Using Communication Technology to Facilitate Scientific Literacy:
A Framework for Engaged Learning

by
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ABSTRACT

The purpose of this research project is to describe how existing communication technologies are used to foster scientific literacy for secondary students. This study develops a new framework as an analytic tool to categorize the activities of teachers and students involved in scientific literacy to describe what elements of scientific literacy are facilitated by such technologies. Four case studies are analyzed using the framework to describe the scientific literacy initiatives.

Data collection at each site included interviews with the teacher, student focus groups, student surveys, and classroom observations. Qualitative analysis of the data provided insight into the learning activities and student experiences in the four cases.

This study intentionally provides a platform for student voice. Very few previous empirical studies in the area of scientific literacy include the student experience. This represents a significant gap in the current literature on scientific literacy. An interpretation of scientific literacy that promotes student engagement, interaction, and initiative corresponds to a need to listen to students’ perspectives on these experiences.

Findings of the study indicated that the classroom activities depended on the teacher’s philosophy regarding scientific literacy. Communication technology was ubiquitous; where the teacher did not initiate the use of social media in the classroom, the students did. The goal of supporting scientific literacy in students is an objective that extends beyond the boundaries of classroom walls, and it can be facilitated by technologies that seem both abundant and underutilized. Technology-enhanced pedagogy altered the classroom practices and resulted in more student participation and engagement.
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Chapter 1

Introduction

The purpose of this research project is to describe how existing communication technologies can be used to foster scientific literacy for secondary students. The goal of supporting scientific literacy in students is an objective that extends beyond the boundaries of classroom walls, and it can be facilitated by technologies that seem both ubiquitous and underutilized. This study develops a new framework as an analytic tool to categorize the scientific literacy activities of teachers and students and to describe how such technologies contribute to specific elements of scientific literacy. Four case studies are analyzed using the framework to describe the scientific literacy initiatives.

This chapter begins by establishing the research questions and issues of importance. It continues with a description of my autobiographical signature, which was the context and experience that provoked my interest in this area. This will include an interpretation of the term scientific literacy from the Ontario curriculum documents. It will then examine the rationale behind why I chose to link the search for scientific literacy with the resources of communication technology and the gap that currently exists in this field. Finally it will describe this study that seeks to respond to these questions.

Research Questions

This research project seeks to describe the ways in which scientific literacy is experienced by students in classrooms where teachers use communication technology. The first research question is: **What kinds of learning experiences aimed at promoting**
scientific literacy are evident in classrooms where teachers integrate communication technology? The second research question explores the link between communication technology and scientific literacy: **How does communication technology contribute to scientific literacy in classrooms where teachers use these technologies?** In order to investigate this question I have developed a scientific literacy framework to deconstruct, define, and describe what is understood as scientific literacy. This framework synthesizes various perspectives from theory and policy and establishes a structure that can be used in a practical context.

**Autobiographical Signature**

I have 13 years of experience as a science and math teacher in both traditional and online learning environments. This teaching experience has included the provincial curricula of Alberta, Ontario, and Quebec and has compared the policies, objectives, and philosophies of these distinct jurisdictions. This experience has reinforced the importance of promoting scientific literacy, communication, and a collective community-based approach in a practical context. My previous research experience has examined how technologies can be used to facilitate hands-on laboratory experiences during an online chemistry course.

As a secondary science and math teacher, there was a clear distinction between my science classes and my math classes. The students seemed to enjoy the science more than the math because there were regular opportunities for labs, demonstrations, and hands-on activities. I enjoyed teaching the science courses more than the math, because it was easier to connect these concepts to the lives of my students. Student participation,
engagement, and conversation were greater in courses where students could personally connect to the material. I began to explore issues of student engagement and curriculum relevance. I observed a continuum of student participation that began with passive interest (i.e., the students had a superficial interest, enough to complete the assignments and obtain the marks, but the material was not relevant to their lives); it continued with engagement (i.e., the students were interested enough to initiate conversations with their peers and to seek or share additional resources); and then proceeded with enactment (i.e., where students took action on scientific concepts such as the environment or community projects or even pursued careers in a certain stream of science). This continuum is shown in Figure 1. Career-route students were not the target audience of the secondary science program; however, I did not want to merely promote superficial interest. The resistance to transition from level one (interest) to level two (engagement) was a concern. What prompts individuals to move beyond a superficial level of interest and become actively engaged in their learning? I surmised that it could involve the relevance and authenticity of the topic.

![Figure 1. The continuum of participation in science education.](image-url)
In my experience, when science topics are relevant to students, they can take ownership of their learning; students’ understanding and engagement improve. Ideally, students can initiate or share in the identification of topics of interest and importance. Students are more likely to continue the scientific discussion outside of the classroom boundaries among their peers and communities if they are engaged in the material. Much of contemporary communication takes place using technological assistance. Indeed, a current shift in educational policy promotes the use of online learning to overcome challenges faced by small schools or to increase the variety of courses available to students (Ontario, 2012). Online learning opportunities use a variety of communication and multimedia platforms to enhance interest, engagement, and interaction.

This concern for student engagement hints at the literature on intrinsic motivation and self-determination theory (SDT) (e.g., Ryan & Deci, 2000). However, although this study acknowledges that student motivation is an important element of developing students’ appreciation of scientific literacy; that is not the focus of this study. Intrinsic motivation provides a foundation and “it is through acting on one’s interests that one grows in knowledge and skills” (Ryan & Deci, 2000, p. 56). It is this acting and interacting, made possible with communication technology, on which this study choses to focus.

My teaching experience has also included teaching and learning via online courses, which has included opportunities for student interaction that may not be possible in a traditional classroom, due to limitations of time, space, policy, or content. In an online teaching environment I observed the students using the various communications technologies available to them. They were using technologies in authentic ways (i.e., to
interact with their colleagues at a distance) and the interactions that resulted were rich, productive, and enriched the social and educational interactions in ways that I could not have planned or predicted. In this study, I anticipate that promoting student interaction with scientific issues via communication technology has the potential to enhance the students’ scientific literacy and their educational engagement.

