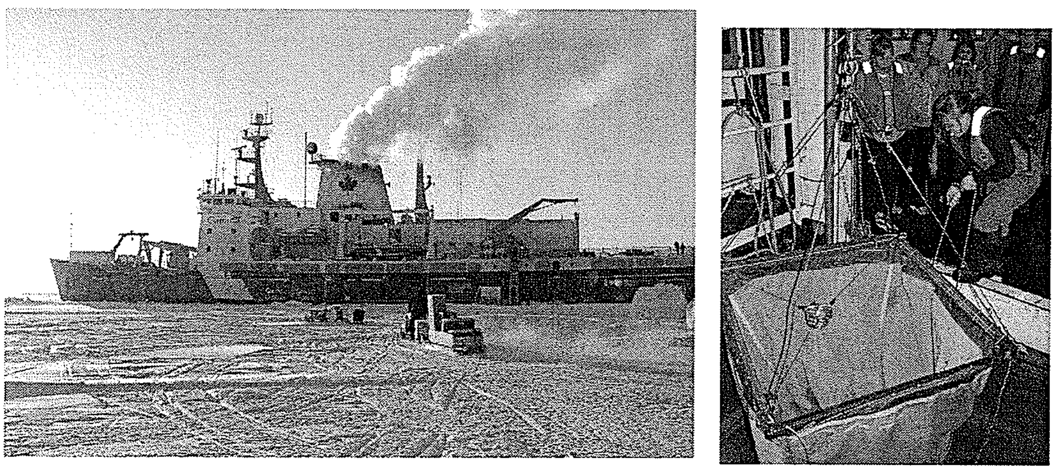


Photo credit: Schools on Board

Much of the program was conducted outside the *CCGS Amundsen*, making the frozen sea ice and weather a significant part of the program setting. Participants were required to prepare for, and adapt to, working in cold environments. This preparation began prior to the trip, with pre-trip information that ensured participants knew what to expect. This information included a suggested packing list and information on dressing for the cold, a 'code of conduct' describing program expectations, and requirements for schools to prepare participants for working in cold environments. As previously mentioned SonB provided proper Arctic gear for all participants.

The social environment of the ship consisted of the small group of SonB participants (14) among a larger group of scientists (30) and Canadian Coast Guard crew (40). Participants had to learn to adapt to life on a working research vessel. This included an appreciation and respect for the order and function of the Canadian Coast Guard Service, which included a code of conduct between officers and crew, and between the coast guard and the science team. SonB was considered part of the science team and this team approach created strong group cohesion within the SonB participants. The diversity of individuals from around the world, across Canada, and from rural to small remote Northern communities, created many opportunities for planned and spontaneous cultural exchanges both among SonB participants, and between the international group of scientists and the French-speaking crew from Quebec.

Key decision: It was necessary to plan for the social environment as well as the physical environment. Group dynamics played an important role in developing and maintaining strong group cohesion that resulted in commitment, active participation, friendships, and a strong emotional connection to the program.

4.5.2 Participants

The national team of participants for the 2004 field program included 9 students (5 females; 4 males) and 2 teachers (1 female; 1 male). These participants came from the following communities across Canada: Inuvik and Tuktoyaktuk in Northwest Territories; Dawson Creek, Chetwynd, and Tumbler Ridge in British Columbia; Winnipeg, and Oakbank in Manitoba.

Figure 4.3 Group photo of the 2004 SonB Field Program participants taken in front of the icebreaker. The group includes 9 students, 2 teachers, program leader, and accompanying scientist, Dr. Grant Ingram (center).

Photo credit: Schools on Board

The following section deals with the logistics and planning consideration used to design, plan, implement, and evaluate the program.

4.5.3 Logistics

4.5.3.1 Application and Selection

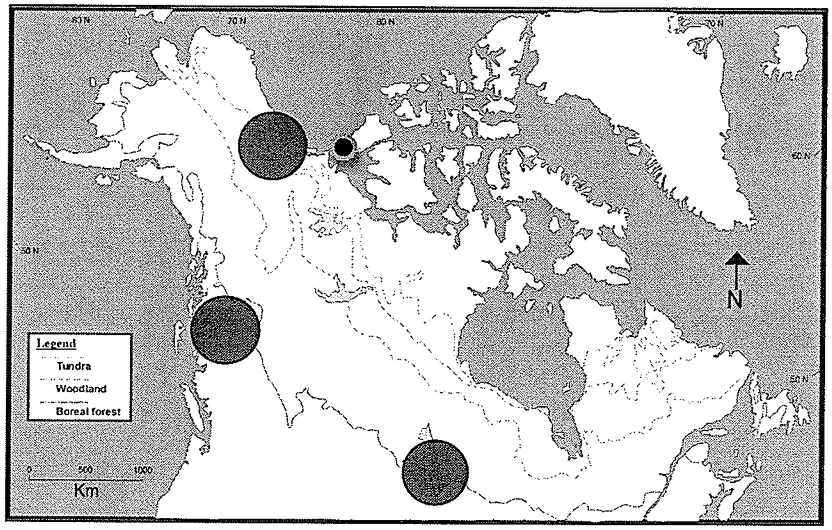
Once the science team determined the number of spaces that would be available, a number of decisions had to be made about application and selection processes. One of those decisions was to make this a national program with equal representation from the East, West, and North, regardless of population size. Competition for the limited number of spaces would occur at the school level. All the application materials, such as selection criteria (Appendix H) and application forms, would be created with the help of the advisory committee, and would be easily accessible on the SonB website.

Selection of schools

For the 2004 pilot program, specific schools with connections to the research program were invited to participate. Selection of schools was based on their willingness and ability to promote Arctic sciences in their school programs, to support the student or teacher, and to accept the risks inherent in the field program. We did not receive any application from schools in Eastern Canada. Despite this, selection resulted in a good cross section of schools that included northern and southern schools, rural and city schools, and schools with small and large school populations. The following schools participated by sending students and/or teachers:

- **Samuel Hearne Secondary School**, Inuvik, Northwest Territories
  - (2 students; 1 teacher)
- **Mangilaluk School**, Tuktoyaktuk, Northwest Territories (1 student)
- **South Peace Secondary School,** Dawson Creek, British Columbia (1student)
- **Chetwynd Secondary School**, Chetwynd, British Columbia
  - (1student; 1 teacher/principal)
- **Tumbler Ridge Secondary School**, Tumbler Ridge, British Columbia (1 student)
- **Grant Park High School**, Winnipeg, Manitoba (2 students)
- **Springfield Collegiate**, Oakbank, Manitoba (1 student).

Figure 4.4 Map showing location of participating schools and location of the ship. The circles correspond to location of the schools listed above. The black dot is the location of the ship in Franklin Bay, NT.



Selection of participants

Once schools were selected, they planned and implemented a selection process that best suited their needs, resources, and expectations for outcomes. Some schools held competitions to heighten awareness on a broad scale, while others selected a specific individual based on anticipated impacts that would benefit the school program indirectly through his/her successes. All schools used the SonB criteria (Appendix H - selection criteria). Schools were given the flexibility to add to these criteria to suit their needs. All successful students, regardless of how they were selected, had to complete and submit a copy of their application form with a letter of intent to the SonB office.

An equal gender split was not imposed as it had been decided not to place restrictions on school decisions, regardless of the implications that an unequal gender split would impose on program logistics (i.e., accommodations in transit and on the ship). Emphasis was placed on picking the best candidate. With regards to supervision, it was discovered that at least one male adult would be needed, which determined that gender might impact the future selection of teachers. In addition, due to the co-ed nature of the program and requirement for overnight stays, school administrators were required to verify school policies with specific restrictions regarding accommodations for teachers and students on supervised field trips. Some schools, for example, allowed teachers to share accommodations with students from other schools, but not their own. This information was important from a logistics and risk management perspective.

Key decision: Selecting schools and allowing them to select participants based on SonB criteria involves the school in a critical aspect of the program. It was acknowledged that schools could do a better job of selecting individual participants based on their familiarity and knowledge of their personality, abilities, and ambitions. Selection of participants at the school level also increased the outreach potential of the program.

4.5.3.2 Funding the field program

CASES contributed 12 berths on board the Amundsen for 6 days during Leg 5 of the CASES project. This in-kind support represented a major cost of the field program, which was estimated at $650/person/day. Principal investigators committed in-kind support for the delivery of the on-board program by contributing materials and their time for the development and implementation of the educational program. A donation received from the Bank of Montreal paid for the promotional materials. Essential gear, such as Arctic parkas, was acquired in partnership with the Centre for Earth Observation Science (CEOS) at the University of Manitoba. The University of British Columbia provided partial funding for the chartered flight from Inuvik to the CCGS *Amundsen*. Fisheries and Oceans Canada and the Aurora Research Institute in Inuvik supported community visits in Tuktoyaktuk and Inuvik.

The registration fee of $4500 per person covered the partial cost of administering and implementing the program and the full cost associated with travel and educational materials associated with the field program. The registration fee was lowered to $2000 for northern participants to reflect the lower travel costs. Each school used different scenarios for collecting the fee. These scenarios included one school board paying the entire fee for 3 participants from 3 different schools, a school board cost-sharing the fee with parents, a fundraising letter campaign, cost-sharing with local sponsors, and full sponsorship from outside sources. The fee included airfare to and from Inuvik NWT (the largest cost and factor determining the fee), meals and accommodations in transit, cultural activities in Inuvik such as dog-sledding, chartered flights to and from Inuvik (on and off the ship), limited on-board communication time, ground transport to Tuktoyaktuk, meals and cultural activities in Tuktoyaktuk, trip interruption insurance, educational materials like the Participant Handbook, participant shirt and neck warmer, loan of Snow Goose Arctic Parka, winter boots and polypropylene socks. Fees did not include the required emergency medical insurance or miscellaneous personal expenses. It was suggested that participating schools choose an alternate, as registration fees were non-refundable. The following payment schedule was provided:

- Payment #1 - 25% due upon accepting the space;
- Payment #2 - 50% due prior to booking flights;
- Payment #3 - 25% due prior to departure.

4.5.3.3 Travel & Onboard logistics

The logistics for travel included all arrangements for air and ground transportation, meals, accommodations, and all of the activities stated above. The services of a travel agent and the Inuvik town office were utilized. Flights were booked only after all required forms were completed by participants and submitted to the SonB office. All logistics for the 'onboard' portion of our trip were coordinated with the coast guard's logistics officer. These activities included berth allocations, arrangements for our arrival on and departure off the ship, a scheduled safety orientation, a 'logistics tour' of the ship, access to communications (email and phone), meals, and facilities. Important considerations for making travel arrangements for 'unaccompanied minors' included the need for detailed information and tips on travelling, adequate backup plans in the event of unexpected changes, and waiver forms to be completed with, and witnessed by, parents or legal guardians.

Pre-trip plan

In addition to selection and field preparations, pre-trip activities included developing a pre-trip information package with general information, a preliminary program plan, and a suggested packing list that was sent to schools and participants well ahead of the field program.

Five suggested activities were sent to all participants by email prior to the field program. The intention of these activities was to introduce participants to each other and initiate group dynamics prior to the field program, as well as provide participants with specific background information or knowledge required for the onboard program.

A student handbook with daily plans, activity worksheets and supporting resource materials, as well as information relevant to life on the ship was created with input from educators and scientists, and was distributed to participants on the first day of the program. This handbook included the following sections: Introduction, Safety, General Information, Orientation, Oceanography, Meteorology, Snow and Sea Ice, Life – productivity, Life – food webs and cycles, Climate Change, Community Visits, and Evening Program. Producing the handbook in a binder facilitated last minute additions and re-organization of worksheets as plans changed in the field. The handbook was linked to the Arctic Marine Science Curriculum (Experiential Science 20) and sections of this curriculum were provided as resources to each module.

Key decision: The suggested email activities were very successful in developing a group identity prior to the program. These activities and the pre-trip information packages were effective at tapping into the anticipation phase of the trip.

Key decision: Linking program to curriculum used in the North, provided links to traditional knowledge and information relevant to environmental issues in the Arctic.

4.5.3.4 Communication

Communication deserved its own category within the program planning and implementation process, separate from promotions and public relations. It includes all communications with stakeholders, participants, schools, and scientists. The primary communication tool for the program was the webpage hosted on the CASES website (www.cases.quebec-ocean.ulaval.ca/school.asp). This site was used to deliver program details and relevant application information, and contained all of the necessary science information about the CASES project and the *CCGS Amundsen*.

Communication came up as an important consideration in both the school and scientist evaluations, with the strong recommendation to identify someone within each group as a contact person. Ongoing communication, although time-consuming, was critical in establishing program expectations and ensuring proper and timely flow of information. This required communication with participants, schools, and scientists, prior to, during, and after the field program (see Appendix I – Communications plan).

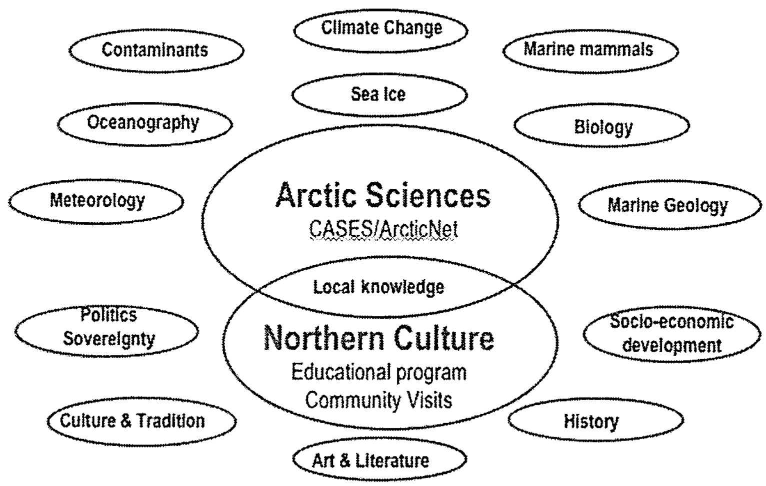
4.5.4 Program Plan

The field program required a detailed plan for 12 days. This plan included travel, the onboard program, and community visits in Inuvik and Tuktoyaktuk. Activities in the community were planned to complement the onboard program and provide participants with a broader social context for the CASES research program. The following sections describe the components of the onboard program (lectures, laboratory, field and evening activities) and the community visits.

4.5.4.1 Content

The main focus of the program was to introduce participants to the breadth of science knowledge and Inuit knowledge involved in climate change research in the Arctic. This was accomplished by ensuring that each science team on the ship was represented in the program plan, and that traditional knowledge was included through written materials and interactions with elders and community leaders in Inuvik and Tuktoyaktuk. Figure 4.5 shows the science disciplines (blue) that were represented within the CASES project. The focus of the field program was on science, more specifically, the sciences required to study the Arctic marine ecosystem, with each day featuring one, or a combination of these disciplines. Northern culture and ecological knowledge (red) provided the broader context for the science and the research.

Figure 4.5 Schematic representation of the content of the 2004 field program. Arctic Sciences (in blue) dominated the daytime activities, complemented by topics related to Northern Culture (in red), which dominated the evening activities.



An emphasis was placed on demonstrating the multidisciplinary and interdisciplinary nature of the research program, the interconnectedness of the science teams around the unifying theme of 'climate change', and the importance of tackling these complex environmental issues from multiple perspectives and ways of knowing. This was accomplished by planning multiple implementation strategies such as lectures, demonstrations, direct experiences in scientific fieldwork, large group discussion, debates, debriefings, concept mapping, role-playing, brainstorming, collaborative group activities, games, inquiry and research projects.

The days were planned around the science, and the evening program was used to include cross-curricular themes such as art, literature, history, and politics. The content of the field program had elements of both science education and environmental education, with the strongest links to the Grade 10 science curriculum including the Arctic Marine Sciences Curriculum developed for the departments of education in the Northwest Territories, Nunavut, and Yukon. These curricula provided guidelines for planning a program that could effectively bridge science education and scientific research through the knowledge and experiences of the average Grade 11 student. It was assumed that the students could use their Grade 10 science education to anchor the new information from the field program. Links to curriculum and specific learning outcomes could also be found in geography, environmental studies, environmental sciences, climate change, learning for sustainable futures, and education for sustainable development programs. The number of appropriate curricula and the provincial differences in course offerings make it unfeasible and beyond the scope of this case study to list specific curricular links of the SonB program. One of the roles of schools and educators was to find the links that best fit their programs.

Key decision: Although the focus of the field program was science, it would include sessions that would allow students to see the science and research in a broader context. The planned activities in northern communities, integration of traditional knowledge, and inclusion of cross-curricular activities were important elements of the program.

4.5.4.2 Structure

The remote conditions and location of the ship required planning a full daytime and evening program that would provide a balance between educational and recreational or social activities. The days typically began at 8:00am and ended at 10:30pm. One issue that came up in response to such a full program was time management and trying to fit everything in without overwhelming participants. Due to the unpredictability of weather conditions and research schedules, another issue that was critical in planning for the field was flexibility. It was important for scientists to know that the necessary changes would be made to accommodate their research. For this reason, the program was planned in manageable time slots of 30 minutes for lectures and multiples of 1.5 hours for labs and fieldwork, which provided greater adaptability, and rapid replacement of one time slot with another when necessary.

All activities were planned by the SonB program coordinator, and were delivered by science teams, CCGS crew, and community leaders. This maximized the contact hours between participants and scientists, and ensured that participants were learning directly from the experts. Emails were sent to all onboard scientists asking for volunteers to participate in the onboard program. A large majority, 27 of the 30 scientists onboard the ship, participated in the program. They were provided with templates to assist them in planning their lectures, labs, and fieldwork activities.