**The Goal of Scientific Literacy**

My interest in scientific literacy began in my M.Ed. program when I began to read and compare the epistemological philosophies outlined in the introductory pages of course curriculum documents. The importance of hands-on activities or connections to authentic contexts was often explicitly mandated in the preamble; although the emphasis sometimes waned in the later details. The Ontario science curriculum described the importance of scientific literacy:

[Science] underpins much of what we now take for granted, from life-saving pharmaceuticals to clean water, the places we live and work in, computers and other information technologies and how we communicate with others. The impact of science on our lives will continue to grow…Consequently, scientific literacy for all has become a goal of science education throughout the world…Scientific literacy can be defined as possession of the scientific knowledge, skills, and habits of mind required to thrive in the science-based world of the twenty-first century. (Ontario, 2008, p. 3)
The emphasis on the relevance of scientific concepts to students’ lives and connecting to authentic contexts was clearly a foundation of scientific literacy, in this interpretation. The curriculum documents differentiated between becoming a scientist and achieving scientific literacy. Not all students will aspire to scientific careers, but scientific literacy is a goal for all students, in order to become informed citizens and consumers. However, the only specifics that are provided in the document about how to achieve this goal are cited from a position paper by the Science Teachers Association of Ontario (STAO):

A scientifically and technologically literate person is one who can read and understand common media reports about science and technology, critically evaluate the information presented, and confidently engage in discussions and decision-making activities regarding issues that involve science and technology.

(STAO, cited in Ontario, 2008, p. 3)

The National Science Education Standards (NSES) defines scientific literacy as “the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity” (NSES, 1997, p. 22). An underlying understanding of science is required, but the literacy is displayed through participation in authentic events. This implies that individuals have gone beyond superficial interest and are actively engaged. The NSES also describes scientific literacy as “the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately” (NSES, 1997, p.
22). Clearly, their vision of scientific literacy includes substantial elements of critical thinking and interaction with others.

Scientific literacy is an issue of global concern. The Organization for Economic Cooperation and Development (OECD) examined scientific literacy at an international conference. The conference was prompted by concern that despite a “high level of interest in science and technology throughout the OECD area, it was coupled with low levels of scientific literacy and stable and/or declining science enrollment among youth” (OECD, 1997, p. 2).

Scientific literacy is a commonly cited goal in curriculum and policy documents. However, the interpretation of a definition for scientific literacy depends largely on one’s perspective and experience, so there is a vast range of meanings for the term, depending on whether it is a pedagogic goal, policy objective, or educational experience (Lindsay, 2011). Likewise, there is a wide range of visions for the implementation and the assessment of programs promoting scientific literacy. Within this array of interpretations, priorities, and initiatives there exist a corresponding assortment of challenges and obstacles that impede the implementation of whichever vision of scientific literacy is being pursued.

I recognized that there was a disconnect between the stated objectives for scientific literacy and the other objectives in the Ontario curriculum documents. The definition in the Ontario science curriculum document referred to students participating in discussions and decision-making activities, but these kinds of activities were not explicitly mentioned in the curriculum documents. There was an opportunity to meet the
A clear definition of scientific literacy is needed in order to convey how this outcome can be achieved. This study considers a context of secondary science education, in which teachers and students work toward this goal. A pedagogic framework was needed that would meet the criteria of a scientifically literate person as defined in the Ontario curriculum. It would need to include elements of traditional literacy (reading and comprehension), discussion, critical thinking, and contextual issue-based decision-making. Therefore, an original framework has been developed to accommodate these criteria. The structure of the scientific literacy framework in this study has been designed to include these four process-oriented themes: communication; collaboration; critical thinking; and connection, all embedded within a foundation of scientific content.

Although the framework design is original, its foundations are not. Chapter two will further justify and connect this framework to both the theory- and practice-based literature in the field of science education. The priorities of communication, critical thinking, and connection are emphasized in the interpretation contained in the Ontario curriculum; connections and critical thinking were valued by the NSES interpretation; collaboration is implied in both of these visions since discussions and arguments are participatory events. Scientific content provides a context, but the emphasis of teaching and learning is in the interactions among students, teachers, and ideas. Individuals engage with the concepts; interact with the ideas and with other people; and apply their learning to their own lives. This definition of scientific literacy integrates the practice-based curriculum documents described previously with the theoretical concepts of fundamental
and derived literacy (Norris & Phillips, 2001) and elaborates on Miller’s (1998) interpretation of scientific literacy as being both knowledge- and process-oriented. Additionally, it aligns the definition of scientific literacy with a pedagogic perspective, emphasizing student participation and learning in a classroom context.

**Rationale**

The rationale for this study considers two factors: a) scientific literacy as a topic of study; and b) how communication technology is used to facilitate engagement in science education.

**a) Scientific Literacy: A purpose with problems.** Literacy has become a popular buzzword in a variety of educational milieu: in addition to traditional literacy we now encounter scientific literacy, media literacy, technological literacy, digital literacy, and ecological literacy. Each of these literacies is impacted by advances in information technologies that make it easier to access information and therefore cause a shift towards promoting informed, responsible interactions with the material. The field of science displays an exponential growth in the amount of scientific content. Scientific discoveries and technological innovation are also an integrated and ubiquitous part of contemporary life, impacting the daily decisions in both explicit and implicit ways. These developments suggest a need to adapt our pedagogic approaches accordingly. These changes provide both opportunities and challenges for providing authentic engaging science programs. However, implementing initiatives in scientific literacy can afford opportunities that
impact students, communities, and society. This study explores the question of how this can be achieved effectively.

**b) Communication technology: Media as means.** Communication is essential to teaching. The media and technologies through which this communication occurs have evolved. Innovations in communication technologies are ubiquitous in modern society. There are various interpretations concerning the degree of integration of technology within a particular demographic. Tapscott (1998, 2008) argued that it is widespread among adolescents outside of school, while his opponents (e.g., Bullen, Morgan, Belfer, & Qayyum, 2009) contend that such claims are empirically unfounded. Regardless of the debates of the extent of assimilation of communication technologies into the social functioning of secondary students, such tools can provide opportunities for innovation and connections. Integrating communication technology features into teaching contexts can result in authentic learning opportunities for students. Educational contexts provide an authentic application for interacting via communication technology. Implementing innovative teaching practices that incorporate contemporary technologies provides an opportunity to promote current communication practices, to encourage student engagement, and to connect teaching practices to contextual community issues of interest and significance.