Key decision: A flexible itinerary ensured that the program could be adapted on short notice to accommodate changes in research plans, availability of scientists, and weather. This flexibility resulted in a program that was predominantly delivered by scientists and local experts.

Lectures

All lectures were to be introductory and geared to the high school level. Some scientists had difficulty determining this, and as a result, some presentations were more advanced and challenging. We relied on teachers to play a role in making the connections to classroom education, and in some cases, clarifying concepts and scientific language so that lectures would be more easily understood by students. The length of each lecture was 30 minutes with another 10 minutes for questions. The lectures were typically slated at the beginning of the morning and afternoon sessions to provide context and background information for the lab and field activities that followed. Extra resources were provided in the Participant Handbook that included a module for each discipline.

Fieldwork & Lab Activities

Fieldwork and lab activities typically required 1.5 to 3 hours. Most activities on the ship, unless they were demonstrations, were limited to groups of 3 owing to the size of laboratories. This required a plan that would offer at least three concurrent sessions, with different activities experienced by the participants during the day. Each small group included at least one teacher or program leader. Fieldwork off the ship could accommodate larger groups. The focus of the lab and field activities was to provide hands-on learning experiences and face-to-face interactions with experts in scientific inquiry and field research.

Figure 4.6 Photos of students engaged in authentic science experiences in Arctic fieldwork, working with the biology team setting plankton nets under the ice (left), with the snow and sea ice group cutting ice cores (center), and sorting zooplankton in the laboratory.

Photo credit: Schools on Board

Build an Instrument

Following a recommendation from an educator on the advisory committee, the program plan included a design activity that would become an ongoing experiment for SonB participants while they were in the field. In this activity, participants would design and build their own scientific instrument (a thermocouple) using basic materials. The thermocouple would be used to measure the temperatures of air, snow and sea ice, and would not only simulate the function of the more sophisticated instruments on the ship, but also results would be compared to those found by scientists. Participants were provided with information on the need for instrumentation in scientific research and background information on thermocouples and the basic materials provided. In groups of three, they designed and built their own thermocouple, installed it in snow and sea ice (outside), and developed a schedule for taking readings and recording other meteorological data (cloud cover, wind speed, precipitation) 3 times per day. The aim of this activity was to teach participants skills in scientific inquiry and allow them to take responsibility for creating and managing their own data set. Scientists provided guidance and assisted with the analysis and discussion of results.

Figure 4.7 Photos of the 'Build an Instrument' activity. Student on the left is building a thermocouple and consulting with a scientist on installation of the instrument (center). The finished product and installation is shown in the photo on the right.

Photo credit: Schools on Board

Key decision: This experiential activity became a very important program element. It provided participants with their own ongoing science inquiry project with the broader research experience, and was not reliant on the availability of scientists. Participants could explore all aspects of scientific inquiry at their level of understanding.

Evening Program

The evening program was planned to provide a balance between the educational and social/recreational components of the SonB program. Each activity was designed to link to the field program in some way. For example, one activity included the game 'Pictionary', starting with each team creating a 'word bank' of terms related in to any aspect of the field program. Members from the opposite team, had to pick a word and draw it on a flip chart paper for the other members of their team to guess. The word bank included such terms as thermocouple, rosette, traditional knowledge, climate change, moonpool, chlorophyll a, and copepod. The evening program included sessions on: Inuit art; legends and literature; art and science; Inuit observations of climate change; Arctic sovereignty; and polar exploration. These activities were open to all members on the ship, thus, providing opportunities to connect with scientists on a social basis, and establishing important links between the science on the ship and planned activities in the communities. This enabled participants to more easily make the connections between scientific research (complex environmental issues) and communities (people).

Conference Call

On the last day of the onboard program, a conference call was planned. This call connected SonB participants and scientists on the ship to participating schools and family members. Schools received instructions for involving their classrooms in this activity. Classrooms prepared questions to ask both scientists and SonB participants. The call started with a welcome from the Captain of the *Amundsen* and the Chief Scientist of the CASES program. To minimize costs to the schools, the call was coordinated from a southern location (Fisheries and Oceans, Winnipeg) and involved the participation of southern scientists from Unviversité Laval and University of Calgary. These were experienced scientists who could answer all questions in the event that a stable connection from the ship could not be established. The conference call connected 4 of the 8 participating high schools with those on the ship. It was an effective and powerful way to connect the activities on the ship to those of the classrooms back home.

Key decision: Although difficult to coordinate from a logistical perspective, this call was critical in connecting participating schools and classrooms directly to the activity and energy of the field program and increased the outreach potential of the program.

Community Visits

Community visits in Inuvik and Tuktoyaktuk, (NWT) provided the northern and arctic context for the onboard program and were planned to complement many of the evening sessions. For example, a meeting in Inuvik with Nellie Cournoyea, the CEO of the Inuvialuit Regional Corporation (IRC), re-visited issues raised in an evening role play activity onboard the ship where students re-created a community meeting to discuss the political and social implications of gas development in the North. After their meeting at the IRC, students gained a greater appreciation for the issues that were discussed on the ship, and the involvement of local people in the economic development of the North.

Figure 4.8 Photos of some of the activities planned during the community visits (left to right) – travelling on ice roads to Tuktoyaktuk, sampling country foods in home of northern community leader, dog-sledding, and storytelling with an elder.

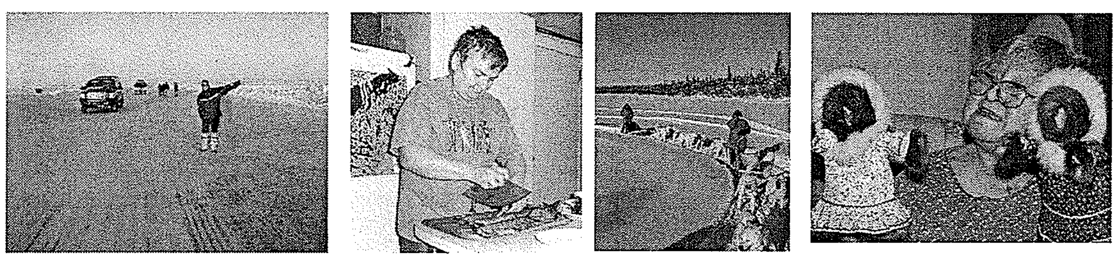


Photo credit: Schools on Board

The group travelled on ice roads to Tuktoyaktuk where they were welcomed in the home of a community member who spoke of the many traditional ways of life that continue to be practiced, and the local observations and concerns about climate change in the Arctic. The community member shared samples of country foods that included dried caribou and whale meat, dried fish, and muktuk (whale blubber), and prepared a meal that featured fresh fish and wild berries. Both visits to the communities included SonB presentations to local schools, tours and interactions with northern youth and community leaders. These activities required travel-related logistics (transportation, meals, accommodation, honorariums), cultural sensitivity, and reinforced the commitment of SonB to present a northern perspective.

Community visits were initially part of the travel considerations for planning the program, but the impacts on participants revealed that these visits were an important component of the program. Through the community visits, participants observed, discovered, interacted with local people, and gained a greater appreciation of the impacts and issues related to climate change in the Arctic. Planning community activities to include face-to-face interactions with youth and leaders was more important than originally anticipated.

Key decision: Planning activities in northern communities provided an important social context to climate change research in the Arctic.

4.5.4.3 Outputs

Participants were expected to record and share their experiences with others. This expectation resulted in wide spread outreach of the program and provided their teachers and schools with evidence of the learning that occurred. Participant handbooks included pages for lecture notes, worksheets, and concept maps for each day. Participants were encouraged to complete these as a record of their learning for teachers back home who might consider providing credit or excusing their absence from school during the field program.

Recognizing that they would be overwhelmed with work when they returned to school, participants were provided with materials, guidance, and time to prepare a

PowerPoint presentation to be ready to deliver upon arrival home. Once again, participants were challenged with reflecting on what they were learning and how they could communicate that to people back home. Our northern students delivered their presentations to students, teachers, and community members during our visits to Samuel Hearne Secondary School in Inuvik and Mangilaluk School in Tuktoyaktuk.

Key decision: Expecting participants to deliver presentations upon their return from the field program required time in the schedule for preparing and practicing their presentations. This program expectation ensured that participants and schools became more engaged in the outreach initiatives aimed at raising awareness in the school and broader community, and resulted in many presentations to diverse audiences following the field program. These new audiences to climate change research included friends, families, colleagues, neighbours, fellow classmates, and sponsors. Presentations by students became a new vehicle for communicating the science of the CASES program to members of the public who saw the activities of the science teams onboard the Amundsen through a new set of eyes – those of the students and teachers.

4.5.5 Program Processes

In addition to logistics, structure and content, a combination of processes were important factors for program implementation and delivery. They included experiential learning, learning alongside experts, inquiry, reflection, group dynamics, and informal interactions.

4.5.5.1 Experiential Learning & Learning from Experts

As previously mentioned, the focus of the field program was to provide students and teachers with real opportunities to gain first-hand experiences in scientific inquiry and research. The focus of all labs and fieldwork was on first-hand scientific investigation. The design activity embodied an experiential learning activity. Students and teachers responded positively to this activity. The experience of working and living in Arctic conditions during fieldwork and community visits was something that could not be taught in a textbook or in planned pre-trip activities. Experiential activities such as dog-sledding, travelling down ice roads, sitting in the kitchen of an Inuit family while sampling country foods, and seeing for themselves the vulnerability of northerners to the impacts of climate change, created a learning experience that was referred to by participants as 'life changing'.

Figure 4.9 Photos showing examples of experiential learning during the 2004 SonB field program. These include an Inuit student learning about snow and ice from an Inuit wildlife monitor hired during the CASES study (left), a student in the background, working in the lab with two scientists (center), and students and teachers doing a group activity with a scientist on the ice.

Photo credit: Schools on Board

Key decision: The decision to have the onboard program delivered by scientists and to include face-to-face interactions with researchers and leaders in northern communities authenticated the information and the experience for participants. Activities planned around these interactions were designed to encourage students and teachers to think critically about the issues related to scientific inquiry, traditional knowledge, and climate change research.

4.5.5.2 Scientific Inquiry

Scientists were encouraged to demonstrate the scientific processes involved in their specific research project. Templates were provided to assist them in creating hypothesis-driven activities for SonB participants (see Appendix J – Example of a hypothesis-driven activity submitted by a scientist). Immersion in an active research program provided many planned and unplanned opportunities for participants to have 'real' experiences with scientific inquiry, working at the 'elbows of experts'.

4.5.5.3 Critical reflection

Each day included time for reflection. Reflection activities included concept maps (individually and in groups) and journal entries. Time was allocated at the end of each day for a debriefing where the day's activities were reviewed and participants shared the different aspects of their day. Participants were given the responsibility of preparing SonB dispatches or journal entries that were posted on the Expedition logbook. This logbook is a web-based journal that included descriptions of the daily activities on the ship. The dispatches were both descriptive and reflective. Reflection occurred on many levels (individually, in small groups, and in large groups) and at different times (during activities and after activities).

Key decision: Debriefing at the end of each day was a good strategy to gauge participants' level of understanding and enthusiasm. As everyone had not participated in the same activities during the day this became a good activity for reflection and sharing.

4.5.5.4 Group dynamics

All participants came from different geographical and cultural backgrounds and were therefore strangers to one another before the program got underway. Since they would be required to work closely together and support each other during an intense and remote field program, specific attention was given to group dynamics. This began with a pre- departure activity that encouraged participants to introduce themselves to each other through interactive email activities. Group cohesion was maintained by pre-determining small groups and switching group members on a daily basis ensuring that each group included a person from each region whenever possible. This created an interesting mix of perspectives between north and south, rural and urban, east and west. Group dynamics played a very important role in creating the spontaneous informal interactions among participants and between students and teachers. In the end, the group of participants who began as strangers ended the program as very close friends.

Key decision: Pre-determining the small groups ahead of time and switching group members on a daily basis worked well to keep the team mentality of the group and helped to keep everyone in the group.

4.5.5.5 Informal interactions and unplanned activities

Life on the ship provided many opportunities for informal interactions and unplanned activities. Unstructured interactions with scientists and observations of scientists in their day-to-day routine presented participants with a unique glimpse of life as a scientist and the culture of research and fieldwork. Participants had free reign to visit the bridge and social spaces on the ship, had shared access to the television, telephones, and computers for sending emails home and to schools, and had freedom to visit the cafeteria for beverages and snacks at any time between structured meal times. Meals provided the opportunity to socialize with each other and with the scientists. Lots of laughter, experienced in the program and recorded in the many photos taken during the field program, suggests a positive interpersonal aspect of the program contributed to the overall personal experience. Strong friendships formed on the ship. Interactions between teachers and students occurred on different levels and in most situations, teachers were learners, working alongside students, a relationship likely unique for most participants. Interactions between scientists and participants were positive and friendly, with scientists going out of their way to comment on the positive energy and spirit that students and teachers brought to the ship. Students exchanged pins and sought out autographs and contact information from scientists during the last day onboard. SonB business cards were made for each participant and were given to the individuals they wanted to stay in contact with after the program.

Recognition is a process that was important both within and outside of our group. Students were responsible for thanking scientists and members of the crew after each session. T-shirts were given as a small token of appreciation for their involvement in the program. A farewell slide show with music was organized for the last evening onboard the ship. Participants individually shared what the experience had meant to them including educational, professional, and personal impacts in their statements. The farewell was also designed to thank SonB participants. Certificates were given by the captain acknowledging their participation and ability to adapt to life on the ship, as well as their contributions to the overall success of the program. Full attendance by scientists and ship crew at this farewell evening demonstrated the positive impact that the participants had on the ship during their short stay.

Key decision: Recognizing everyone's efforts through small tokens of appreciation – teachers and students (certificates and t-shirts), scientists (t-shirts and prizes); schools (certificate); chief scientists and captain (gift) was very important.

Key decision: Planning a farewell evening with slides of the week allowed scientists and crew to see the full breadth of the SonB field program and their contribution to the whole experience including the community visits. It also reminded students of the breadth of their experience.

4.5.6 Evaluation Process

This program was evaluated primarily from a planning perspective. The main objective of the evaluation was to determine the success of the first pilot program and, if successful, to determine what would be required to repeat the program. Evaluation was both informal and structured. The informal, or formative evaluation, was ongoing and started in the early stages of program development with consultations with scientists and the advisory committee to ensure the program would meet expectations of the various stakeholders. This consultation helped to anticipate and overcome possible barriers.

Informal evaluation, conducted by the program coordinator, also occurred on a day-to-day basis. Backup plans and changes were implemented as required and open communication, frequent orientations, and evening debriefings, provided opportunities for informal evaluation in the field. Structured, or summative evaluation included different program evaluations given to the participants (students and teachers), to the participating schools, and to the participating scientists. Participant evaluations were given on the first day of the program, and participants were asked to complete them on an ongoing basis. School Evaluations were given 3 months following the field program, to allow impacts to become visible, and to give participants a chance to deliver their presentations. Scientist evaluations were given after our departure from the ship and were collected by an onboard scientist on our behalf. These three evaluations provided three perspectives and enough information to determine whether the goals of the SonB program had been successfully met. Feedbacks from the evaluations as well as input from the program coordinator and the SonB advisory committee were compiled in a comprehensive list of program considerations and recommendations (Appendix J - Recommendations).

The evaluation of the 2004 program, of which this case study is part, is best presented as goal-oriented evaluation with attention to process. The evaluation tools used were not designed to evaluate specific outcomes, such as changes in attitudes, changes in knowledge, or changes in behaviour. The two main goals of the SonB program were to increase awareness and inspire the next generation of scientists, resource managers, and policy-makers.

Key decision: Having separate evaluation tools for participants, scientists, and schools was effective in getting feedback from three major stakeholders.

4.5.6.1 Raising awareness

The goal of raising awareness was evaluated by describing and documenting the outreach activities that resulted from the program. It was recognized from the start that this type of program had a high potential for outreach, and that the uniqueness of the field program could be used to capture the imaginations of media, sponsors, and the general public. By involving the schools, it was possible to create a shared and vested interest in outreach that maximized this potential. As a result, the outreach activities of the 2004 field program were widespread and successful in raising awareness on two levels:

1. Creating a better understanding of the Schools on Board program and its educational objectives
2. Introducing the public to the CASES program and its scientific objectives

This was accomplished through the combination of media interviews, dispatches from the field and a series of presentations delivered by scientists, the SonB program coordinator, and the 2004 Field Program participants.

Web-based outreach

During the field program, participants submitted daily dispatches to the Expedition logbook (http://www.cases.quebec-ocean.ulaval.ca/trip/log_feb.asp). This site included text and photos recounting the daily activities of scientists and participants for the dates of February 24 to March 3, 2004. The site allowed schools, sponsors, teachers, friends, and families to share the experience. The site is still active today.

Presentations

One of the required outputs of the field program was the preparation and delivery of presentations by participants to their schools and communities. This expectation resulted in presentations being delivered to a wide range of groups that included the following: national and international scientists; elders from Paulatuk, Holman, and Sachs Harbour; university faculty members; environmental educators; church groups; service groups; school boards; parent councils; students and teachers of all grades and subjects (including Physics, Mathematics, Chemistry, French, English, Social Studies, Biology, Science, Environmental Studies); the Inuvialuit Regional Corporation; the Aurora Research Institute; national and regional science fairs; community libraries; Meals on Wheels; Naturalist Society; receptions for sponsors; Fisheries and Oceans Canada - Oceans Day; and meetings of provincial science teachers associations. Approximately 50 presentations were delivered to an estimated 3300 people. This information was provided in the School Evaluations that were submitted months following the field program.