**A Current Gap in Scholarship**

Theoretical work has been completed on scientific literacy, including elements of communication (Lemke, 1990), authentic contexts and citizen science (Jenkins, 2002;
Lee & Roth, 2002; Roth & Lee, 2004), humanistic science (Aikenhead, 2006), and personalized science (Hodson, 1998). Likewise, studies have been completed that examine the benefits of technology (or digital literacy) for students to learn in an interactive format (Cullen, 2011; Jones, 2012; Knobel & Lankshear, 2008; Lankshear & Knobel, 2009; Poore, 2013). However, the intersection of these two areas, specifically how communication technology can be integrated in classrooms to meet the goals of scientific literacy is missing. Only one of the previously mentioned studies (Jones, 2012) explicitly examines science classrooms, the others focus on technology, history, English, or media classes. This study addresses that gap.

This study also intentionally provides a platform for student voice. Very few previous empirical studies in the area of scientific literacy include the student experience in this discourse. This represents a significant gap in the current literature on scientific literacy. Encouraging student engagement, interaction, and initiative corresponds to a need to listen to their perspectives on these experiences. This study addresses this gap by including the students’ perspective in their own words.

**Overview of this Study**

This current study explores the learning experiences that involve communication technology in four classroom case studies. What kinds of learning experiences that promote scientific literacy are evident and what role does communication technology contribute? In each case I am not the teacher; this permits me the freedom to focus on the research aspects of this study without the pedagogic responsibilities. Four sites with very different characteristics are examined; while this is advantageous in order to provide a
variety of experiences, resources, and teaching philosophies, it is also practical because no two sites will be alike in these features. The selection reflects the range of contexts in Ontario schools.

The following chapter will examine the literature in two parts. The first part will consider scientific literacy in current policy, theory, and a pedagogic perspective. It develops a new framework from which to view scientific literacy at the secondary level. In part two of the literature review I examine some of the previous empirical work in integrating communication technology in classrooms. Chapter three will establish the methodological foundations and the methods of site selection, recruiting, data collection, and data analysis in this study. Chapter three will also present the coding definitions and examples that are used in this study. Chapters four, five, six and seven are data chapters. Each case study is presented in a separate chapter, including data collection and data analysis for that site. Chapter eight explores the cross case analysis, including the emic and etic issues which were evident. Chapter nine contains a discussion of the implications of these findings, the limitations of this study, future directions for this research, and concludes this thesis.
Chapter 2

Literature Review

The purpose of this literature review is to examine how communication technologies have been used to facilitate scientific literacy. This chapter has been structured in two sections to examine each part of this goal. The first part examines literacy and the construct of scientific literacy. Part one describes the current state of scientific literacy initiatives by three advocacy groups (i.e., in the United States, Canada, and internationally). In this chapter I then consider the theoretical elements of scientific literacy. I synthesize the essential tenets of a variety of perspectives to establish a new framework through which the pedagogic practices that foster scientific literacy can be explored. In the second part of this literature review I explore relevant empirical research that investigates the classroom uses of communication technology and how this technology has been used to facilitate the goals identified in the scientific literacy framework. I identify the potential match of the pedagogic needs of scientific literacy with the possibilities afforded by communication technologies.

Part 1: Scientific Literacy

Scientific literacy is a complex and poorly-defined term. Many of the differences of opinion on this issue stem from different perspectives and a distinct interpretation of literacy in general terms, or scientific literacy in particular. Therefore, in this section on scientific literacy, I will begin by establishing a clear umbrella definition of literacy that acts as a foundation for this work on scientific literacy. Then, I examine scientific literacy
in several policy initiatives and theoretical perspectives. I synthesize the theoretical elements of scientific literacy to establish a new practical pedagogic framework. This framework will provide the structure for this study.

**Literacy: A Label with many applications**

Classrooms have focused on the 3 R’s of reading, writing, and arithmetic. However, the curricular landscape has expanded. Teachers and students are now challenged to become proficient with traditional literacy, math literacy, financial literacy, media literacy, digital literacy, communication literacy, ICT literacy, technology literacy, and scientific literacy. Technology infuses many of these new strands, and it also reshapes the traditional perspectives. Martin (2008) described the evolution of traditional literacy to include three models: functional literacy, sociocultural practice, and intellectual empowerment. Functional literacy refers to the cognitive and practical skills required to function in a community; the model of sociocultural practice refers to the social context and includes the cultural, economic and political structures of a society that affect literacy; and the intellectual empowerment model that involve a transformation of thinking such as when a new tool or technology is developed. These three facets of literacy are echoed by other authors, sometimes labeled as operational, cultural, and critical (Facer, 2011, p. 226).

Martin (2008) defined some of the various branches of literacy: he stated that digital literacy is the ability to understand and use information in multiple formats from various sources; communication literacy is the ability to communicate effectively as individuals and work collaboratively in groups, using technology and other tools; media
literacy is the ability to access, analyze, evaluate and communicate information in various forms including print and non-print; ICT literacy is the ability to use digital technology to access, manage, integrate, evaluate, and create information; technology literacy is the ability to use, manage, and understand technology. Martin’s interpretations of literacy have significant overlap and could complement each other; unfortunately, perceptions of subject-specific boundaries often prevent such collaboration. Knobel and Lankshear (2008) integrate these disciplines under an inclusive definition. They define literacy as “socially recognized ways of generating, communicating, and negotiating meaningful content as members of discourses through the medium of encoded texts” (Knobel & Lankshear, 2008, p. 249). This definition can be inclusive of various content and media formats and it is participatory in nature, including both receiving and producing ideas. Thus, this interpretation of literacy encompasses the various new literacies defined above as well as traditional literacy and subject specific forms such as scientific literacy. Their interpretation of literacy is well corroborated in the literature. Gee (1997) defines literacy “as a matter of social practices – something to do with social, institutional, and cultural relationships” (p. 2). These interpretations of literacy as an interactive, dynamic, social process align well with the version described in this study.