Media

Media attention came from both regional and national coverage with the Canadian Broadcasting Corporation (CBC North; CBC – BC North; CBC Manitoba; CBC National). This coverage featured live interviews from the ship and from northern communities. Newspaper coverage included feature articles in the Winnipeg Free Press, News North, community newspapers in northern BC, and the Meridian of the Canadian Polar Commission. Strategies for maximizing outreach will be discussed in the following chapter.

4.5.6.2 Inspiring our next generation

The second goal of the program was to inspire the next generation of scientists. Following the first field program this goal was extended to include the next generation of resource managers and policymakers. Anecdotal information on the impacts of the program on participants was gathered from the open-ended questions on the program evaluations and from email correspondence received after the field program. Since the three evaluation instruments were not developed to measure specific learning outcomes impacts of the program are communicated through testimonials of the participants (Appendix L). These testimonials suggest that experiences in the field program occurred on very profound personal and professional levels. Much of the feedback received is consistent with the impacts described in the literature.

Photo credit: Schools on Board

CHAPTER FIVE – FINDINGS

The case study presented in the previous chapter provided a complete picture of the program and context for the findings in this chapter. The purpose of this chapter is to create an understanding of why the SonB program is working from a theoretical perspective (based on the literature) and a practical perspective (based on what actually happened). The following interpretations are those of the research practitioner. Critical reflection, observations, and direct experiences of the researcher play important roles in evaluating the program and making the transition from evaluation to action plan.

Before proceeding to the findings, the reader is reminded of the two propositions stated in Chapter Three that guided data collection, analysis, interpretation, and the presentation of these findings.

Proposition #1: There is enough common ground between EE and SE to develop criteria or guidelines for environmental science education programs that will assist the development and evaluation of the SonB program to ensure that it is based on current theories on learning and education.

Proposition #2: A systematic examination of the SonB program (design, planning and implementation stages) will reveal the key decisions that contributed to the program's success in the 2004 pilot year (and all subsequent years) and will contribute to future program development and ongoing evaluation of the program.

The findings from this chapter are organized around 1) the criteria for quality ESE programs, 2) the evaluation of the 2004 SonB program and 3) discoveries about the program that emerged through this thorough and systematic examination.

5.1 Criteria for quality ESE program

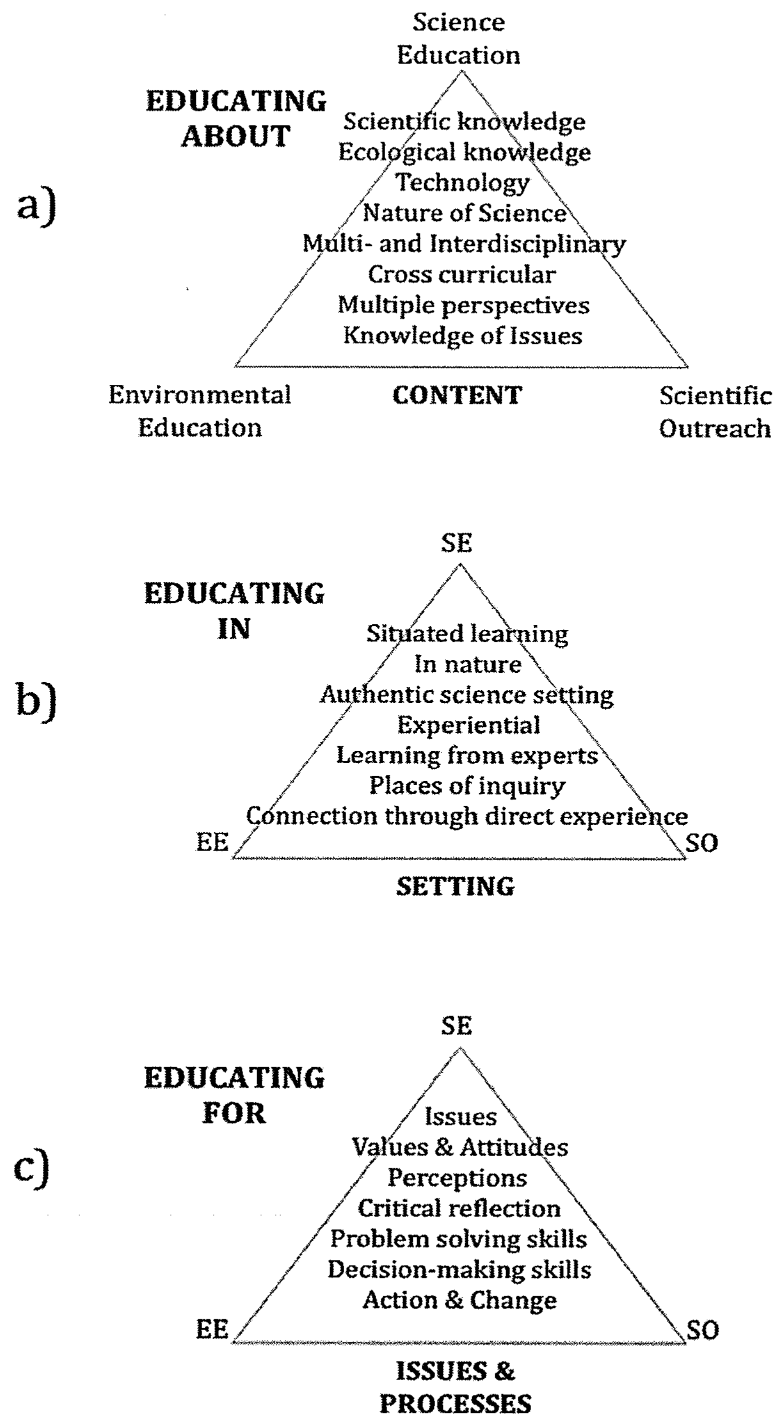
The data generated from the literature reviewed for this study revealed enough common ground between EE, SE, and SO to develop criteria or guidelines for developing quality environmental science education (ESE) programs from a theoretical perspective. This overlap between EE and SE is reflected in their respective goals toward raising environmental and scientific literacy and their shared pedagogical approach to learning that recognizes the learner as actively constructing meaning and knowledge through interactions with others and their environment.

The findings or criteria that resulted from the analysis of the literature database are based on the characteristics of quality EE, SE, and SO programs, that converged in this study around the following themes:

1. Educating 'ABOUT' the environment/science
   - Referring primarily to content and knowledge.
2. Educating 'IN' the environment/science
   - Referring primarily to the experiential learning in authentic settings (in nature or in places where scientists 'do science').
3. Educating 'FOR' the environment/science
   - Referring primarily to the issues, and decision-making relevant to pro-science and pro-environmental attitudes and behaviours.

The shared program characteristics that led to this breakdown are listed in a table in Appendix M. The following sections describe each of the criteria, or essential aspects of a quality ESE program summarized in Figure 5.1.

Figure 5.1 Criteria for quality environmental science education programs. These criteria were determined from the findings in the literature that converged around program characteristics related to educating: a) ABOUT (content), b) IN (setting) and, c) FOR (issues and processes) the environment and science.



5.1.1 Criterion #1 - Educating ABOUT the environment and science

This criterion relates primarily to the content or knowledge, attitudes and skills of a program (Figure 5.1a). This study suggests that the content of a quality ESE program will include essential, credible and reliable ecological and scientific knowledge that is relevant to specific concepts, environmental issues, and technology - its impacts on society and the environment, and its role in the scientific process. Content should be grounded in real life and presented within the broader social context, for example, connecting to global environmental issues such as climate change and sustainability. In this sense, content is connected to attitudes related to environmental issues and perception related to the philosophy and nature of science.

Education 'about' the environment and science should be age appropriate and relate to concepts that are already known or familiar. It should be multidisciplinary or interdisciplinary in nature, to reflect a holistic or systemic perspective of science and the environment. Whenever possible educating 'about' science and the environment should include multiple points of view or alternative 'ways of knowing' such as traditional ecological knowledge (TEK) and should consider cross curricular links to other subjects such as the arts, mathematics, political sciences, social studies, and health.

5.1.2 Criterion #2 - Educating IN the environment and science

This criterion relates primarily to the setting of a program (Figure 5.1b) and the belief in situated learning suggesting that 'how' we experience learning is affected by the places and spaces in which we learn. This criterion recognizes the environment as a setting for learning, not just a topic to cover in a classroom and recognizes authentic science settings such as laboratories (school-based and off site) and field sites, as places of scientific inquiry. An important characteristic of authentic science experiences is the opportunity to learn from experts, including very knowledgeable teachers and peers. Educating IN science and IN the environment includes scientists or other experts as part of the setting and aims to bring the learner in direct contact with an authentic learning environment in nature and science. The benefits of these direct experiences with regards to raising positive attitudes (caring, a sense of ownership) and positive behaviours (decisions and actions) towards the environment and science have already been identified in the review of literature.

5.1.3 Criterion #3 - Educating FOR the environment and science

This criterion relates primarily to the environmental issues and processes such as critical reflection, problem solving, and decision-making (Figure 5.1c). This is an action-oriented criterion that is aimed at encouraging pro-science and/or pro-environmental behaviours. It involves delving into issues that relate to both the environment and scientific inquiry, and suggests that quality ESE programs include activities that encourage learners to examine and challenge attitudes, values, and perceptions about the environment and the nature of science. These activities examine the ethical issues and considerations related to environmental science and can inspire individuals to consider future studies or careers in field related to the environment and/or science. Educating FOR the environment and science is an empowering process that encourages the learner to take ownership or personal responsibility of their learning and apply this learning to real life situations and personal lifestyle choices.

These findings (criteria) provide a structure for evaluating the 2004 SonB program from a theoretical perspective. Comparing this scientific outreach program to these criteria provides greater understanding of how and why the program was successful in linking classroom education with scientific research. They also provide insight for ways that the program can improve.

5.2 Evaluation of SonB

The evaluation of the SonB program is two-fold. It includes the detailed examination and resulting case description of the program presented in Chapter Four and the evaluation of the SonB data against the three criteria identified in the previous section. This section explores the fit between the 2004 SonB program and the criteria for quality ESE programs.

In order to evaluate the program against the criteria for quality ESE program the SonB dataset was sorted by the themes that corresponded to ABOUT, IN, and FOR in the literature data set.

- 110/210 (SonB dataset) compared to 101 and 201 (literature dataset)
- 120/220 (SonB dataset) compared to 102 and 202 (literature dataset)
- 130/230 (SonB dataset) compared to 103 and 203 (literature dataset)

To identify what aspects of the program fit with the criteria, the entire SonB dataset was sorted by the 'already doing' column. Claims of how the program meets each criterion are supported by testimonials from participants and stakeholders and recommendations are presented at the end of each section. To identify what aspects of the program are missing or need improving, the entire SonB and literature datasets were sorted using the 'to consider' column. See Table 3.3 (p.61) for a sample of data entries taken from the database.

5.2.1 Criterion #1 - Educating ABOUT the environment and science

What we're already doing

The educational component of the field program acknowledged the critical role of prior knowledge for creating new knowledge. The program requirements identified Grade 10 Science as a minimum requirement for the student criteria. The program also required that school representatives (administrators and/or teachers) select students based on their knowledge of the student's abilities and knowledge. Background materials and resources were also provided to participants prior to departure. During the planning of the onboard program, educators on the advisory committee provided insights to curricular links to science, geography, environmental education, learning for sustainable futures, climate change, and Experiential Sciences/Arctic Marine Science Curriculum (developed in the North).

Scientific and ecological knowledge

The content of the program focused on science and scientific investigation of the Arctic marine ecosystem. Scientists were given templates to create hypothesis-driven labs and field activities. The program reflected the multidisciplinary and interdisciplinary nature of the research program by providing an onboard program that included introductory lectures from each major science discipline represented on the ship, namely: physical oceanography; marine biology; marine geology; traditional ecological knowledge; physics of snow and sea ice; meteorology; and chemistry (contaminant and carbon fluxes). Direct and indirect teaching strategies and a variety of teaching methods were used to accommodate different learning styles (auditory, visual, and kinaesthetic-tactile). These included lectures, demonstrations, hands-on activities, group discussions, small group work, experiments, a design project, role-play activity, concept maps, journaling, and debriefings. Suggested email activities were sent to participants prior to the trip providing additional background information for some of the onboard sessions.

Technology

Participants were introduced to the diversity of research tools and techniques used by science teams working at the different scales of investigation (i.e. microscopic to satellite imagery). Many hands-on activities involved the use of simple and sophisticated scientific instruments. A planned design activity called, 'Build an Instrument', challenged participants to design and construct an instrument from basic materials that would simulate a more sophisticated instrument in its performance and utility to solve a specific problem. The living and learning environment of the research icebreaker brought participants in direct contact with state-of-the art engineering and technology. This included the desalination of all their water needs, the telecommunication systems used for navigation, and the deployment of instruments through the 'moonpool', a unique engineered feature of the icebreaker.

Multiple perspective

The program included traditional ecological knowledge (TEK) and Inuit observations of climate change. TEK was included as a component of each module of the Student Handbook. Face-to-face interactions with northern community leaders, elders, and local high school students in the North, as well as interactions with the Inuit wildlife monitor on the ship, provided participants with another 'way of knowing' to complement the scientific focus of the program.

Cross curricular

Cross-curricular sessions included Inuit art and legends, Arctic literature, Arctic exploration, Arctic sovereignty, and the Northwest Passage. These links to art, history, and political sciences also included the lecture 'Picasso and DNA' which featured the connection between science and art, and the lecture titled 'From Earth to Europa', which focused on the relationships between Arctic research and astrobiology.

Knowledge of Issues

Climate change was an underlying theme of the research agenda and the SonB educational program. Participants were introduced to the diversity of science teams working together to understand the complexity of climate change and to contribute to a more ecological and informed understanding of the impacts of climate change on the Arctic marine ecosystem. The activities related to observations of climate change by Inuit presented a broader socio-political and economic context to the science onboard the icebreaker.

Testimonials

- *"Schools on Board turned me onto studying science and opened my eyes to what science is about and how it relates to daily life...I feel honored to have been a part of it."* Student – Evaluation.

- *"Before the program I knew very little about Arctic Sciences and had no idea that anything like CASES was happening."* Student – Evaluation.
- *"This program makes people look differently at the Arctic: it is such an incredible ecosystem!"* Student - Evaluation
- *"An outstanding link between curriculum and global scientific issues. It was a life changing experience for each of our students."* School - Evaluation

Recommendations

The following list of recommendations is based upon my analysis of the 'to consider' data. These recommendations are aimed at improving our ability to educate 'ABOUT' Arctic sciences and climate change research.

- Improve our understanding of students' prior knowledge from formal schooling that new knowledge planned in the field program can build upon.
- Identify what students will be learning in the field program and increase the possibilities of this knowledge being the foundation for future learning in the classroom.
- Consider both 'content' and 'process' goals for major activities (see Martin and Howell, 2001).
- Introduce a session on the nature of science that includes a reflection activity that is re-visited at the end of the program.
- Identify modules and content in the field program not directly or indirectly addressed in the Grade 10 science curriculum and provide necessary background information.
- Develop a module that can be used by all participating schools prior to and during the field program to ensure that participating students are prepared for the field program

and that participating schools integrate Arctic sciences into classrooms while the student is in the field.

- Develop a guiding or unifying 'question of the day' for each day in the field. The question will determine the day's activities and focus the discussion at the end of the day.
- Develop a self-assessment for each module, to ensure understanding of content.
- Further develop the traditional knowledge components of the program. Integrate the Inuit and northern perspective more in the science program not as a separate session and encourage scientists to include TK in their talk whenever possible.
- Connect regional climate change and global climate change whenever possible.
- Review the program itinerary to ensure that the SonB field program maintains a balance between maximizing opportunities and overwhelming or overloading participants. This may require sacrificing content for more free time and reflection activities.

5.2.2 Criteria #2 - Educating IN the environment and science

What we're already doing

The field program was designed to integrate participants directly in the research activities of an active Arctic research program. The setting was the Arctic and the *CCGS Amundsen,* a state-of-the-art research icebreaker. The program promoted science partnerships between teachers and scientists, mentoring opportunities for teachers and students, and classroom visits by scientists. Educating 'IN' the environment and learning from experts were two key features of this field program. The remote and extreme nature of this program's setting required the management of risk and the collaboration of schools to allow students and teachers to participate in such an experiential program. The reality for most schools is that risk management policies often make it difficult for schools to endorse these types of programs. Creating safe learning environments and managing risks was a high priority for this program and addressed this barrier to participation.

IN the Arctic

Participants travelled to the Arctic, visited northern communities, met and interacted with community leaders and local students, and learned about northern culture and northern perspectives of climate change from Arctic residents. Participants worked on the ice with Inuit wildlife monitors and scientists, studied about climate change while observing some of the changes personally, and learned outdoors in Arctic winter conditions.

IN a research environment

Living and working on a research icebreaker created a unique learning environment. The focus on fieldwork and lab activities in the program itinerary immersed participants in scientific inquiry delivered by scientists and the coast guard crew. The science teams included national and internationally recognized senior scientists, graduate students, and technicians. Living on the ship exposed participants to the protocol of the Canadian Coast Guard and life as a scientist. An extended stay on the ship exposed students and teachers to the interconnectedness of scientific researchers, the creativity, and the teamwork required to understand climate change. The participants engaged in scientific dialogue with scientists, witnessed the scientists' passion, experienced the 'aha' moments and the frustrations of scientific inquiry, and observed the commitment of scientists to their research. The program plan included activities from 8:30am till 10:30pm each day. This 'full' itinerary introduced participants to the reality of working in the field, where every moment counts and research agendas take priority over weekends and free time.

The conference call on the final day of the onboard program connected participating schools to the field program in real-time virtually bringing the school-based participants onto the ship. The captain welcomed these participants onboard the *CCGS Amundsen*. Students, teachers, and in some cases, parents from home communities, asked participants or scientists questions related to Arctic climate change research, life on the ship, or more generally, the Arctic. Questions were asked in rotation, providing each school with the opportunity to be introduced and to ask three or four questions.

IN a social learning environment

The overnight nature of this program included unstructured informal interactions with scientists and like-minded students and teachers that resulted in new friendships. Attention was given to group dynamics and team-building prior to and during the program. Participants were pre-assigned in small groups for fieldwork and living arrangements in transit and on the ship. Group or collaborative learning activities included the 'build an instrument' activity and its ongoing experiment, dispatches, and a role-play activity related to sustainable development in the North. Planned social and recreational activities included movies, games, pin exchange, and a farewell evening of recognition. Students interacted socially with scientists and members of the crew during meals and in the evenings. On the final evening on the ship, participants enjoyed a social farewell event with the scientists, and on the day of our departure many scientists came by to bid us farewell and thank the participants for their involvement in the program.

The uniqueness of the setting for this field program (the Canadian High Arctic and the CCGS Amundsen, a state-of-the-art research icebreaker) contributed to the anticipation and heightened emotional aspect of the experience, and to the transformative nature of the program for all involved - participants, scientists, and program leader.

Testimonial

- *"Thank you for reminding me of who I am."* Northern student – personal communication to an elder.
- *"The value of this program is to explain what these crazy scientists are doing – I had no idea. It's made me think differently about science."* Student –Evaluation
- *"Thank you for letting us interrupt you and join you for the best week of my life."* Student – Email to scientists
- *"This has been an incredible journey of exploration and growth."* Student – Evaluation
- *"When I thought of becoming a scientist before this program, I never thought about conducting experiments in the Arctic but now I see it in a totally new and positive way."* Student –Evaluation
- *"It helped me to put into perspective a career that I would like to pursue (Marine Biology)...this has been a life-altering experience."* Student - Evaluation
- *"Having students experience our day to day routine with a twinkle in their eye is a great moral booster. Sometimes we tend to forget how cool and exciting our careers are."* CASES scientist, 5/3/04 – Email

Recommendations

The following list of recommendations is based upon my analysis of the 'to consider' data. These recommendations are aimed at improving our ability to educate 'IN' an Arctic and science inquiry environment.

- Evaluate our risk management plan on a yearly basis to ensure that it is consistent with legal requirements for managing risks for school-related programs.
- Consider linking scientists and interested schools during pre-trip phase – when possible.
- Provide links to websites that publish extensive data sets or make field data available to educators who can then develop active inquiry exercises related to working with real data, thus enabling some of the tasks and thought processes used by scientists in the field. Using field data from the Arctic research program would link or connect classroom education directly to the field program.
- Plan for more reflection 'in ' action - in the field. Create specific 'minds on' activities to complement the 'hands on' fieldwork activities.
- Identify follow-up opportunities to complement the experience IN the field.
- Actively promote the creation of meaningful research partnerships and authentic science experiences to educators and scientists prior to, during, and after the field program.
- Recognize outreach initiatives of Arctic scientists.

5.2.3 Criteria #3 - Educating FOR the environment and science

What we're already doing

The unifying theme of climate change provided an environmental context to the scientific research program and was the theme of the final day onboard the ship. On this day participants shared what they had learned from the scientists in discussions on the interconnected nature of climate change research, the role of science in dealing with complex environmental issues, and the impacts of climate change on people living in the Arctic. Problem solving and decision-making activities related to climate change included discussions on issues of adaptation and mitigation, issues of sustainable development in the Arctic, sovereignty, and the role of science in policy making. A role-play activity related to economic development in the Arctic introduced students to the numerous issues faced by northerners as they attempt to balance concerns for economic growth with concerns for the environment. Meetings with community leaders involved in socioeconomic development and resource management in the Arctic exposed participants to the complexity of these issues and socio-economic and political aspects indirectly related to climate change research. These activities encouraged students to challenge their own assumptions, attitudes and values related to climate change as they prepared to share what they learned and experienced with others.

Each participant was expected to contribute to the expedition logbook by working with a partner to prepare a dispatch (daily journal entry) for one of the days in the field program. These dispatches required reflection on the activities of that day, reflection on what they learned and how they could best share it with others. All participants were required to prepare a presentation during the field program that would make it easier for them to communicate and share their experience when they returned to their schools and communities. Their commitment to communicate their experience and raise awareness of climate change translated into numerous presentations delivered upon their return. This focus on leadership and communication skills empowered participants to become involved in scientific outreach, provided them with skills, tools, and opportunities to practice presentations and media interviews, and reinforced the idea that with great opportunities come great responsibilities to act (share the experience, communicate and raise awareness, become a scientist).

In addition to raising awareness of science and climate change, the SonB field program was aimed at promoting an interest in careers in science and research. The field program provided opportunities for high school students interested in science, to meet scientists, opening doors to research agencies that could provide mentoring and employment opportunities in science related fields. Each participant received 10 business cards with his/her contact information and was encouraged to exchange these with scientists and community members during the field program. The field program provided a vehicle for scientists to engage in outreach and communication, as well as an opportunity for teachers to become more familiar with science inquiry and climate change, resulting in changes to their teaching.

Testimonial

- *"This has been the first program that I have been a part of where I feel that it has changed the direction of my life."* Student – Email
- *"Being immersed with scientists has been great, and I'll be sure to share everything that I have learned with as may people as possible."* Student – Evaluation

- *"The Arctic Ocean and the Arctic are changing rapidly because of climate warming. And yet, scientifically these regions still represent the less studied biotas on Earth. The demand for Arctic specialists will increase tremendously in the coming decades, and a central objective of research networks such as the Canadian Arctic Shelf Exchange Study (CASES) is to train the next generation of Canadian Arctic scientists. The School on Board program is an excellent way to make high school students aware of the possibility to develop an enriching career in a fascinating research field."* - Dr. Louis Fortier, Scientific Director of CASES and ArcticNet, 2003

Recommendations:

The following list of recommendations is based upon my analysis of the 'to consider' data. These recommendations are aimed at improving our ability to educate 'FOR' the environment and science, and promoting positive attitudes and behaviours related to environmental science education.

- Consider addressing global social and ethical issues such as social justice, poverty, and the environment using some of the approaches presented in the environmental ethics workbook created by Jickling and colleagues (Jickling et al., 2006).
- Consider integrating reflection activities presented by Amulya, (2004) such as critical moments reflection, inquiry driven reflection, and interviews.
- Examine climate change from the human rights perspective used by Sheila Watt Cloutier (Inuit Circumpolar Council) to bring international attention to climate change in the Arctic.
- Consider the trade-off of reducing number of activities to include more free time for reflection activities such as journaling.

- Teach a session on problem-solving and decision-making techniques and strategies.
- Include a student debate to challenge assumptions and attitudes on issues related to scientific research (e.g., nature of science; role of science in policy-making) and the environment (e.g., sustainable living; balancing society's needs for energy with the need to protect the environment).
- Work with students and schools to create action plans before, during, and after the field program. This could be part of the pre-trip package and included in the Student Handbook.
- Add an 'Individual Action Plan' to the Student Handbook and encourage participants to come up with actions (direct or indirect) that they can do (individually or as a group, school or community) that promote awareness of the sciences and issues related to their Arctic climate change research experience.
- Be careful not to maximize outreach at the expense of a positive experience for the participant, for example, students getting overloaded with questions by email, Skype requests, and media requests during field program.
- Encourager participating teachers to develop lesson plans and mentoring plans as part of their action plan.
- Consider a Student Lesson Plan as one of the outputs of the field program. Have students develop a lesson plan as a group, which they will carry out with younger students back home. This would add an additional level of reflection on the content of the program and foster ownership of learning.

- Share information on fostering research partnerships that are mutual and meaningful, with schools and scientists and promote more authentic science opportunities for students and teachers.
- Provide information to scientists related to communicating science, classroom visits, and mentoring.
- Consider setting up a SonB outreach award for scientists who participate in SonB outreach activities (not limited to the field program).
- Create a post-event activity to follow-up with participants after the field program.
- Consider the ethical considerations of transformative experiences and the need to have a mechanism for follow-up and debriefing after the program.
- Create a monitoring plan for keeping in touch with participants and track their involvement in scientific and environmental fields of study.
- Re-examine the SonB evaluation process and explore assessment tools to monitor success of the program.

In summary, the findings of this case study support the conclusion that the 2004 SonB field program met the three criteria for quality ESE programs. Students and teachers were actively engaged in learning ABOUT science, research and the Arctic environment. They were immersed IN the Arctic, IN scientific inquiry and IN life at sea on a research icebreaker. They were challenged to consider existing and new attitudes and actions FOR the environment and FOR science inquiry. They engaged in dialogue on issues related to climate change and scientific research. They critically reflected on the complexity of environmental issues and scientific inquiry, and they actively engaged in problem solving and action–oriented thinking and reflection on their experiences and their role in the big climate change picture – their contributions to both the problems and solutions related to this complex environmental issue. The patterns in the data were strongest in the ABOUT and IN criteria, which reflects the focus of the program on science and authentic science experiences. The climate change focus of the research program provided the opportunities to educate FOR the environment and FOR the role of science in environmental policy-making.

5.3 Discoveries

Critical reflection was an important objective and outcome of this study. In addition to the findings already presented, the re-creation and documentation of the 2004 field program was an opportunity to critically reflect on the data as findings emerged, and critically reflect on the implications of applying the criteria to the SonB program. It was through this process of reflection-in-action, during the research process, that discoveries surfaced. Key decisions and processes that contributed to the success of the program emerged, aspects of the program and its experiences that did not occur became important, and implications for program planning were considered.

5.3.1 Key decisions

Since the 2004 field program continues to be the model for successful field programs, one of the objectives to this study was to identify why the program worked from a practical perspective and to ensure that the evaluation of the program identified and documented the key decisions taken during the design, planning, and implementation of the program. Some are very obvious while others are subtle and could go unnoticed without close scrutiny. It is important to note that a program evaluation should not only be intended to identify what isn't working. Knowing and understanding what is working is of equal value to program planning.

Although they have already been identified in Chapter Four under relevant sections of the case study, the key decisions that were taken for the 2004 SonB field program have been compiled and summarized in Appendix N. Documenting these key decisions is important for future planning and knowledge transfer within the SonB organization.

5.3.2 What did not occur?

The findings of the case study focus on describing in great detail what occurred from the many sources of data that were used to gather information about the program. The question 'what did not happen?" produces interesting observations and insights that should be considered for the formal program evaluation process (i.e., questionnaire). The following statements are based purely on the observations and reflections of this practitioner/researcher.

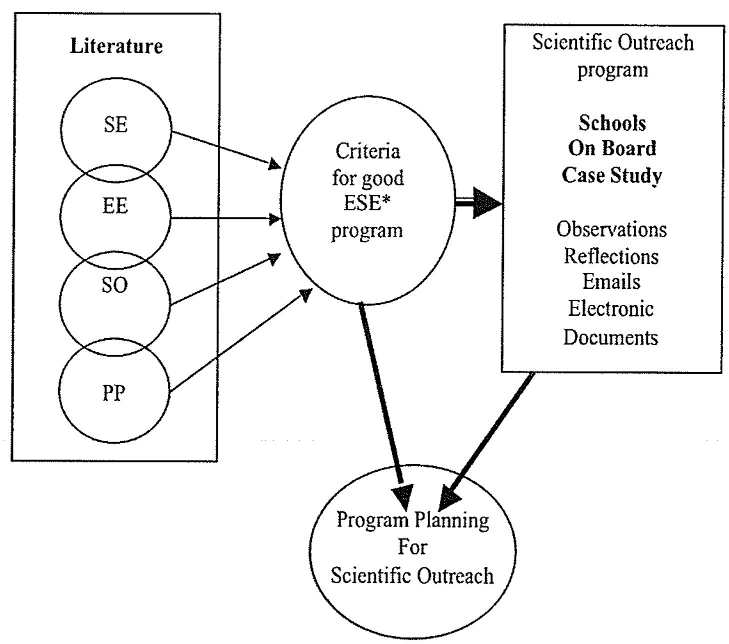
1. Participants had limited input in planning. Participants indirectly input into the program during debriefings and orientation meetings and at the end by completing a program evaluation. Providing more choices without compromising logistics and safety should be explored.
2. Despite the perception that this program is high risk, there were no injuries or problems reported. Despite the harsh conditions and remoteness of the field site, this program demonstrated that with the due diligence of all stakeholders involved risks are manageable and should not be a barrier to participation.

3. Despite the long hours and intensity of the program schedule, no participant refused to participate in any activity, and all were punctual and ready to go for the duration of the program. This could be due to the diligence taken by schools to select students and teachers who meet or exceed the program criteria, the high interest level of participants, and/or clear program expectations communicated to participants in a code of conduct and during orientation sessions at the very beginning of the program.
4. An absence of conflict and cliques among participants suggests that attention given to group dynamics and team-building activities was effective in building group cohesion.
5. An absence of TEK in science talks suggests a need to encourage scientists to prepare this part of their talk where applicable and/or refer to materials provided in the student resource book.
6. Fewer questions than expected to scientists and community leaders suggest that participants either lack background information or lack confidence to ask. Both of these can be addressed in the program planning process.
7. Follow-up opportunities after the field program were not part of the program plan. This was identified as an important missing piece to the program, especially in light of the comments shared in the program evaluations that indicate the transformational aspect of this program.

The insights into the SonB program resulting from a thorough examination of literature and practice provide new understanding of how success factors fit together to produce an effective model used to deliver the 2004 SonB program and what factors will guide future program improvements. Specific strategies for maximizing outreach or maximizing impacts, beyond what has already been shared in the key decisions and other findings, is not the intention of this work and would be inappropriate for this type of study, as all findings are case specific. It is up to the reader to determine the applicability of the findings to their own practice.

The large amount of data generated from this study required structure and a systematic process to guide the inductive analysis and interpretation of findings. This structure is represented in Figure 5.2 that shows the literature informing the program of what constitutes a quality environmental science education program. These criteria, and the lessons learned from the 2004 Schools on Board field program come together to inform the process for planning change and improvements to this scientific outreach program.

Figure 5.2 Map used to guide analysis and interpretation of findings for this study.



5.3.3 Implications for program planning

This thesis has identified where theoretical concepts of environmental education and science education converge to suggest criteria for developing quality environmental science program and scientific outreach partnerships. Based on these criteria that present a holistic perspective of programs, I propose implementing an approach based on "ecosystems thinking" to the next stage of program development for the SonB program. "Ecosystem thinking" is a holistic and integrated way of viewing the world and produces an approach to planning that looks at a program as a system made up of interrelated component parts, and the many relationships among those parts. It recognizes that the program is part of a broader social system that should be considered when planning.

This claim is supported by the fact that characteristics related to ecosystems thinking found in ecosystems management textbooks (Grumbine 1994, 1997; Mitchell, 2002) have also been referred to many times within this evaluative study. These characteristics include words such as holistic, flexible and adaptable, participatory, diversity, uncertainty, complexity and change. A table in Appendix O provides examples of each of these characteristics found in the three stages of development for the SonB program: design, planning and implementation. An ecosystems approach to planning would integrate these concepts into guidelines for planning, in much the same way that they are applied to other environmentally friendly activities such as ecotourism (Fennell, 2002) and natural resource management (Mitchell, 2002). A stronger link between ecosystems thinking and program planning would not only assist with effective programming but would acknowledge the potential of outreach programs, such as SonB, to contribute to the long term goal of sustainable living through effective environmental science education.

This final assessment of the findings completes the journey to understanding the 2004 Schools on Board field program. The action plan identified in the final chapter, describes how these findings will be transformed into steps aimed at improving the program.

CHAPTER SIX – CONCLUSIONS

Complex environmental issues such as global climate change are evidence that ecological issues are societal problems that require an environmentally, scientifically, and ecologically literate citizenry capable of making decisions and judgements about, in, and for, the environment. This 'knowledge culture' (Gough, 2002), evolves through a continuum of learning experiences that develop through a broad spectrum of approaches and programs, and leads to a citizenry that 'rethinks' the ways in which it interacts with the environment (Puk & Behm, 2003). We all have a role to play in becoming educated and educating others to become more environmentally conscious of the finite and fragile nature of the human habitat on this planet. This responsibility extends beyond the public education system and includes the efforts of scientists to inform the public of their research and inspire the next generation of scientists and policy-makers.

Research suggests that knowledge alone does not translate into changes in attitudes, behaviours or actions (Hungerford & Volk, 1990; Jensen, 2002; and Kollmuss & Agyeman, 2002). Significant life experiences in nature and influential role models are considered critical factors in developing pro-environmental behaviours and attitudes (Palmer et al., 1998). Through research partnerships with schools, the scientific community has demonstrated the ability to create programs that can result in significant life experiences for students and that scientists can become influential role models for both students and teachers. This case study demonstrates that the challenges of linking education and research can be addressed through effective planning of content, setting, and outcomes. One of the results of this case study has been to define the common ground from which science teachers, environmental educators and scientists can test their ideas and launch programs.

6.1 Summary

This study has examined one example of a scientific outreach program in an effort to better understand what makes an outreach program successful from a theoretical, practical, and experiential perspective. The purpose was to come to a better understanding of 'how' and 'why' the Schools on Board program is still experiencing success using the planning model established for the pilot program in 2004. The study of the SonB program was initiated by a desire to understand and identify strengths rather than weaknesses or problems. This was accomplished using an action research strategy that included ongoing reflection towards program evaluation and an action plan for program changes and improvements. The objectives identified at the beginning of this study provided direction at all stages of the research. The following were accomplished:

- Review literature on EE, SE, and SO to gain a better understanding of the criteria for a quality ESE program.
- Examine the planning process and stakeholder input of the 2004 field program to build a detailed case study of the program and identify the key planning decisions made during the design, planning, and implementation of the program.
- Apply criteria to the 2004 SonB program to evaluate the program from a pedagogical perspective.
- Identify recommendations for program improvement based on literature, practical experiences, and reflection.
- Identify an action-plan for change and future work (end of this chapter).