This section has considered the multi-faceted interpretations of literacy and brought them together under a cohesive umbrella definition. Subsequent to this inclusive interpretation of literacy, later sections in this literature review will consider the practical aspects for achieving it. The next section explores the concept of scientific literacy. In order to develop a unified definition of this term, it is necessary to examine the historical context and ongoing initiatives in this field. The next section explores these ideas and
then develops a pedagogic definition and framework to apply such concepts in the classroom.

**Scientific Literacy: A Label with Multiple Interpretations**

The term scientific literacy is a popular buzzword but it represents an elusive goal in educational policy and practice (Arons, 1983; DeBoer, 2000; Laugksch, 2000; Miller, 1983; Roth & Lee, 2004). Some of the difficulty in implementation is due to a wide range of interpretations of what scientific literacy actually means. Scientific literacy has been described as the public understanding of science (Arons, 1983); a social practice of citizen science (Roth & Lee, 2004); and as the relationship between science and society (DeBoer, 2000). These three definitions illustrate the different perceptions of scientific literacy that emphasize knowledge, action, or interaction. The American Association for the Advancement of Science (AAAS) defines a scientifically literate person as someone who understands key scientific concepts; appreciates the interdependent nature of science, technology and society; recognizes the benefits and limitations of science; and uses scientific ways of thinking in his daily life (AAAS, 1989). Some of the difficulty can be attributed to an incongruity in the goals of individuals from different fields such as education, science, policy, and assessment.

This section examines the challenges in defining the dynamic concept of scientific literacy. It examines the history behind the current status in three jurisdictions (the United States, Canada, and internationally). It gleans the relevant and appropriate features in preparation to synthesize these common ideas into a single framework.
Background and Current State of Scientific Literacy Initiatives

The concept of scientific literacy has developed during 50 years of international discourse and debate. The history behind the development of modern scientific literacy and the policy, controversy, and debate that it has engendered are beyond the scope of this chapter. A detailed examination of the history can be found in DeBoer (2000) or Laugksch (2000).

This review will focus on three main contributors to the current discourse on scientific literacy. This section examines and critiques the interpretation of scientific literacy by each group: the American Association for the Advancement of Science (AAAS), the Council of Ministers of Education of Canada (CMEC), and the Program for International Student Assessment (PISA). This review is not intended to provide a comprehensive evaluation of every element of policy and practice in each area. It is intended to provide an overview of the three approaches; present some of the strengths and weaknesses; and select the best elements from each one for a new pedagogic framework. The three separate approaches inform the development of a new cohesive framework for this study.

The reasons for the selection of these three areas are relevance and influence. The study examines schools that are using the Ontario curriculum; the Canadian context is relevant. The American initiatives were among the first to produce policy, practice, and theory literature in the field of scientific literacy. Inclusion of the international initiatives recognizes the global impact of education initiatives and the comparative and competitive nature of education reform.
**American Initiatives.** In the U.S. the goal of scientific literacy was initiated as a response to political and economic pressures. Early innovators considered science as essential for success in the space race and to establish a position of global economic strength (Hurd, 1958). Later contributions by the AAAS defined its vision of scientific literacy and a plan for its achievement in the document *Science for all Americans: Project 2061* (AAAS, 1989). The decade-long plan was developed after consultation with academics, scientists, engineers, and educators. Phase one focused on the criteria of scientific literacy: defining the knowledge, skills, and attitudes that students should acquire in the disciplines of science, mathematics, and technology during their school experience. Phase two involved curriculum reform and material development, and the third phase included a collaborative effort to implement the developed strategies. The proposal was ambitious in scope. It recommended reform involving systemic changes in all levels of education, teacher training and educational funding. It was intended to be implemented across all states, without accommodating for local culture, economics, or current curriculum reform initiatives. This prescriptive approach to scientific literacy initiatives resulted in resistance from teachers in the classroom. Implementation is ongoing, but has been impacted by other (conflicting or competing) educational visions and policy initiatives in the United States.

**Scientific Literacy Initiatives in Canada.** In Canada, education is a provincial jurisdiction. Each province has its own Department of Education, with its own priorities, polices, and funding constraints. The Council of Ministers of Education, Canada (CMEC) is a national advisory body without legislative authority. Therefore, it provides a national framework as a guideline that can be interpreted and implemented according to the
different needs of each province. The strength of this broad-based approach is that it allows each jurisdiction to value and support these ideas differently. The weakness of this system is that the national framework may not be implemented and the interpretation may vary.

In Canada, the Common Framework for Science Learning Outcomes (CMEC, 1997) established a national goal of achieving scientific literacy, and it formed the foundation for provincial curriculum reform to meet this goal. The Common Framework stated that “scientific literacy is an evolving combination of the science-related attitudes, skills, and knowledge students need to develop inquiry, problem-solving, and decision-making abilities, to become lifelong learners, and to maintain a sense of wonder about the world around them” (CMEC, 1997, p. 2). This vision of scientific literacy was based on four key foundations: science, technology, society, and the environment (STSE) outcomes; skill outcomes; knowledge outcomes; and attitude outcomes. It included such dimensions as communication and teamwork; collaboration; appreciation of science; analyzing and interpreting data; stewardship; and safety (Roscoe & Mrazek, 2005). It encourages diverse learning experiences that facilitate understanding and appreciation of the interrelationships among science, technology, and society. Table 1 illustrates these four components and their subcategories, as described in the Canadian Common Framework.