Summary of key outcomes of this study:

- Detailed documentation of the planning of the 2004 field program
- Identification of key planning decisions made leading to the 2004 program
- Evaluation of the SonB program indicating that the program meets the criteria for quality ESE programs.
- Identification of general and specific recommendations for program improvements.
- Discoveries about the program not previously noted or recorded

Summary of key findings of this study:

- Identification of criteria for quality ESE programs from which to assess the 2004 program and plan future programs to meet these criteria
- Better understanding of 'how' and 'why' the program works and the combination of factors (IN, ABOUT, and FOR) leading to successes.
- Better understanding of the forces larger than the program that influence the success of the program (i.e., increased public interest in climate change and environmental research, social and political influences on EE, reforms to SE, and the endorsement of SO by research funding agencies).

In addition to findings linked directly to the case study, the use of action research as a tool for reflective practitioner evaluation has resulted in personal transformation of the researcher. In the process of studying my own practice and program, I have become part of the change process explicit in the action research design. In the process of conducting this research, I have increased my own theoretical understanding of science education, environmental education, and scientific outreach. I am more comfortable in defining the program and my own role in educational terms, and I can now communicate with educators with a shared knowledge of language and understanding of EE and SE pedagogy. This research process has improved my professional knowledge and has helped me to define myself as a program planner and educator. I have a greater appreciation of the role that SonB can play in promoting outreach and education to scientists and educators by providing a vehicle for linking science education and scientific research.

During the two and a half years, consistent with reflection-in-action, I have implemented some of the changes and adopted some of the strategies described in the literature. Examples of this action-in-practice include: the expansion of the traditional knowledge component of our program both in content and in the creation of more opportunities to learn from experts in northern communities; integration of specific reflection activities in the onboard program; collaborations with teachers to become more aligned with learning outcomes documents; international collaboration with the ARMADA program of the University of Rhodes Island (USA) that offers training and field opportunities for teachers; facilitating one-on-one mentoring opportunities with scientists for 2 students following the 2005 and 2006 field program; greater involvement and networking in the EE community; and the promotion of education, communication and outreach at national science and education conferences. This immediate implementation of knowledge and understanding gained during the research process is consistent with the dynamic and transformational characteristics of action research.

In addition to the impacts of findings on changes to the program and the practitioner, the relevance of this study to the stakeholders of the SonB program includes the greater ability to transfer of knowledge within the Schools on Board organization through the documentation of the program planning process; supporting rationale for scientific outreach for funding agencies; and the potential for contributions to the growing literature and field of scientific outreach, most specifically, to literature related to research partnerships and authentic field-based experiences for students and teachers.

The purpose of doing an action research study on this existing program was to identify the planning considerations that will lead the SonB program into the future and ensure that the findings are transformed into action.

6.2 Action Plan

An action plan for implementing the recommendations from this study will require feedback and input from all of the major stakeholders of the SonB program and will be subject to funding. That said, I expect to do the following with the results of this study:

1. Report findings in a published Masters thesis
2. Report findings to SonB stakeholders by distributing copies of this thesis to program partners.
3. Contribute to the growing number of case studies on scientific outreach and research partnerships.
4. Develop a mission statement for SonB and re-visit program goals and objectives
5. Engage a greater number of stakeholders in the next phase of reflective practice with a planning meeting aimed at developing a 4-year plan that considers greater input from the advisory committee regarding recommendations presented in this study.

6. Plan a workshop with scientists and educators to develop polar resources that are linked to curricula.
7. Develop an evaluation plan at the program level and the participant level.
8. Subscribe to research journals in EE and SO to keep up-to-date on new developments in the field.
9. Become more involved in the education, outreach and communication networks in environmental science education.
10. Use findings to promote scientific outreach within ArcticNet.

6.3 Future Work and Study

This study has involved a review of literature across three related fields of study. In addition to the findings that point to program improvements and change, this research process has been a transformative learning experience for this practitioner-researcher. In addition to a greater understanding of the theoretical underpinnings and rationale for the program that I remain committed to, the learning experience in the research process has sparked interests in topics and questions previously not known to me. Potential areas of future research include:

1. Program Evaluation - investigate the feasibility of using or adapting existing tools to evaluate long-term impacts of the program such as Significant Life Experience research (Chawla, 2001; Palmer et al., 1998)
2. Program Evaluation - further develop criteria into an assessment tool for ESE programs
3. Participant Assessment - investigate the feasibility of using or adapting existing tools found in the literature such as BASSSQ – Beliefs About Science, and School

Science Questionnaire – (Alderidge, Taylor & Chen, 1997); and the Realistic Understanding of the Nature of Scientific Knowledge Instrument (Burnley et al., 2002).

4. Review literature on cultural landscapes to gain a better understanding of the emotional and cultural identity to the Arctic landscape; the impacts of climate change on cultural landscapes in the Arctic; the possible links between cultural landscapes and educating 'IN' the environment; and the culturally diverse responses to science experiences 'IN' the Arctic.

6.4 Postscript

Four years after the first field program, the SonB program is continuing to experience success. Based on the success of the pilot, this field program received unanimous support from the science community to continue offering unique field experiences through the ArcticNet scientific expeditions. To date, five field programs have occurred since the pilot. These included our 2008 International Polar Year (IPY) initiatives onboard the scientific expedition of the IPY- Circumpolar Flaw Lead system study (www.ipy-cfl.ca). IPY launched the SonB program to an international scale of activities related to education, outreach, and communication through its two international field programs that included students and teachers from 9 countries and the unique Circumpolar Inuit Field Program that included Inuit youth from Alaska, Canada, Greenland, and Russia.

In addition to the field program, the student forum has been developed into a standing component of the overall SonB program with the successful pilot of the Arctic Climate Change Youth Forum (ACCYF) that we now co-host every two years with a school in conjunction with a science conference. This event allows SonB to broaden its reach by bringing scientists together with more students and teachers, from a greater number of schools, for a day that explores the science behind Arctic climate change research and the role of science in decision-making. These successes have gained the attention of educators and scientists at national and international levels, with invitations to collaborate on outreach initiatives and speak at both science and education conferences.

Although our successes are specific to the SonB program, they are not limited to the SonB community and stakeholders. An Outreach Award from the University of Manitoba, an Award of Excellence in Environmental Education from Canadian Network for Environmental Education and Communication (EECOM), PromoScience funding from the Natural Science, Engineering and Research Council of Canada (NSERC), recognition by networks of scientists that include CASES, ArcticNet, IPY-CFL, International Arctic Polynya Program (IAPP), and most recently, the IPY Education, Outreach and Communication (EOC), are indicators that this program meets the standards of success of larger educational and research institutions, and that programs such as SonB, that link education and scientific research, are desired by both communities. It is with the knowledge of these successes that I needed to step back, observe, reflect, evaluate the program, and plan for the next stage of this ever-evolving program. In closing, we are all responsible for education that leads toward a more sustainable relationship with the natural world. This study confirms that action research, research partnerships, and authentic research experiences such as those created by the SonB program are several of the ways by which this responsibility can guide action.

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APPENDICES

Appendix A - Instructional Approaches in Science Education

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Appendix A – Instructional Approaches in Science Education

Instructional Approaches: Roles, Purposes and Methods				
Instructional Approaches	Roles	Purposes/Use	Methods	Advantages Limitations
Direct Instruction	• Highly teacher directed • Teacher uses didactic questioning to elicit student involvement	• Providing information • Developing step-by-step skills and strategies • Introducing other approaches and methods • Teaching active listening and note taking	Teachers: • Explicit teaching • Lesson overviews • Guest speakers • Instruction of strategic processes • Lecturing • Didactic questioning • Demonstrating and modeling prior to guided practice • Mini-lessons • Guides for reading, listening, and viewing	• Effective in providing students with knowledge of steps of highly sequenced skills and strategies • Limited use in developing abilities, and attitudes for critical thinking and interpersonal learning • May encourage passive, not active learning
Indirect Instruction	**• Mainly student centered • Role of teacher shifts to facilitator, supporter, resource person • Teacher monitors progress to determine when intervention or another approach is required**	**• Activating student interest and curiosity • Developing creativity and interpersonal skills and strategies • Exploring diverse possibilities • Forming hypotheses and developing concepts • Solving problems • Drawing inferences**	**Students: • Observing • Investigating • Inquiring and researching • Jigsaw groups • Problem solving • Reading and viewing for meaning • Reflective discussion • Concept mapping**	**• Active involvement is an effective way for students to learn • High degree of differentiation and pursuit of individual interests is possible • Teacher requires excellent facilitation and organizational skills • Focused instruction of content and concepts may be difficult to integrate**
Interactive Instruction	**• Student-centered • Teacher forms groups, teaches and guides small group skills and strategies**	**• Activating student interest and curiosity • Developing creativity and interpersonal skills and strategies • Exploring diverse possibilities • Forming hypotheses and developing concepts • Solving**	**Students: • Discussions • Sharing • Generating alternative ways of thinking and feeling • Decision-making • Debates • Role-playing • Panels • Brainstorming • Peer conferencing • Collaborative learning groups • Problem solving • Talking circles**	**• Student motivation and learning increase through active involvement in groups • Teacher's knowledge and skill in forming groups, instructing, and guiding group dynamics are important to the success of this approach • Effective in**

Interactive Instruction	• Student-centered • Teacher forms groups, teaches and guides small group skills and strategies	• Activating student interest and curiosity • Developing creativity and interpersonal skills and strategies • Exploring diverse possibilities • Forming hypotheses and developing concepts • Solving problems • Drawing inferences	Students: • Discussions • Sharing • Generating alternative ways of thinking and feeling • Decision-making • Debates • Role-playing • Panels • Brainstorming • Peer conferencing • Collaborative learning groups • Problem solving • Talking circles • Interviewing • Peer editing	• Student motivation and learning increase through active involvement in groups • Teacher's knowledge and skill in forming groups, instructing, and guiding group dynamics are important to the success of this approach • Effective in assisting students' development of life skills in cooperation and collaboration
Experiential Learning	• Student-centered • Teacher's role may be to design the order and steps of the process	• Focusing on processes of learning rather than products • Developing students' knowledge and experience • Preparing students for direct instruction	Students participating in: • Learning activities • Field trips • Simulations • Primary research • Games • Focused imaging • Role-playing • Surveys • Sharing observations and reflections • Reflecting critically on experiences • Developing hypotheses and generalizations in new situations	• Increase in student understanding and retention • Additional resources and time required for hands-on learning
Independent Study	• Student-centered • Teacher's role	• Accessing and developing student initiative	Students: • Inquiry and research projects	• Students grow as independent, lifelong learners

Instructional Approaches: Roles, Purposes, and Methods: Section 2-39 of Grade 11 Chemistry: Implementation of Grade 11 Chemistry, Manitoba Education and Training, 1999.

Appendix B – Chain of Evidence for the Schools on Board Case Study

Question	**Data**	**Outcomes**
How did S/B work? Case study Goals, objectives program components	Archival records – S/B computer files – getting started, planning, logistics, budget, map, curriculum documents Casual conversations with teachers; advisory committee Field notes – blue journal – early beginnings; black journal Meetings - Advisory committee Email interactions 2002-2006 Documents - letters, memoranda, announcements, written reports, agendas, proposals, media – newspaper clippings; posters & conferences; debriefings Expedition logbook Participant –observation	Links with science education and EE Links with scientific outreach Guiding principles Corroborate LB inputs Stakeholder input into development of the pilot program Ongoing reflections Stakeholder input Re-trace steps; stakeholder input Re-trace steps taken and decisions made to plan pilot program Reflections
Why did the program work? Explore the relationships between EE & SE Identify where scientific outreach and research partnerships are located in the literature	Literature – EE Literature – SE Literature - SO	Theoretical foundations Historical context Epistemological context Id similarities, differences Limitations Corroborate and augment evidence from observations
How can we improve the program? Look at other programs	Participant – Observation Evaluation forms Recommendations Literature results – criteria for evaluating a quality environmental science program Other programs Record of emerging interpretations Reflections – in and on practice	Viewpoint of someone inside the case study rather than external to it Corroborate and augment evidence from observations Evaluate the SonB program against criteria found in literature Id unique features Guiding principles Recommendations Future work and program improvements as result of this research

Appendix C – Letter of Permission

ArcticNet
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Quebec City, 5 July 2007

Graduate Studies Committee
Department of Environment and Geography
Clayton H. Riddell Faculty of Environment, Earth and Resources
University of Manitoba
Winnipeg, MB R3T 2N2

Dear Madam, Sir,

This letter confirms that Lucette M. J. Barber, Masters of Environment (candidate) at the University of Manitoba, is authorized to access *Schools on Board* files and documents for research purposes related to the following project:

Scientific Outreach: Linking Science Education in High Schools to Scientific Research - A Case Study of the *Schools on Board* Program.

This access is limited to non-confidential files.

Sincerely,

Martin Fortier
Executive Director, ArcticNet

Pavillon Alexandre-Vachon, local 4081 • Université Laval • Québec (Québec) • Canada • G1K 7P4 • T (418) 656-5830 • F (418) 656-2334
arcticnet@arcticnet.ulaval.ca • www.arcticnet.ulaval.ca

Appendix D – Initial Data Coding for Emerging Themes

Theme	Description	Sub-code	Description of emerging themes
100's	Environmental	100	EE – about (physical)
	Education	102	EE – about (cultural)
		103	EE – in (physical)
		104	EE – for (decision making)
		105	EE – (for) action
		106	EE – in (research culture)
200's	Science	200	SE – general
	Education	201	SE – scientific inquiry
		202	SE – technological problem-solving
		203	SE – decision making
		204	SE – traditional knowledge
		205	SE - learning by expert
300's	Scientific	300	SO – general – rational
	Outreach	301	SO – impacts – students
		302	SO – impacts – teachers
		303	SO – impacts – scientists
		304	SO – impacts – society
		305	SO – other programs
400's	Program	400	Planning consideration
	Planning	401	Ecosystem thinking
		402	Implementation consideration
		403	Evaluation
		404	Strategies to maximize impacts
500's	Program	500	Knowledge construction – reflection
	processes	501	Instructional strategies
		502	Experiential
		503	Group dynamics

Appendix E – Re-classification of Literature Dataset

Theme	Description	Sub	Description of emerging themes
100's	Environmental Education	101	EE – about (physical; cultural, socio-political)
		102	EE – in (physical; research culture)
		103	EE – for (decision making; action)
200's	Science Education	201	SE – about (general; scientific inquiry; technology; TEK)
		202	SE – in (research culture; learning by expert)
		203	SE – decision making; reflection; action
300's	Scientific Outreach	300	SO – general – rational
		301	SO – impacts – students
		302	SO – impacts – teachers
		303	SO – impacts – scientists
		304	SO – impacts – society
		305	SO – other programs
400's	Program Planning	400	Planning consideration
		401	Ecosystem thinking
		402	Implementation consideration
		403	Evaluation
		404	Strategies to maximize impacts

*Note that the 500's no longer appear as they were integrated into relevant themes within the 100-400 themes.

Appendix F – Re-classification of SonB Dataset

Theme	Categories	Sub	Description of emerging themes
100's	Environmental Education	110	SonB – content – About
		120	SonB – In
		130	SonB – For
200's	Science Education	210	SonB – content –About
		220	SonB –design – In
		230	SonB – For
300's	Scientific Outreach	300	SonB – rational
		310	SonB – impacts – students
		320	SonB – impacts – teachers
		330	SonB – impacts – scientists
		340	SonB - outreach
*400's	Program Planning		
	410 – Stakeholders – input; needs and resources		
	410 – Network		
	410 – Operations - administration		
	410 – Funding		
	410 - Public Relations		
	410 – Risk management		
	410 - Communication		
	410 – Program design – goals, objectives, rationale, key features		
	410 – Program structure – specific to field program		
	410 – Logistics – selection; criteria; travel; social & cultural components		
	410 – Program processes – reflection; group dynamics; experiential; informal interactions; social processes; happenstance		
	410 – Evaluation - process		
	410 – Ecosystems planning		

*The consolidation of the 400's was necessary due to the overlap occurring in the initial data entry. All 400 entries were renumbered and re-classified based on recurring themes specifically related to program planning. These themes were used to structure the case study in Chapter four.