Some provinces have cited and endorsed this goal with policy, practice, curriculum reform, and resources. Examples of these approaches towards implementation include emphasizing specific media resources, including periodicals, science trade books and online resources (Foundation for the Atlantic Canada Science Curriculum, nd);
Table 1
The Four Foundations of Scientific Literacy in Canada (from Roscoe & Mrazek, 2005, p. 15)

<table>
<thead>
<tr>
<th>Foundation 1</th>
<th>Foundation 2</th>
<th>Foundation 3</th>
<th>Foundation 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nature of Science &amp; Technology</td>
<td>Initiating &amp; Planning</td>
<td>Life Science</td>
<td>Appreciation of Science</td>
</tr>
<tr>
<td>Relationships between Science &amp; Technology</td>
<td>Performing &amp; Recording</td>
<td>Physical Science</td>
<td>Interest in Science</td>
</tr>
<tr>
<td>Social &amp; Environmental Contexts of Science &amp; Technology</td>
<td>Analyzing &amp; Interpreting</td>
<td>Earth &amp; Space Science</td>
<td>Science Inquiry</td>
</tr>
<tr>
<td>Communication &amp; Teamwork</td>
<td>Stewardship</td>
<td>Safety</td>
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promoting specific scientific behaviors such as inquiry, problem solving, and decision-making (Newfoundland Department of Education, 2004); and accentuating an awareness of Aboriginal knowledge in sustainable development, biological and ecological science (British Columbia Ministry of Education, 2008). Some provinces have been criticized for implementation that is incomplete or inconsistent. Sammel and Zandvliet (2003) warn that the Ontario curriculum reforms to STSE are biased. The curriculum “emphasizes the positive role of technology, to the virtual exclusion of any critique of science or its problematic relationship with society or the nature environment” (p. 514). Sammel and
Zandvliet suggest that this biased approach reflects a political position of promoting economic development over environmental stewardship.

The CMEC model contains potential useful ideas for science education. However, some problems are evident. A national policy for an issue of provincial control results in uneven implementation. The ideas contained in the CMEC proposal have to be mapped onto multiple provincial curricula. The chart in Table 1 presents some general ideas, but they are vague and lack clear guidelines for implementation. Redundancy is evident, as shown by the model’s use of separate terms for teamwork and collaboration or for stewardship and environmental contexts. There is opportunity for clarification and simplification so that teachers can easily implement these ideas.

**International Initiatives for the Assessment of Scientific Literacy.** In the international context, PISA 2006 focused on science literacy but it interpreted this term more broadly (Bybee, 2009). This science assessment focused on what students know, value, and are able to do within reasonable and appropriate personal, social, and global contexts. This perspective differed from one grounded exclusively in school science programs that are contained within subject boundaries.

The PISA definition of scientific literacy included the use of scientific knowledge to ask questions, to acquire new knowledge, and to draw evidence-based conclusions about science-related issues; understanding of the characteristic features of science as a form of inquiry; awareness of the influence of science and technology on our physical, intellectual, and cultural environments; and a willingness to engage in science-related issues as a reflective citizen (Bybee, 2009, p. 17). In using the term scientific literacy
rather than science, PISA emphasized the importance of the application of scientific knowledge in the context of life situations as compared to the simple memorization and recall of traditional school science knowledge.

The American, Canadian, and international approaches agree on the importance of scientific literacy. However, they are distinctive in their methods: the American one is a standards-based, top-down approach to reform; the Canadian approach is a foundational approach that anticipates and encourages diversity of implementation; and the PISA interpretation recognizes that scientific literacy cannot be confined or defined by either a classroom or a curriculum. Rather, the PISA interpretation describes student engagement through action and interaction. Figure 2 contrasts the different emphases of these three perspectives. Each of these approaches has merit in certain contexts. However, the missing component in each of these methods is a pedagogic perspective that emphasizes interactive and engaging learning. The previous endeavors (i.e., AAAS and CMEC) portrayed a traditional emphasis on product and outcomes rather than a process-oriented approach. A learning emphasis would consider the interests, actions, and attitudes of the teacher and students involved, instead of the documents. This is the motivation for developing the Scientific Literacy Framework presented in this chapter. The Scientific Literacy Framework synthesizes the predominant ideas from the previously examined perspectives and integrates them in a practical manner.
The previous section examined initiatives in the field of scientific literacy, focusing on a historical perspective and policy differences. It is also informative to consider the theoretical perspectives, academic ideas, and how this impacts educational practice. Shifting the emphasis from the material to the stakeholders in science education is not a new philosophy. Although much has been written, it often emphasizes the theory, rather than a practice-based format. Unfortunately, although obstacles often impede the implementation of new ideas, technology-infused science education reform could mitigate the challenges created by alternative priorities, resources, and professional development requirements.
Aikenhead’s (2006) work advocates a more humanistic approach to science education and provides insight to current innovations. Inspired by the work of Dewey, humanistic science is a “student-oriented school science that treats science as a human endeavor” (p. 2). It moves away from scientific content as discipline-specific facts and rules and it emphasizes the applications and interactions of science in society. Aikenhead recognized that “school science is out of date” (p. 23) and he recommended a humanistic approach to high school science that would make it more relevant to students by considering the students’ cultural self-identities, their career goals, and their personal interests.

Lemke (2001) advocated a sociocultural perspective to science education. He recognized that in order to remain relevant, science education needed to move beyond the content. Instead, it should focus on the community of learners, integrating social organization and social interaction. The sociocultural perspective considers the organization behind the development and dissemination of scientific ideas. It also recognized the importance of social interaction to encourage students to engage in their learning and apply new ideas. Lemke proposed that science education researchers need to go beyond the scope of the individual learner and consider the sociocultural influences (i.e., individual and peer interests, community values, current events, and technological resources). Lemke hoped that “new technologies will stimulate fundamental structural change in science education” (p. 306). He envisioned that new technologies would expand the physical and temporal boundaries imposed by traditional physical classrooms if students could collaborate online with peers, access expert mentors, develop long-term
projects, and enjoy individualized study paths. He anticipated that technology could facilitate interaction in education similar to that seen in social environments.

Many of the features of scientific literacy imply engagement with real-life issues. “Individuals actively engage in developing scientific knowledge…based on their experiences and interactions contextualized in the real world” (Novak & Krajick, 2006, p. 77). Scientific literacy also includes the social interaction (through communication and action) with others who also are affected by and have influence on these scientific issues. Scientific literacy is also political: the issues are value-laden; they require decision, action, and consequences. Political action and engagement require authentic contexts and meaningful issues (Hodson, 2002). Fostering scientific literacy in education should also reflect these relational, social, and political elements. Authentic scientific literacy exhibits the characteristics of relevance, interaction, and engagement. Communication technology can facilitate this interaction if it is chosen and implemented appropriately (Webb, 2005). The match between the environment required for fostering scientific literacy and the affordances of educational communication technology requires an examination of the pedagogic potential of the match in a learning context.

**Pedagogy for Scientific Literacy: A Strategy, not a Slogan**

There are many opinions regarding the optimal emphases in scientific literacy education. Many authors have tried to simplify the concept of scientific literacy by deconstructing it into smaller and simpler parts. It can be: private or public (Bridgman, 1940); extrinsic and intrinsic (Liu, 2009); practical, civic, or cultural (Shen, 1975); or a gradual continuum ranging from nominal, functional, conceptual, and ultimately
achieving multidimensional literacy (Bybee, 1997). However, when a label is merely a slogan it does not provide a clear pathway to success. The Canadian Common Framework subdivides scientific literacy into four foundations: (1) science, technology, society and the environment (STSE); (2) skills; (3) knowledge; and (4) attitudes. Further deconstructing these key components produces 16 subcategories (as shown in Table 1). Unfortunately, some of these subcategories overlap (e.g., the nature of science is a subcategory of STSE, but it comprises aspects of the body of knowledge of science and the inquiry processes that generate such knowledge) (Roscoe & Mrazek, 2005). This approach is better at deconstructing the term, but still lacks specific implementation strategies. Others have considered scientific literacy in the context of how it is manifested in authentic scientific endeavors:

If you ask scientists what qualities make a good scientist, they might come up with a list like the following: the ability to explain ideas and procedures in written and oral form, to formulate and test hypotheses, to work with colleagues in a productive manner, to ask penetrating questions and make helpful comments when you listen, to choose interesting problems to work on, to design experiments, and to have a deep understanding of theories and questions in your field. (Collins, Hawkins, & Frederiksen, 1993, p. 205)

These skills should be encouraged in scientific literacy education.

Miller (1998) deconstructed the multidimensional concept of scientific literacy into knowledge and process, thus paralleling the knowledge and actions required by
scientists in the workplace. For educators, the process components of scientific literacy clearly align with the elements of instructional pedagogy. These are concrete steps for implementation in a classroom environment, rather than rhetoric, theory, or policy.

A New Framework: The Scientific Literacy Framework

Miller (1998) stated that scientific literacy consisted of both knowledge and process components. Unfortunately, science education has often focused more heavily on the knowledge components than on the processes. A new approach that recognizes the importance of both elements is needed to achieve the goal of scientific literacy. This study attempts to create and apply such a framework.

The Scientific Literacy Framework is a new framework. It expands on Miller’s emphasis on the processes required for scientific literacy. It builds on the Ontario curriculum mandate for communication, critical thinking and authentic contexts. It includes the Canadian Common Framework foundational elements in a simplified and process-oriented approach. The Scientific Literacy Framework model incorporates five components for promoting scientific literacy. They include: communication, collaboration, critical thinking, connectedness, and scientific content knowledge. The first four are processes that emphasize the interactive aspects involved in student learning, rather than merely on the subject content. This framework will then be used as the foundation for examining the interaction between the practices of scientific literacy and opportunities of communication technology. Each of these components is ineffective in isolation. The authenticity of a task and the engagement of students rely on the rich learning environment afforded by the integration of two or more of these concepts.
Scientific content knowledge, which has traditionally dominated science curricula, is assigned a reduced emphasis in the Scientific Literacy Framework. This also aligns with the educational philosophies that promote the benefits of reducing content quantity in favour of increased quality (CMEC, 1997; AAAS, 1989). The five elements of the scientific literacy framework are derived from various foundations in science education. These will be described and justified in the following sections.

The five components of scientific literacy are illustrated in Figure 3. They can be metaphorically interpreted as strands of a rope, assisting the ascent of students from a level of prior knowledge to a higher-order thinking level of enacted scientific literacy. The action of climbing a rope suggests a participatory endeavor. The interwoven strands of the rope support and strengthen one another; a single strand is ineffective. This lends support as to why previous content-focused initiatives were unsuccessful in achieving the climb to scientific literacy.

The Scientific Literacy Framework is a descriptive model. It describes the actions of students in active learning environments. These descriptions can be used to categorize what elements of scientific literacy the students are experiencing. If the framework is shown to be robust for describing scientific literacy activities in this study, it could be used as a planning tool to target scientific literacy goals, or as an assessment tool to provide evidence of students’ scientific literacy achievements. The next section defines the Scientific Literacy Framework categories, justifies their importance to scientific literacy, and highlights their connection with the previous models.
Scientific Content. Scientific content refers to the knowledge of concepts, facts, principles, terminologies, and processes. Historically, content knowledge has been the main emphasis in science education (Chiapetta, Sethna, & Fillman, 1991). A study of the scientific literacy content in textbooks by Chiapetta, Fillman, and Sethna (1991) concluded that 60% of the content of science textbooks was knowledge-based. Of the
remaining material, 24% promoted the investigative nature of science; 9% emphasized the relations among science, technology and society, and only 1% presented science as a critical way of thinking.

Although it is recognized that, “the link between specific facts and principles of science and any of the stated goals of science education is weak” (DeBoer, 2000, p. 598), these facts and principals remain a focus of many science education resources and activities. Lemke (2001) argued against the sterile isolation of science concepts and suggested that “it is a falsification of the nature of science to teach concepts outside of their social, economic, historical, and technological contexts. Concepts taught in this way are useless in life, however well they may seem to be understood on a test.” (p. 300). He implied that deep understanding of science required authentic interaction by students: talking together, working together, thinking together, and applying their new ideas.