Appendix G – 2004 Onboard Program Itinerary

(Subject to change due to weather and research schedules)

Day 1: **Travel and Rendez-vous** February 23rd (Monday)

Morning	Afternoon	Evening
ARRIVAL IN EDMONTON	ARRIVAL IN EDMONTON	ARRIVAL IN EDMONTON - Brief meeting prior to Inuvik departure - Pep talk - Introduce Discovery article – 06/96 "Running on Tundra" 10:30 Lights out

Day 2: **Life in the North** February 24th (Tuesday)

7:00 Airport 8:00 Depart for Inuvik	1:00 arrive in Inuvik - Check-in at Aurora Research Institute - 2:00 tour of ARI 3:00 community tour - focus on challenges of living, development, infrastructures etc. in high arctic – what do we take for granted living in the south?	6:00 Dinner and cultural event – ARI - Arctic Games demo? 8:00 Winter survival workshop – modern and traditional practice. 9:00 Email classes Pep talk - find out who has schoolwork to do while on the trip 10:00 Lights out

Day 3: **Student Exchange/Shuttle to the ship** February 25th(Wednesday)

8:00 Breakfast 10:00 school visit – student exchange – introduce themselves and share where they are from – discuss climate change from their perspective – use climate change poster series 11:00 conference call from classroom – invite northern leaders. Opportunity for students to ask question about life in Northern communities – their concerns for climate change. Northern students – ask questions back to specific schools in the south. 11:30 wrap up – thank you's	11:45 bag lunch (ARI) @ school 1:00 - airport 2:00 Shuttle to ship 3:00 Arrival and unpacking 4:00 Tour of ship – Karine Lacoste?	5:30 Dinner 7:00-7:30 Welcome – captain Stéphane Julien & chief scientist, Jody Deming 7:30-8:00 Icebreaker – meet the scientist – introductions all around - share a story or experience - sharing circle – scientists – how did they become…; students – why did they apply, and what do they want to take back from this experience. 8:30-9:00 – wrap-up - review format and schedule for next day - review expectations – punctuality; participation; daily recorders; outputs – daily logs, ppt presentation ready to be

		delivered; science article ready for submission - recommended routine – re: showers/meals - confirm field work chart 10:30pm Lights out

Day 4: **Oceanography** February 26th (Thursday)

Morning	Afternoon	Evening
8:00 Breakfast 8:45 Gather – identify recorders and recommended dress for afternoon fieldwork 9:00 Lecture – Oceanography – G. Ingram see Oceans 10 Student (1.0/2.0); currents; last slide – generate group discussion 9:30-10:00 – intro & demo of Salinity & Density/buoyancy lab – Seawater and its elements - Electrolysis of water – formation of oxygen; Conductivity of water versus seawater (making electrical circuits); Measuring dissolved solids – salinity and Ph; Electroplating e.g. with copper or silver OR Oceans 10 Lab 4; expanding step #13; use different combinations for more mixing; incorporate salinity and temperature; using a hand-held refractometer 10:00-10:45 – lab 10:45-11:15 – discussion of results (links to lecture) 11:15-12:00 – Polynyas – G.I slide show vs lecture; video clips; documentary; pictures, maps – "you are here.." National Film Board "The Secrets of Ice" and "Life of Ice"	12:00-12:45 Lunch 1:00-1:30 – features of the Arctic icescape see – Oceans 10 Module 1 sec. 5 1:30 – prepare for ice tour 2:00-4:30 – ice tour in half track and snowmobiles – identify features G.I & wildlife monitor Include traditional knowledge Input from northern students Backup: 1. demo of rosette by technician 2. tour of ships' operations – chief engineer (30min); CASES tech guy (30 min); navigations – including maps (30min).	5:30 Dinner 6:30 Debriefing of the day's activities - linking everything together – lecture; lab; and tour. Informal discussion. Use a concept map to summarize. Link to climate change: what will happen in a climate change scenario if we get more polynyas. Refer to significance of the NW passage and the ISUMA article on Sovereignty. Invite someone from the CCG to share their views. See Oceans 10 Module 5 Student Guide p.20 8:00 Arctic Literature – using short stories/legends to stimulate discussion on social issues. Read short story. In small groups identify the social issues embedded in the story. Large group discussion/sharing of ideas. 9:00-10:00 Recreational activity in cafeteria i.e card game – first draw of a tournament – check for traditional northern game. 10:30 Lights out

Day 5: **Snow & Sea Ice** February 27th (Friday)

Morning	Afternoon	Evening
8:00 Breakfast 8:45 Gather – identify recorders	12:00-12:45 Lunch 1:00 – 1:30 – organize for field work – assign new groups each day	5:30 Dinner 6:30/7:00 Debriefing of the day's activities - linking

9:00 Lecture - S-2 Snow & Sea Ice **9:00 – 9:30 – physical char. of snow and ice R.S** 9:30-9:45 – intro activity A – Ice and other crystals (GI/HB) Growth of ice crystals from the melt (i.e. water);Effect of salt on ice crystals – morphology, depression of freezing point of water, cooling curves; growth of crystals from solution precipitation of calcium carbonate; growth of crystals of potassium alum/copper sulphate growth of crystals in gels 9:45 – 10:15 – Activity A 10:15-10:30 – discussion – linked to navigation and safety 10:30-11:00 – the ice habitat & ice distribution C.B/CJ 11:00 – 12:00 Activity B – small group work with maps see Oceans 10 Teachers Guide p.29; acquire maps from DB and CIS. "What do you see?" ; ice coverage maps showing seasonal variability. Report back to large group. Discussion on impacts of ice-free summer in the Arctic	and disperse according to schedule 1:30 – 3:00 – Fieldwork session #1 Gr. 1: Gr. 2: Gr. 3: 3:00 – 4:30 – Fieldwork session #2 Gr. 1: Gr. 2: Gr. 3: 4:30-5:00 – inputting – time to catch up on logs, journals, presentations, articles, etc. email back home	everything together – lecture; lab; and fieldwork. Informal discussion re: challenges 8:00 Inuk names for ice – see Oceans 10 Module 1-sec. 3. In small groups, make a chart of both ways of characterizing sea ice. Social Issue – how do we blend traditional and scientific knowledge? What are the challenges? Invite anyone who is currently working of TK as part of their thesis. 9:00-10:00 Recreational activity in cafeteria i.e card game – round 2 10:30 Lights out

Day 6: **Meteorology** February 28th (Saturday)

Morning	Afternoon	Evening
8:00 Breakfast 8:45 Gather – identify recorders 9:00 Lecture – S-2 Meteorology R.H/J.B Background – importance of solar energy; seasons; incoming energy cycles (24hr vs 0hrs of sunlight); role of wind and hydrology – see Arctic Observatory CDROM Climate monitoring and research Role of Environment Canada	12:00 – 12:45 Lunch 1:00 – 1:30 – organize for field work – assign new groups each day and disperse according to schedule 1:30 – 3:00 – Fieldwork session #3 Gr. 1: Gr. 2: Gr. 3: 3:00 – 4:30 – build an instrument; set it up and start recording data – group project (RH)	5:30 Dinner 6:30 Debriefing of the day's activities - linking everything together – lecture; lab; and fieldwork. Informal discussion re: challenges. Arctic Night sky – Northern Lights- scientific explanation; traditional; legend – come prepared to discuss it if the opportunity presents itself 7:00 Recreational time –

in forecasting. 9:30-10:00 - intro & demo Albedo – see Oceans 10 Lab 7 with modifications; Radiometer experiment. 10:00-10:45 - lab 10:45-11:15 - discussion of results; "what if's…."; difference between open water & ice cover; role of sea ice 11:15-12:00 – components of a Met station; chart– scavenger hunt – find components on ship	4:30-5:00 – inputting – time to catch up on logs, journals, presentations, articles, etc. email back home	Popcorn & Movie – "The Fast Runner" - think of the social issues discussed the previous night. 10:30 lights out

Day 7: **Life – Productivity** March 1 (Sunday)

Morning	Afternoon	Evening
8:00 Breakfast 8:45 Gather – identify recorders 9:00 Lecture – S-3&4 9:00 – 9:30 – primary production intro to phytoplankton; biology of…; role of light; intro to color mapping. KL/HB? 9:30-9:45 - intro activity A – extracting chlorophyll a & b using chromatography. HB/GI 9:45 – 10:30 – Activity HB/GI 10:30-11:00 – discussion – absorbance of light – intro to maps with reference to difference of scales – micro – to satellite 11:00 –11:15 intro to Activity B - Colors of the Ocean –graphing out productivity using color maps from S.Demers 11:15-11:45 – Activity B 11:45 – 12:15 discussion of results	12:30 Lunch 1:15 – 1:30 – organize for field work – assign new groups each day and disperse according to schedule 1:30 – 3:00 – Fieldwork session #4 Gr. 1: respiration experiments on copepods (S5 – G .Darnis) Gr. 2: "Wet chemistry" (S4- Llyd Wells (J.Deming) Gr. 3: 3:00 – 4:30 – Fieldwork session #5 **Gr. 1:** Gr. 2: Gr. 3: 4:30-5:00 – inputting – time to catch up on logs, journals, presentations, articles, etc. back-up: visit ice camp – fieldwork logistics, setup, instrumentation etc.	5:30 Dinner 6:30/7:00 Debriefing of the day's activities - linking everything together – lecture; lab; and fieldwork. Informal discussion re: challenges 7:30 Jody Deming – Astrobiology – linking the study of arctic marine life to the study of life in outer space. 8:30 Recreational time – Popcorn & Movie – "The Shakelton Expedition" – issues of Arctic vs Antarctic exploration; Are scientists modern-day explorers? 10:30 Lights out

Day 8: **Life – Food Webs/Climate Change** March 2 (Monday)

Morning	Afternoon	Evening
8:00 Breakfast	12:00 Lunch	5:30 Dinner

8:45 Gather – identify recorders 9:00 Lecture –S5/6/7 ? Food webs and the carbon cycle. Describe work. 9:20-9:45 - Using real lab samples, identify their place in the food web – (TB - Ddeibel's student). Bring in benthic community – shells (A.Aitken) 9:45- 10:00 Food Web activity Small group work- simulate a food web using pictures; demonstrate connectedness with string activity. 10:00-10:15 - Discussion: what happens when one piece disappears? Or when something new is introduced? 10:15 – 10:45 -Contaminants video clips (Rzuk) – other suggestions? 10:45-11:30 Carbon Cycle activity – worksheets. Demonstrate the connectedness of the global carbon cycle – will the oceans become carbon sinks or will they 'expire' more carbon into the atmosphere?	1:00 – 2:30 – Fieldwork session #6 Gr. 1: Egg production experiments on copepods (S5 – G. Darnis Gr. 2: : Llyd Wells (J.Deming) Gr. 3:TBA 2:30 – 3:00 – Climate change – background 3:00 – small group work- prepare positions 3:30 Debate – climate change – See Oceans 10 Module 5 Student Guide p. 26-39. How should we react? Precautionary principle? Philosophical debate – include articles in booklet or consensus-building exercise – role playing; stakeholders; arrive at an Arctic Climate Change accord. HB/GI/teachers facilitate each stakeholder group (aboriginal, scientist, developers, international) – establishing positions on given set of questions. Discussion – bring it back home 4:30 wrap up loose ends Email back home	Student Forum – brainstorming issues and format 8:00 Thank-you's and Student send-off Student presentation to the science team – re: their experiences - summary of the weeks activities – slide show with pictures and music – candid Evaluation

Day 9: **Wrap-Up/Departure** (Tuesday) March 3rd

Morning	Afternoon	Evening
8:00 Breakfast 8:45 Gather - Wrap up - prepare news article - ppt presentation 10:00 Packing and cleaning 11:00 Shuttle to Inuvik	12:30 airport 1:48 depart for Edmonton Alternative: overnight in Inuvik and depart the next day for Edmonton	6:39 Arrival into Edmonton

Day 10: **Travel** March 4th (Wednesday)

Morning	Afternoon	Evening
DEPARTURE ARRIVAL	FROM TO	EDMONTON DEPARTURE CITY

Appendix H – Schools on Board Selection Criteria for Students and Teachers

Student Criteria	Teacher Criteria
• Grade 10-12 (15-18 yrs old) • Keen interest in science – currently enrolled in related science courses • Strong academic record – minimum 'B' average • Self motivated • Works well in teams • Demonstrates strong communications skills • Experience in extracurricular activities • Moderate level of physical fitness • Healthy level of curiosity and sense of adventure • Capable of travelling unaccompanied • Working knowledge and understanding of English	• Experience teaching science at the high school level • Keen interest in science, the environment and research • Experience chaperoning students on field trips • Meets the schools requirements for chaperoning students • Good facilitation skills • Willing to engage in group work • Willing to participate as learners and educators • Demonstrate strong communication skills • Healthy level of curiosity and sense of adventure • Moderate level of physical fitness • Working knowledge and understanding of English

Appendix I – Communication Plan

Ongoing flow of information to field program participants (students, teachers, schools, scientists)

A. Students and Teachers

* It's important to recognize that parents and families are an important subgroup and that they will have questions regarding logistics, waivers, risks, and how to keep in touch with participants and their activities during the program. This information should be communicated through the participants.

Pre-trip	• How to apply - selection process and criteria – web and mail • Selection results – Welcome On Board – email • Required forms (waivers; code of conduct) – email and mail • Pre-trip information: general information about life on the ship; facilities; suggested packing list - email • Background information – resources; access to research information on the CASES website - email • Suggested Email Activities to prepare and provide background knowledge - email • Travel arrangements - email • Travel documents & itineraries - email • Field program itinerary - email
During field program	• Program orientations and teachers meeting – face-to-face • Establishing open lines of communications for the ease of expressing concerns – face-to-face • Daily schedule – Participant manual • Resources on each discipline – Participant manual • Review schedule and identify changes at beginning of each day • Daily debriefings at the end of each day • Pep talk – mid trip – face-to-face • Recognition – Student Certificate; Teacher Certificate - given at the end of the program • Participant evaluations – forms • Follow-up with scientists/researchers – contact list of onboard scientists in handbook; participants each given their own SonB business cards to exchange with scientists
Post-trip	• Involving participants in the School Evaluation - email • Follow-up on presentations and outreach - email • Identifying 'success stories' – email

	• Letters of reference – upon request – email; mail • Tracking participants - email • SonB Alumni - email • Sending future SonB Announcement of opportunities to SonB Alumni – email

B. Schools

Pre-trip	• Schools on Board Announcements to schools; teachers' associations; school boards; SonB Network of Educators – email and mail. • Thankyou for their interest in the program – acknowledge all interested schools – email • Information on the Application process – email, mail • Registration to the SonB Network - email • Results of Selection of schools – email • Welcome on Board – to successful schools – email • Process, application forms, and criteria for selecting students and teachers – website; email • Required forms – website; email • Payment schedule and invoices for registration fee – email; mail • Program expectations – email • Resources & links for connecting classrooms - email • Schools cc'd on all information sent to participants – email • Encouraging schools to coordinate media interviews with their students and teachers while onboard the ship – email; phone
During field program	• Contact with student or teacher from the ship – email; phone; conference call • Following the students and teachers from their dispatches – website
Post-trip	• School Evaluation • Recognition of their sponsors - website • Facilitate follow-up with scientists/researcher – contact list of onboard scientists • Recognition – thank you for their collaboration – email; School Certificate • Copy schools on communications regarding follow-up opportunities with scientists

C. Scientists

*It is important to keep emails to scientists short – not lengthy with description.

Pre-trip	• Ongoing communication of outreach activities – SonB Announcements; SonB Network • Support requests for information by scientists who are promoting the program to schools in their area - email • 1st contact with onboard scientists – intro to SonB; invitation to participate in the

	onboard program – email to scientists and their Principal Investigators (PI) – email • Contact PI's to identify a contact person for each science team - email • 2nd contact with onboard scientists – communicate directly with interested scientists to plan onboard program – email • Encouraged to do classroom visits • PI's cc'd on relevant communications with scientists – email • Invitation to participate in conference call – email; phone • Directions for participating in conference call – email; phone • First draft of schedule sent to captain and chief scientist for feedback - email • Updates on the onboard program to all scientists – email • Request for background information and materials to add to participant manual – supplements to their lecture, lab, or field activity – email; handouts • Identify possible conflicts in the schedule re: shared lab spaces; research schedules etc • Send final version of onboard plan prior to departure –email
During field program	• Confirming commitments upon arrival and on a daily basis • Making changes when necessary – face-to-face • Recruiting new opportunities on a daily basis • Attending onboard science meetings to inform scientists of our activities – face-to-face • Inviting scientists and ship crew to feel free to attend evening activities – posted on ship's notification board • Requesting copies of their presentations – face-to-face • Recognition – thank you's by students and teachers; program t-shirts; planned ThankYou and Farewell presentation on last day; special presentation to captain and chief scientist as representatives of ship's crew and science teams.
Post-trip	• Scientist evaluations - email • Expedition report submitted to chief scientist - email • Final report – email and printed • Communicating SonB activities and outcomes at the following science meeting or conference – powerpoint presentation; poster • Access to SonB slides to add to science presentations – ftp site cds • Thankyou to all participating scientists – email • Communications with interested schools re: followup activities with school or student – classroom visits; invitations to attend science meetings, workshops, conferences; providing co-op, volunteer, or employment opportunities as research assistants.

Appendix J – Example of Hypothesis-Driven Activity

Schools on Board – Field Program
HYPOTHESIS DRIVEN LAB ACTIVITY
Subgroup: **3. Light, Nutrients, Primary and Export Production in Ice-Free Waters**

Tracking down phytoplankton biomass in the water column

Lab Created by: Karine Lacoste
Lab Instructor: Karine Lacoste

This lab will take place: In the conference room

Time required to complete this lab:
Investigation: 1½hr (see field activity)
Breakdown for a 1½hr lab: 10-15 minutes to describe and demo activity; 45 min. for the students to put into graph the data they collected in the fieldwork activity as well as other data from other time periods or areas, also to look at results from nutrients.

Student output: 30 min. compare and interpret results of data worked on

PREPARATION
Background reading on phytoplankton attached document.
*This lab activity needs to be done after the fieldwork activity. Results will have come from the fluorometer readings that the students will have done prior to the lab activity. In the event of problems related to filtration or fluorometer readings, dataset from previous sampling on board the ship will be provided to the students for them to analyse.

BACKGROUND

Planktonic production estimates for the arctic continental shelves are scarce, due to the difficulties associated with access to these areas. Furthermore, the mechanisms related to the inter-annual variability of primary production with regard to natural physical and/or biological forcing are not well known. The lab activity done during the Schools on Board programme intends to describe the water column distribution of the size-fractionated phytoplankton community of Franklin Bay during the month of February and compare it to other time periods of the CASES project. Although the CASES project will cover a much larger area over a longer time frame, the results of this lab activity will contribute in answering some of the objectives of the primary production subgroup of the CASES project that are:

1. To determine the biomass and the production of pico-, nano- and microphytoplanktonic cells in the photic zone over the Mackenzie Shelf, and in the Cape Bathurst polynya and Franklin Bay areas.
2. To evaluate the relative contribution of phytoplankton to the total primary production in these areas
3. To assess the effects of the bio-optical factors on the vertical attenuation of the ultraviolet component of the solar spectrum in the water column, and
4. To define the bio-optic characteristics of the assemblages of pico- and nanophytoplanktonic cells by flow cytometry, to calibrate SeaWifs satellite images which reflect the local characteristics of the Beaufort Sea.

RESEARCH QUESTION
What is the size-fractionated distribution of phytoplankton in the water column of Franklin Bay?

HYPOTHESIS
H1 Water column distribution of phytoplankton biomass in the Franklin Bay area will be lower during the winter months that in the fall period
H2 Small phytoplanktonic cells will be dominant during the winter period

EQUIPMENT/INSTRUMENTATION (none needed for this lab)

METHODS

1. Enter data sets into spreadsheet (done on front screen by lab instructor)
2. Enter formulas to calculate Chl *a* quantities (done on front screen by lab instructor)
3. Make graph with data sets of different fraction size and of various areas
4. Interpret results, discuss them and compare with results from other stations of the study site

DATA COLLECTION (enter final results into this table)

Station	Depth sampled *(m)*	Filter type *(μm)*	Chl *a* conc. *(ug/L)*		

RESULTS (Student Output)

Sheets for making graphs will be provided

DISCUSSION/CONCLUSION

Is there a chlorophyll maximum at this station for this period of the year? What can you say about this chlorophyll profile of the water column?

How does this data set compare to the other data sets that you analysed? What is similar? What is different?

How could you explain those similarities and dissimilarities?

PREPARATION DOCUMENT

Plankton, a word derived from the Greek term "planktos" which means to wander, are bacteria, plants, and animals which drift passively in the water because their swimming ability is limited or non-existent. Many can swim actively, but they are so small that they usually cannot move faster than the waters are flowing. Plant members of the plankton are termed phytoplankton (phyto=plant) while the zooplankton (zoo=animal) are the animal plankton. Phytoplankton are microscopic plants that contain chlorophyll and hence obtain energy for growth by phytosynthesis. Zooplankton are small herbivorous or carnivorous animals that feed on phytoplankton or on other zooplankton. Phytoplankton live near the surface in the *photic zone* where there is enough light for photosynthesis (<100 m approx.), while zooplankton are present in the photic zone as well as in much greater depths.

One simple way in which oceanographers describe planktonic organisms, whether plants, animals, or bacteria, is to classify them by size. Three groupings are commonly used. Those having diameters between 20 and 200 micrometer (μm) are called microplankton; we find in this group phytoplankton cells called diatoms and dinoflagellates. (A human hair is about 100μm in diameter.). Plankters less than 20μm in diameter but larger than 2μm are called nanoplankton; this group has phytoplankton organisms such as coccoliths and silicaflagellates. The smallest category of plankton is the ultraplankton that are smaller than 2μm and include bacteria and cyanobacteria.

Diatoms are the most common and most important group of phytoplankton found in arctic waters. They are single-celled algae and have hard external skeletons made of silica, in either a pillbox or rod-like shape. Some species have sticky threads or long spines protruding from their bodies and form long chains of individual cells, especially in nutrient-rich waters. The second most abundant phytoplankton are dinoflagellates. Dinoflagellates come in a variety of shapes and forms but are usually recongnizable because of their paired, whip-liked flagella that renders them capable of movement. Some have rigid cell walls made of cellulose, while others do not. Coccolithophores, another major group of flagellated phytoplankters, are distinguished by their coatings of tiny calcareous plates. Finally, a group of bacteria – the cyanobacteria (having blue-green pigments) – include some of the smallest types of phytoplankton as well as some of the largest. Some cyanobacteria play a very important role as nitrogen fixers in the ocean. Phytoplankton cells contain *chlorophyll* or some other light-absorbing pigment that allows them to synthesize organic matter, using energy from sunlight and nutrients dissolved in the water.

These pigments capture energy from sunlight, and the marine plant then uses that energy to combine dissolved carbon dioxide with water, forming carbohydrates, which are energy-rich compounds consisting of carbon, hydrogen, and oxygen.

$$6\,CO_2 \;+\; 6\,H_2O \;+\; 120\text{ kcal} \;\rightarrow\; C_6H_{12}O_6 \;+\; O_2$$

carbon dioxide   water   radiant energy   carbohydrate   oxygen

The availability of light controls plant growth and phytoplankton distributions in the ocean. Light is absorbed as it passes through water. The clearest open-ocean water is most transparent (absorbs the least amount of light) in the blue-green range of colors. As concentrations of particules and dissolved organic matter increase, the color of the light that penetrates deepest into the water shifts from yellowish green in coastal ocean waters to red in the most turbid estuarine waters. Thus, as light gets dimmer with increasing depth, its color also changes. This change in color affects plant production because each plant pigment is most efficient with a specific color of light. The combination of pigments found in any type of phytoplankton will determine its *optimal depth distribution.*

The chlorophyll content per volume of seawater gives a direct reading of the total *biomass* of plants present. The determination the chlorophyll *a* pigment, using the fluorimetric method, represents the most common method of assessing the production of phytoplankton in the sea. Color sensors on satellites also measure chlorophyll concentrations, however only of surface waters, and consecutive satellite images show how these concentrations change with season. Such measurements can be averaged and combined to provide maps of the global distribution of marine plant growth.

Primary production is affected by several factors. The most important are:
Light: Phytoplankton production is closely coupled to sunlight as a source of radiant energy for photosynthesis. There are four aspects of light which are mostly important when studying phytoplankton productivity: (1) the intensity of incident sunlight; (2) changes in light on passing from air into water; (3) changes in light with increasing water depths; and (4) the utilization of radiant energy by phytoplankton cells.

Nutrients: In addition to light, marine plants need a number of nutrients for adequate growth and reproduction, the most critical being nitrogen, phosphorus, and silicon.
Nitrogen (as nitrate (NO_3), nitrite (NO_2), and Ammonia (NH_3)) is the chief limiting element to primary production growth in estuarine and oceanic waters. Nitrogen is particularly important in the formation of proteins.

Phosphorus plays a role in energy transfers and in the formation of cells membranes and genetic materials. Phytoplankton takes up phosphorus primarily in the form of phosphate (PO_4). Zooplankton grazing and excretion account for rapid regeneration of phosphates in *pelagic waters*. The amount of phosphate in seawater is rarely limiting which makes nitrogen shortage rather than phosphorus limitation more deemed to be responsible for halting the growth of phytoplankton populations in marine ecosytems. Nitrogen and phosphorus undergo seasonal cycles usually accumulating and peaking in the winter, subsiding rapidly in the spring, remaining low in the summer, and rising again in the late fall. As phytoplankton populations increase in the spring, they assimilate nutrients which then become depleted. In winter, phytoplankton populations decline, and the nutrients attain maximum levels.

Silicon (Si), when present in very low amounts, represses metabolic activity of the cell and can limit phytoplankton productivity. However, it also represents an essential element for the skeleton growth of diatoms. Some of these elements are often scarce in seawater, and this scarcity limits production for many organisms, even when there is enough sunlight. Scarcity of any one nutrient can limit production, but in many ecosystems two or more nutrients are co-limiting. As plants die and decompose in the surface zone, about 95 percent of the nutrients contained in their tissues is released into surface waters by decomposition and quickly taken up by growing plants. The remaining 5 percent is released below the surface zone, because some of the tissues and shells sink before decomposing. Because there is usually too little light for photosynthesis at these lower depths, nutrients released in the *aphotic zone* accumulate there. These deep-sea nutrients move along with sub-surface currents and are returned much later to surface waters. Hydrographic components exert a major influence on primary productivity in the ocean as well. Currents and upwelling create mixing of the water column and help deep-sea waters to return to the surface of the sea. They therefore, both effect light and nutrients conditions by limiting or enhancing phytoplankton productivity.

Zooplankton grazing: Of all biological factors, grazing by herbivorous zooplankton most significantly limits phytoplankton production. Whereas some phytoplankton losses in the ocean arise via sinking below the photic zone, the vast majority of cells disappear by zooplankton grazing. Grazing intensity by these herbivores varies both in space and time. Selective feeding by zooplankton potentially governs the composition of the phytoplankton community. When grazing is intense and phytoplankton abundance decreases below a critical level, zooplankton abundance likewise wanes after a lag period.

Coastal waters and estuaries typically are much more productive than the open ocean. These habitats are shallower which allows light to sometimes penetrate the entire water column and nutrients levels to be much higher than in open-ocean areas therefore creating an excellent environment for plant growth. When these favourable conditions are present, there is usually a rapid increase in phytoplankton abundance and biomass; such a rapid increase is called a bloom. When a bloom occurs, the number of phytoplankton cells can double in a day or two. The bloom ends when one of two things happen, either the growing phytoplankton populations use up the available nutrients which they require for photosynthesis, or the herbivores eat the phytoplankters, greatly reducing their numbers. In seasonal plankton cycles, phytoplankton blooms are often superseded by a peak in zooplankton abundance.

Definition of key words:

Aphotic zone: part of the water column where there is not enough light for photosynthesis.

Biomass: amount by weight of plant (or animal) matter per volume of seawater (g/m^3 or mg/l).

Chlorophyll: green pigment of plants and bacteria that is necessary for photosynthesis.

Optimal depth distribution: depth at which productivity is most favoured.

Pelagic waters: part of the water column where most organisms live

Photic zone: part of the water column where there is sufficient light radiation to allow photosynthesis.

Primary production: rate at which new organic material is synthesized from inorganic substances (primarily carbon, nitrogen, and phosphorus) using radiant light as a source of energy for photosynthesis. Primary production is measured as grams of carbon produced in one square meter of water per day (g $C/m^3/d$).

Text inspired from the following references

- Gross, M.G., Gross, E.R, and Maybaum, H.L. (1996). Oceanography: A view of Earth 7th Ed. Prentice Hall Inc., Upper Saddle River, NJ
- Kennish, M.J. (1989). Practical handbook of marine science 2nd Ed. CRC Press, Inc. Boca Raton, FL

Meadows, P.S. and Campbell, J.I. (1978). An introduction to marine science 2nd Ed. Tertiary level Biology, London

Appendix K – Recommendations from 2004 program evaluations

The following recommendations are the result of critical examination by the program coordinator, discussions among the 4 supervisors on the 2004 Field Program, as well as the accumulation of feedback from participant, scientist, and school evaluations. For the purpose of organization, the comments have been divided into 4 main categories: 1) Planning and logistics; 2) Communication and outreach; 3) Onboard program; and 4) Community visits. The items are randomly presented (not in order of importance).

1. Planning and logistics:

S/B contact identified on school application – someone who will be cc'd on all correspondence sent to students
Email correspondence – consolidate requests for info; identify who the email is directed to in the body of the email i.e.: ATTN: Participants; ATTN: Schools
Separate Application form for teachers
Student application form – add postal code
New application forms for schools; students; teachers
Lawyers – one generic waiver for all S/B activities
Waiver – include: I hereby authorize the University to seek emergency medical assistance for my child named in this @ if the parents/guardian or emergency contact cannot be contacted. I understand that over the counter mendications (e.g. Tylenol) may be used during Camp and hereby authorize the use of such medication for my child if required
Gear – add to registration fee but then turn it over to the school - provide an allowance for gear – managed by the school (budget allowing)
Student criteria – ability to travel unaccompanied; or stress that the trip starts from Edmonton
Criteria for teachers – same as students; primary role is supervision; willingness to prepare and/or engage activities for the students; expectation that teachers would prepare a set of lesson plans ~3; same as students'; participation in all activities
School – willingness to prepare students ahead of time – do an orientation with the student; pre-readings or discussions; participate in conference call
Accompanying teachers – need one male; one female
Summary student info form– use form from (CASES)– add medical insurance details
Accompanying academic/science teacher – integrates and fills in the blanks
Make arrangements ahead of time with captain re: space for evening – conference room dedicated to S/B for the duration or a combination of the conference room and the cafeteria.
Make arrangements for a complete safety orientation – i.e. emergency drill
Re-evaluate templates – make them simpler in design
Shirts – student shirt –- Different color/graphic for instructors and scientists
Scientist shirts – good idea – M/L's – need to bring extras for additional scientist participation
Mentoring – selected students/teachers are paired with a scientist (voluntary) who will be on board during the field trip – suggested email activities with the participating scientist prior to the trip; working more closely during the trip; and follow-up after the trip.
Need at least 2 computers for students to use –schools should provide a computer
Need a digital video camera and one blank tape per student – conducting interviews etc.
Need 2-3 GPS units – one for each group
Plan a GPS activity for schools – see Polar husky web site

Re-visit climate change poster activity for schools – pre-trip activity
Re-evaluate length – 4 full days, one half day on departure probably better?
Honorariums for food – gave a bit too much money – re-calculate
Exit interviews are NB to continue – one-on-one; face-to-face with each participant

2. Communications and outreach:

Web page – revamp – update 2004 program and create new content re: ArcticNet
Web page - add educational tabs – include field program activities; links resources; teacher's page
Web page - a tab for Educator's role & recommended prep activities – include the climate change activity; students organizing a speaker; specific labs; prep for conference call; activity to introduce entire classroom to the science of ArcticNet
Web – content - Re: general information - participants must be self-insured (via work, parents, or purchased) – S/B provides trip cancellation insurance only
Web- tab for sponsors
Web – tab for Outreach – S/B should become the posting site for all ArcticNet outreach – including international projects i.e. La Carotte de Classe (France)
Web – interviews between students and researchers – created onboard the ship
Give students more time to prepare their presentations – practice & feedback from the group
Live media interviews went well – should be planned ahead of time – important to inform students on proper interview techniques – get a handout from A.Blouw (DFO) or article on communicating science from Peter Calamai (Toronto Star)
Conference call – excellent idea; important to have scientists (South) involved – important to direct questions to them; could have been longer in duration; need to make this a required activity with all schools involved; could provide more guidance re: questions directed to the science and students
Get a copy of ppt presentations from students before they depart
Students should know what their school/school board expects re: presentations – minimum – one to school and school board.
Communication with schools while on the ship – live links?

3. Onboard Program:

As many hands-on activities as possible – focus on labs and fieldwork
One or two hypothesis-driven activities that whole group can follow.
Handbook – create as one document – in outline format
Handbook – breakdown into two books – 1) a resource book – intro, general information readings to be sent ahead of time – summary of the scientific team; intro to some of the major themes of the project – i.e. - oceanography; carbon cycling; primary production; climate change; meteorology; etc. and 2) a student handbook – orientation; safety; schedules; daily schedule and lecture, lab and fieldwork outlines – plan one less activity replaced by more time to work – use handbook
Evaluation/participant report – include the following questions: Why did you apply to S/B? What did you expect? How did the program meet or fail to meet your expectations? How did it impact you personally? If you had to describe your experience in one paragraph, what would you say? Did you have any additional comments?
Icebreakers on-hand for delays during transit
Plan a lighter first day – time for orientation; familiarization; etc. – place immediate emphasis/expectation re: filling out worksheets in the handbook
Communications – phone home 2/wk; phone school 1/wk; email school each day

Students introduce speakers and thank them
Students should introduce themselves to the scientists before they go do fieldwork – who they are, where they are from, etc.
Pin exchange between participants was good – should be done in day 2/3 of the program – they should introduce their town, region, school, identify a few concerns they have re: climate change; and exchange the pins; more dialogue
Sachs Harbour activity – movie; note taking
Need to ensure that the worksheets and concept maps are completed
Concept maps – provide more time to complete – make them required – proof to teachers back home of the learning involved in the field program.
One less activity per day – more time to use worksheets in the handbook
Teachers – actively engaged in the program – delegate specific activities; duties – lead at least one evening activity
Small group designation – one from each region worked well; change them everyday – rotate them so that they are working with different people every day
Dispatches – done by students – in groups – one recorder from each group
Debriefing activities – looked forward to these activities – talking stick was an excellent idea – used something different each night (pen, thermometer, Pringles container, ruler, etc.
Socializing with scientists was important – planned socializing – limited and with curfews
Important to review code of conduct on first night – with the entire group
Orientation meeting include - media – review sensitivities re: photography, video recording
Pictures – continue to use a central library – identify a common resolution so that the quality is adequate and consistent. – each participant should have a folder in a central library
Building an instrument – very positive activity – make sure instruments can work in cold environments – weren't able to get readings.
Take group picture indoors and/or outdoors – faces exposed to identify participants
Recreation - Pictionary game – terms learned in the program – went well – good to do later in the program - Recreation - Need an icebreaker activity in day 1or 2 of the program
Oceanography: get video of NOW polynya from Grant Ingram; CTD demo and salinity profiling lab provided good hands-on
Sovereignty discussion – good to keep; include the captain – ask in advance and provide him with materials ahead of time.
Include evening session on communicating science – media (interviews); public – invite scientists
Sea Ice – processes and structure – a little too technical
GPS tracking activity – would have been nice to have GPS for each group of 3; start with an introduction on how to use the units, and follow it up with a tracking activity
Arctic Literature – good – get copy of video from Clint Surry; might be nice to organize a bookclub activity – i.e. get short story/legend to students before the trip and have a discussion on the ship – invite scientists to participate
Recreation - Movie (Atanarjuat; Shakelton; CASES – Nature of Things) good choices; nice break
Evening presentations by senior scientists – very good; well attended by scientists –NB to find out if sen.scientists that will be on-board are willing to give a presentation – does not necessarily have to be on their science – find out if there is someone on-board who has a related interest/presentation that they would like to share i.e. Picasso and DNA; Europa/Mars
Evening session on Inuit Knowledge – NB to continue – Sachs Harbour video and role play activity good – should be done in 2 sessions – 1) video and worksheets to identify changes and impacts; 2) role-play activity re: politics of change; community involvement
Climate change – important to include – should re-visit the climate change poster series;

important to link the field program topic areas to climate change debate – can be used to engage classrooms back home
Last evening – thankyou slide show was well received – include music – both French and English, traditional– summary of the whole week – followed up by social time with scientists
Thankyou draw for $20 canteen (phoning home) – one draw for the crew and one draw for the participating scientists (graduate students)
Piloting a TEACHERS' FIELD PROGRAM? Summer; fewer teachers (3-4) for a longer period of time; teacher paired with a specific science team/project – see TERC and TEA (U of Rhode Island)