Trying to cover too much content often reduces the course to superficial treatment of facts & formulae. “If science educators are to meet the goal of scientific literacy, science educators must promote a more realistic, less absolutist view of scientific knowledge” (Bell, 2006, p. 430). Ideally, content should emphasize the big ideas of science and these should be interdisciplinary and emergent to be as authentic as possible. An emphasis on science as a body of disconnected facts has been attributed to a decline in student interest due to a lack of relevance to their lives. Big ideas promote the relationship between natural phenomenon and a causal explanation that helps students understand how their world works (National Science Foundation, 2010). Harlen (2010) suggests that part of the reason for a decline in interest education is school science is not presented in a way that is relevant or meaningful to students. Content, connections, and
context do not concur. Pedagogic reform that emphasizes big ideas can help remedy such issues.

The scientific content provides a foundation for active learning. There is little agreement as to the best possible content, resulting in major variations in topics, techniques, and pedagogies. A recent Delphi study polled experts in the field to determine the ‘best’ content for science classrooms (Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003). This study polled a panel of experts who identified nine main themes that were considered to be essential components of the school science curriculum. Some of these were already included in the UK curriculum, others were not. The authors compared their empirical findings to a prior document analysis of curricula and standards and found general consistency. They concluded that although “no one method and no one group of individuals can provide a universal solution as to what should be the essential elements of a contemporary science curriculum” (p. 715) the consensus indicated that these themes should be integrated into the science program to help it meet the needs and interests of students.

Scientific knowledge is a dynamic field, evolving as new discoveries are made. Entirely new disciplines are added in relatively short timespans (e.g., nanotechnology or genetically modified organisms). The advances in understanding, combined with re-organization of school curriculum, often result in textbooks being out of date or irrelevant. The image of the body of knowledge as a fixed entity, complete and published within the pages of a textbook has never been more inaccurate. The internet provides opportunities to access more up-to-date material that is relevant to the interests of students and the issues in their communities. Accessing and evaluating online
information is an authentic skill at which students will need to become proficient. Advances in the field of science and the development of new technologies can establish a context for engagement, participation, and potential contributions to emergent fields.

A teaching philosophy that prioritizes the transfer of content knowledge will generate pedagogy compatible with this goal. Traditional approaches to teaching and learning emphasized transfer of content and thus embraced the focus on content in science education. As new education theory is integrated into the field, new approaches evolve. Tsai (2002) described a Taiwanese study that examined whether teachers’ epistemological beliefs were categorized as traditional, process-oriented, or constructivist. Nearly 60% of the respondents were categorized as traditional in their views of teaching and learning science (they emphasize the transfer of knowledge from teachers to students, learners should acquire reproducible knowledge, memorize formulas, definitions, and facts). Only 27% espoused a process-oriented pedagogical approach that included teaching the scientific method, problem solving, and self-discovery methods. Eleven percent of the teachers in the study were categorized as constructivists. Tsai stated that constructivism was a “controversial topic in science education” (p. 773) but that it is a “sound theory to help science educators understand how students learn science” (p. 773). Tsai’s participants were classified as constructivist if they were “helping students make interpretations, providing authentic experiences, interacting with students, encouraging discussion, and paying attention to students’ prior knowledge” (p. 774).

Different curricula reflect the local culture and priorities. The Ontario science curriculum document appreciates that an “effective way to learn is for students to be
actively involved in thinking and discussing during both class and investigation activities, with the goal of having the students develop a deep understanding of scientific concepts” (Ontario, 2012, p. 31). The curriculum recognizes that students bring their individual interests, abilities, cultural experiences and prior learning to the classroom and that they will be engaged when they “are able to see the connection between the scientific concepts they are learning and their application in the world around them and in real-life situations” (p. 31). Without using the terminology of constructivism, the curriculum includes many of the features that the previous Taiwanese study classified as such. The directive to shift the emphasis from the content to the context has been established. The curriculum documents indicate a potential shift in pedagogy, with an emphasis on active involvement and engagement; however the goal remains the scientific concepts.

Meaningful learning occurs when students are actively engaged in authentic contexts, rather than just studying the inert content of textbooks (Jonassen, Howland, Marra, & Crismond, 2008). Consequently, the Scientific Literacy Framework moves the emphasis of scientific content into the background in a foundational role. The emphasis turns to the process of interacting with the material, rather than acquiring it.

**Communication.** Communication refers the exchange of verbal and non-verbal information and ideas. These could include text, symbols, images, and video. Communication is a participatory action and students will both receive and contribute to the conversation. Technology provides a medium that students and science educators can use for communication and information management.
Communication includes reading comprehension; writing; oral conversation; presentation skills; and visual expression of scientific ideas, vocabulary, and understanding. It is a two-way process in which individuals receive information and, in turn, use a variety of language media to express their ideas and comprehension.

One major controversy in the scientific literacy debate is whether the emphasis should be on the traditional definition of literacy, i.e., solely reading and comprehending text. Norris and Phillips (2001) distinguish between a fundamental scientific literacy, which emphasizes reading and writing skills in a science context, and derived scientific literacy, which implies an understanding of scientific facts and concepts. They attribute the lack of achievement in derived scientific literacy to a lack of focus (and thus low success) in fundamental literacy. They suggest that students who do not have explicit instruction in fundamental scientific literacy will not have the foundational skills needed to access the concepts, which is the first step towards synthesizing personal meaning and understanding of such concepts. Norris and Phillips expanded their definition of reading from being more than merely decoding, but to also include comprehending, interpreting, analyzing, and critiquing texts, thus applying the vocabulary to an interactive context using students’ higher-level thinking skills. Lemke (2001) also commented that low fluency in English language would impact a student’s ability to understand lessons involving new scientific concepts and to participate in scientific conversations and activities. The Scientific Literacy Framework definition of communication proposed here also promotes these skills.