4. Community visits:

Best done after the field program – students can share their experiences and northern students can deliver their ppt presentations.
School visit – should include a presentation of schools on board; activity time with students of similar age – opportunity to interact;
Include meetings with local elders; politicians, monitors, etc…
Link community visits to community-based monitoring activities where ever possible
Include a blend of cultural activities, tours, and school visits
Having 2 community visits worked well – Inuvik is a larger, more modern center; Tuktoyaktuk was more remote and traditional.
Facilities and services at the Aurora Research Institute were excellent
Should include a presentation/tour of ARI and its role in education, research, and management
School visits – include a visit to the lower grades – presentation about the S/B program and experiences on the ship. One school in BC prepared letters by 4th graders in their community that they exchanged with students from Tuk – this should be repeated.
Schools on Board – important to present on ArcticNet
Storyteller in Inuvik – a good activity to repeat; or another traditional activity i.e. drum dancers, northern winter or summer games activities

Appendix L – Testimonials to the 2004 Field Program

Participants – Students & Teachers

"Thank you for letting us interrupt you and join you for the best week of my life."
Student – Email to scientists – 3/30/04

"It was awesome for my fellow students to see that a kid from plain old Grant Park High School in Winnipeg can take part in this amazing study with all of you extraordinary people."
Student – Email to scientists – 3/30/04

"Schools on Board turned me onto studying science and opened my eyes to what science is about and how it relates to daily life...I feel honored to have been a part of it."
Student – 2004 – Program Evaluation

"This has been an incredible journey of exploration and growth." (BC)
Student – 2004 – Program Evaluation

"Before the program I knew very little about Arctic Sciences and had no idea that anything like CASES was happening."
Student – 2004 - Program Evaluation

"When I thought of becoming a scientist before this program, I never thought about conducting experiments in the Arctic but now I see it in a totally new and positive way."
Student – 2004 - Program Evaluation

"Being immersed with scientists has been great, and I'll be sure to share everything that I have learned with as may people as possible."
Student – 2004 - Program Evaluations

"It helped me to put into perspective a career that I would like to pursue (Marine Biology)...this has been a life-altering experience."
Student - 2004 Program Evaluation

"I came to this program with very high expectations and these expectations were exceeded."
Student – 2004 Program Evaluations

"This program makes people look differently at the Arctic: it is such an incredible ecosystem! The value of this program is to explain what these crazy scientists are doing – I had no idea. It's made me think differently about science."
Student – 2004 Program Evaluation

"Thank you for all your work in making this tremendous project available to this school, and especially for Angela."
School principal – 2004 School Evaluation

"The value of this program is great because I walked away smarter and most of all, happier."
Student - 2004 Program Evaluation

"This experience has renewed my motivation to do well in school and for that I want to thank you."
Student – 2004 – Program Evaluation

"This has been the first program that I have been a part of where I feel that it has changed the direction of my life."
Student – 2004 – Program Evaluation

Schools and Community
"As you may have observed, things are maybe not what you expected here - it certainly is very meaningful when agencies are able to provide another perspective to our students."
School principal – 2004 – School Evaluation

"Our staff decided that the opportunity to explore arctic sciences through the Schools on Board field program would be a truly exciting and significant learning event."
Letter of intent – school in Newfoundland

"We are talking to contacts made on the ship about possible partnerships. The program will continue to have a major impact on our school district."
School administrator– 2004 School Evaluation

"An outstanding link between curriculum and global scientific issues. It was a life changing experience for each of our students."
School teacher – 2004 School Evaluation

Scientists
"I'm just now coming down to ground from the adrenalin rush of the Schools on Board trip."
Dr. Grant Ingram, Senior scientist and Principal Investigator for CASES who was part of the Schools on Board team. 3/15/04

"It's important for the future to have strong Arctic science component to climate change research - introducing kids to science is part of this."
CASES scientist interviewed in NewsNorth, 3/12/04

"Schools on Board was, from all accounts, a tremendous success. Students saw more science and northern culture than most of us see in a career."
Senior Scientist and Theme leader for CASES, 3/9/0404

"I think that the entire group of scientist and crew really enjoyed having your gang onboard."
CASES scientist, 5/3/04

"I think a lot of them (scientists) enjoyed having a 'kid's' perspective on their work."
CASES scientist, 5/3/04

"Having students experience our day to day routine with a twinkle in their eye is a great moral booster. Sometimes we tend to forget how cool and exciting our careers are."
CASES scientist, 5/3/04

"Seeing our science through the students' eyes was an inspiration for my own science as well as for others on the icebreaker."
CASES scientist, 5/3/04

"The demand for Arctic specialists will increase tremendously in the coming decades, and a central objective of research networks such as the Canadian Arctic Shelf Exchange Study (CASES) is to train the next generation of Canadian Arctic scientists. The Schools on Board program is an excellent way to make high school students aware of the possibility to develop an enriching career in a fascinating research field."
Dr. Louis Fortier, CASES chief scientist, 2004

Appendix M – Shared Characteristics of EE and SE Programs

Goals: Promoting Environmental and Scientific Literacy		
Education About…Content	Educating IN…Setting	Educating FOR…Issues and decision-making
Multidisciplinary Interdisciplinary but grounded in science and ecology Cross curricular Relevant science and ecological concepts Grounded in real world Nature of science Credible and reputable Valid and reliable Skills and issues related to technology Respects multiple point of view Constructivist in pedagogy Actively engaged in constructing own understanding New learning is built on a foundation of students' previous knowledge Has structure and is age appropriate Includes social, political, economic, ethical Based on systems thinking Complex relationships	Experiential Situated learning approach Place-based learning Science and environment as places of inquiry In-dept opportunities to develop sensitivities to the environment and to the culture of research Direct experiences IN the environment Direct experiences IN science inquiry Learning through doing Authentic research experiences and research partnerships with schools Working at the elbows of scientists Experiencing the excitement of science Experiencing the passion and commitment of scientists Activities connected to the real world Importance of setting in creating 'aha' moments Elevating emotional	Systems approach to problem solving and decision making Examination of science and environment includes social, political, moral, economic dimensions Skills in decision-making related to environment and scientific research – inquiry, questioning validity and reliability of scientific knowledge and information, making interpretations Identifying the science that will inform decisions on environmental issues Dealing with issues of sustainability Role of technology in society; creating and solving real problems Issues of complexity; no single right answers; tradeoffs Critical thinking & critical reflection Challenging & questioning Consensus building Take into account alternative perspectives or explanations Address values, attitudes and beliefs on the nature of science and environmental issues

Dynamic	connection and sensitivity through direct contact and experiences in nature Proximity – rediscovery and reconnection to the natural world around us Agreement that how we experience learning is affected by the places and spaces in which we learn	Collaborative learning and problem solving Address big picture – social justice, health, governance, climate change Foster a caring attitude Includes teaching action skills and strategies for applying them Ownership and Empowerment

Appendix N – Key decisions for the 2004 SonB Field Program

Goals & objectives

- From the very beginning it was realized that in order to meet our stated goals and objectives, the program would have to be broader than a field program. Therefore, the concept plan for the program included the three components: a network, a field program, and a student forum. The three components allow us to extend our outreach beyond the few participants, schools, and scientists that participate in the field programs.

Program design

- The three components of the program would be implemented in stages. Prioritizing program components allowed energies and limited resources to be focused on developing and piloting the field program in the first year. The network was seen as a work in progress that would evolve at the rate of the program, and the forum was tabled for future development.

Target and scope

- Targeting schools rather than individuals established a more collaborative and supportive relationship with schools, and extended the outreach potential of the program from a single individual to the wider school population and its extended community (staff, alumni, sponsors, administrators, parents, and families).
- Targeting schools across Canada provided more diversity and extended the outreach on a national scale. This, however, required more flexibility to accommodate different jurisdictions, school systems, curricula, languages and cultures.

Needs and stakeholders

- Identifying both the needs and resources of stakeholders expanded our resource base and our ability to meet their needs and expectations.
- Establishing an advisory committee at the design stage of the planning process helped ensure that the program was addressing the needs of major stakeholders and that all available resources were assessed. This step was critical in creating a program that would be mutually beneficial and meaningful to participating students, teachers, schools, and scientists. This step was critical in creating a program that would be mutually beneficial and meaningful to participating students, teachers, schools, and scientists.
- Keeping the advisory committee up-to-date with program developments kept them

involved and committed.
Funding • Charging a fee for the program. • Making the schools responsible for the registration fee secured greater commitment to the program, and ensured participants got support and assistance in fundraising. Schools were invoiced directly for the fee, and they raised the funds through a variety of methods, including support from school boards, parent councils and teachers' associations, letter campaigns to alumni and sponsors, cost sharing with participants, etc. Every letter written for support, served to inform new audiences about the SonB program.
Public relations • Specific schools were targeted to pilot the program before promoting the program to every school across the country. As such, promotion was initially limited, but was gradually stepped up to keep pace with the development of the program. Full-scale promotion did not occur till it became clear that a successful program could be sustained.
Risk Management • Leveraging support to operate SonB at the University of Manitoba provided institutional and legal support for managing risks. • Allocating spaces to schools rather than individuals and requiring an application from the school and their acceptance of the risks inherent to the program ensured their collaboration in the management of risk. • Using exit interviews were especially important since participants were minors.
Networking and partnerships • Including a SonB Network as a program component in the design stage enabled the building of a network and the identification of potential partnerships that facilitated the planning and implementation stages of the program.
FIELD PROGRAM • Selecting schools and allowing them to select participants based on SonB criteria involved the school in a critical aspect of the program. It was acknowledged that schools could do a better job of selecting individual participants based on their familiarity and knowledge of their personality, abilities and ambitions. Selection of participants at the school level also increased to outreach potential of the program. • The suggested email activities were very successful in developing a group identity prior to the program. These activities and the pre-trip information packages were effective at

tapping into the anticipation phase of the trip.

- Linking program to curriculum used in the North, as it included traditional knowledge and information relevant to environmental issues in the Arctic.
- Although the focus of the field program was science, it would include sessions that would allow students to see the science and research in a broader context. The planned activities in northern communities, integration of traditional knowledge, and inclusion of cross-curricular activities were important elements of the program.
- A flexible itinerary ensured that the program could be adapted on short notice to accommodate changes in research plans, availability of scientists, and weather. This flexibility resulted in a program that was predominantly delivered by scientists and local experts.
- This experiential activity [Build an Instrument] became a very important program element. It provided participants with their own ongoing science inquiry project with the broader research experience, and was not reliant on the availability of scientists. Participants could explore all aspects of scientific inquiry at their level of understanding.
- Although difficult to coordinate from a logistical perspective, the conference call was critical in connecting participating schools and classrooms directly to the activity and energy of the field program and increased the outreach potential of the program.
- Planning activities in northern communities provided an important social context to climate change research in the Arctic.
- Expecting participants to deliver presentations upon their return from the field program required time in the schedule for preparing and practicing their presentations. This program expectation ensured that participants and schools became more engaged in the outreach initiatives aimed at raising awareness in the school and broader community, and resulted in many presentations to diverse audiences following the field program. These new audiences to climate change research included friends, families, colleagues, neighbours, fellow classmates, and sponsors. Presentations by students became a new vehicle for communicating the science of the CASES program to the public, who was able to see the activities of the science teams onboard the Amundsen, through a new set of eyes – those of the students and teachers.
- The decision to have the onboard program delivered by scientists and to include face-to-face interactions with researchers and leaders in northern communities, authenticated the information and the experience for participants. Activities planned around these interactions were designed to encourage students and teachers to think critically about the

issues related scientific inquiry, traditional knowledge and climate change research.

- A debriefing at the end of each day was a good tool to gauge participants' level of understanding and enthusiasm. As not everyone participated in the same activities during a day, this became a good activity for reflection and sharing.
- It was necessary to plan for the social environment as well as the physical environment. Group dynamics played an important role in developing and maintaining strong a group cohesion that resulted in commitment, active participation, friendships and a strong emotional connection to the program.
- Pre-determining the small groups ahead of time, and switching group members on a daily basis worked well to keep the team mentality of the group and helped to keep everyone in the group.
- Recognizing everyone's efforts through small tokens of appreciation – teachers and students (certificates and t-shirts), scientists (t-shirts and prizes); schools (certificate); chief scientists and captain (gift) was very important.
- Planning a farewell evening with slides of the week allowed scientists and crew to see the full breadth of the SonB field program and their contribution to the whole experience, including the community visits. It also reminded students of the breadth of their experience.
- Having separate evaluation tools for participants, scientists and schools was effective in getting feedback from three major stakeholders.

Appendix O – Characteristics of Ecosystem Thinking in the SonB Program

Program design	Program planning	Program implementation
Holistic • Plan for the content, experience & adventure • Target school, participants & families. • Goals for broad outreach and individual impacts • Recognize socio-political influences on program plan. • Systems approach to understanding and solving problems.	**Holistic** • Include logistics and risk management in program plan (well-being and safety). • Plan the experience to be personally meaningful. • Plan for anticipation, expectations, social interactions, and informal interactions. • Recognize the participant as possessing knowledge, emotions, attitudes, values, and predisposed to action. • Plan for the whole person – age and maturity sensitive.	**Holistic** • Utilize multiple teaching strategies that support a systems approach to knowledge construction. • Recognize multiple learning styles • Teach an appreciation for the environment as a complex system of interconnected parts and relationships. • Teach an appreciation for climate change research as a complex system of interconnected science disciplines. • Systems approach to understanding and solving problems in the field.
Flexible and adaptable • Accommodate needs of schools across political and geographical jurisdictions – for selection of participants and links to classroom programs and curricula. • Decrease institutional barriers to participation by	**Flexible and adaptable** • Flexible program plan and itinerary. • Innovative and alternative planning • Plan program in interchangeable units or pieces that can easily be changed or exchanged. • Happenstance (planning	**Flexible and adaptable** • Flexibility rules the day. • Be prepared to adapt on short notice to accommodate research schedules of scientists and uncertainty of weather. • Implement backup plans as required. • Take advantage of

giving schools flexibility in student selection, payment schedule, outreach plans, integration of Arctic sciences into school programs.	for the unplanned) – to take advantage of new opportunities. • Need to communicate the flexible nature of the program to participant so that they do not expect structure of a class schedule.	unplanned opportunities (happenstance). • Importance of formative evaluation - ongoing evaluation or reflection in action.
Participatory • High level of involvement of schools - active role in application, selection and preparation of participants • High level of involvement of scientists. • Schools play active role in outreach. • High level of stakeholder input through the advisory committee. • Growing network and partnerships.	**Participatory** • High level of input from participants, schools, and scientists through formal evaluations process. • Collaborative program delivery. • Collaborative learning • Collaborative problem solving	**Participatory** • Include as many people as possible in the program delivery – scientists, CCGS crew members, elders, community leaders. • Participants expected to take ownership of their own learning. • Peer learning and group work. • Active learning • Hands-on and minds on • Experiential • Participants actively engaged in outreach
Diversity • SonB program includes three components – not limited to the field program • Field program includes science, environmental issues, TEK, and northern culture.	**Diversity** • Multiple ways of knowing • Culturally sensitive • Multiple external influences • Multidisciplinary • Interdisciplinary • Cross-curricular • Culture, science,	**Diversity** • Program delivered by community leaders, elders, scientists, coast guard crews, program leaders, accompanying teachers. • Local, national and international perspectives. • Scientific and traditional

• National scope results in range of participants geographically, culturally, and demographically. • Diversity of stakeholders – students, educators, scientists, funding agencies, sponsors, participants, families. • National representation results in diversity in participant demographics	environment • Diversity of settings • Diversity of issues – related to science and those related to environment	perspectives. • Pay attention to group dynamics to take advantage of diversity of group. • Mix of teaching strategies to accommodate different learning styles: direct and indirect teaching; lectures, hands-on activities, group work, reflection activities, demonstrations, panel discussion, debates.
Uncertainty, complexity and change • Need for flexibility creates uncertainty • Evaluation leading to action and program improvements. • Program is vulnerable to changes in socio-political and economic influences i.e. support for climate change research, legal barriers to school participation, etc.	**Uncertainty, complexity and change** • Program plan changes with every field program – new scientists, new location, new research agenda, new schools and participants. • Balancing the needs and timelines of educators with the needs and timelines of scientists. • Planning activities related to addressing the complexity of issues related to science and climate change.	**Uncertainty, complexity and change** • Uncertainty related to travel, availability of scientists; changing sampling schedules; ice conditions; weather. • Concepts inherent in environmental issues such as climate change. • Teach skills in decision-making. • Introducing the precautionary principle. • Changes in knowledge, skills, attitudes and behaviours. • Transformational

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