A clear understanding of technical vocabulary is essential to effective scientific communication (Arons, 1983; Lemke, 2001; Miller, 1983; Norris & Phillips, 2001;
Osborne, 2002). However, the terminology must play an active role, i.e., it must be used in conversation. The vocabulary must be meaningful in the lives of the students. “A scientific concept involves an idea first and the name afterward ... understanding does not reside in the technical terms themselves” (Arons, 1983, p. 92). The Scientific Literacy Framework encourages opportunities for students to engage in meaningful conversation in order to assimilate new terminology into their active vocabulary. “Meaningful learning does, however, take time. If students are truly to understand science and develop useful skills…they must take time to wrestle with new ideas and discuss their ideas with their classmates and teachers” (Bybee, 2006, p. 8)

Lemke (1990) warned that science language could be exclusionary if it over-emphasized vocabulary in an authoritative and technocratic manner. Gaining competency with the language of science is like learning a second language; conversational practice is necessary to make it fluent and meaningful (Brown & Sprang, 2008; Lemke, 1990). When students translate from scientific language to the everyday vernacular language and use scientific language in peer conversation, it becomes more relevant and contextual (Brown & Sprang, 2008; Lemke, 1990; Wallace, 2004). Students are encouraged to practice both oral and written expressions of their scientific language skills. This helps to both master the language skills and also to express their conceptual understanding of scientific topics. Superficial methods such as multiple choice tests or worksheets do not evaluate a deep understanding of the material.

Scientific writing is a genre that requires instructional support, feedback, and practice. Students often struggle to become proficient with this skill. An Australian study described an attempt to improve the report-writing skills of third-year undergraduate
science students (Chuck & Young, 2004) using a combination of explicit instructor feedback, peer review, and self-assessment. Competition among the students superseded collaboration. These results point to a need to develop a classroom culture of cooperation and community. Such relationships contribute to the success of pedagogic activities.

Scientific conversations can help students formulate and express their ideas. It can help peers by introducing another perspective, or by using age-appropriate language. Such conversations can illuminate lingering questions or misconceptions for the teacher to clarify. On-task conversations also provide a context for students to use vocabulary, express their understandings, and develop justified explanation of scientific phenomena. “Scientific understandings are constructed when individuals engage socially in talk and activity about shared problems or tasks. Making meaning is thus a dialogic process involving persons-in-conversation” (Driver, Asoko, Leach, Mortimer, & Scott, 1994, p.7).

**Collaboration.** In the Scientific Literacy Framework, the third element is collaboration. Collaboration is the sharing of effort and expertise exhibited through teamwork, cooperative learning. It showcases the interpersonal skills of planning, delegation, and negotiation. It may involve elements of peer review or peer editing. The framework recognizes that learning is a social activity. Human beings naturally work together in knowledge-building communities, sharing knowledge and building upon it (Jonassen, Howland, Marra, & Crismond, 2005). Cooperative learning fosters conversation among participants, which in turn promotes language skills and the integration of new concepts into social contexts. Collaborative activities provide
opportunities for students to share prior knowledge and to fully explore their conceptual understanding.

Roth and Lee (2004) recognized the interactions that are an inherent part of classroom dynamics. It impacted their interpretations of both scientific literacy and lifelong learning. “Human activities (including conversations) are irreducibly social phenomena that are more than the sum of the contributions of individuals. …we propose to think about scientific literacy as a collective rather than individual practice.” (Roth & Lee, 2004, p. 269). Roth and Lee described scientific literacy metaphorically, as an intertwined rope. The rope is “(collective) rather than as a property of the threads (individuals). Scientific literacy exists within the collective.…This implies that individual students learn to engage in collective endeavors, even though they bring different dispositions, interests and skills” (p. 269).

In his sociocultural perspective, Lemke (2001) emphasize the importance of communities. Science education takes place within an institutional and cultural framework. This context impacts the interactions, the choice of language, the perceptions of relevance, and the sense of identity (both individual and as a group).

Collaboration can foster a sense of community in a classroom. Wenger (1998) described the various communities of practice that exist in a school setting and the roles, behaviour, social interactions that occur in a classroom, in the school yard, or on a sports team. He suggested that the most personally transformative learning for youth takes place within such a community of practice (p. 6). Directing some of the influence of their peers towards a collaborative learning activity could harness some of this power for scientific literacy initiatives.
The link between collaboration and the existing models of scientific literacy is clear. The Canadian Common Framework described its goals of promoting collaboration, teamwork, and the social contexts of science (Roscoe & Mrazek, 2005). A teamwork approach to science education should reflect the character of group work experienced by scientists and engineers in the workplace (AAAS, 1989). A community of learners is established when learning becomes a collective endeavor. It recognizes the benefits of a distributed model of learning in which students can interact to share knowledge without always relying on the teacher as the central authority (Scardamalia & Beretier, 1994).

**Critical thinking.** In the Scientific Literacy Framework, the fourth element is critical thinking. Critical thinking is an umbrella term for questioning, argumentation, justification, logic, bias, metacognition and self-reflection (Zoller & Nahum, 2012). Students will create and critique arguments with rigorous and logical justification. Students will identify flaws in the articles or advertisements in the media. Students will ask questions of interest or concern to them and their community and they will seek answers. Metacognition provides the opportunity for self-reflection, to identify issues that lack clarity, make connections with prior knowledge, and potential applications. The emphasis on critical thinking indicates a shift from lower-order cognitive skills to higher-order cognitive skills (i.e., a paradigm shift from rote learning of content to application, evaluation, and problem solving) (Zoller & Nahum, 2012).

Critical thinking, or critique, includes evaluations based on evidence and criteria; posing critical questions and forming coherent arguments; and reflective metacognition to organize and examine knowledge (Shen, 2010). These elements also effectively show the
interrelated nature of the Scientific Literacy Framework: evaluation of evidence requires an understanding of the content, and coherent argumentation requires communication skills. The cohesive nature of the Enacted Scientific Literacy Framework contributes to its authenticity.

The analysis and evaluation of data is a key component of scientific work. Understanding how scientists use logic and evidence to develop theories is an important component of scientific literacy (Lawson, 2009). The current body of scientific knowledge has a long history of forming discoveries based on research, which is followed by a process of communicating it to a body of peers for review and approval. “Scientific knowledge is constructed by a community of practicing members in the field, who constantly evaluate theories and empirical findings” (Shen, 2010, p. 1). The skeptical nature of science is often missing in classrooms. Since scientific ideas are routinely presented as irrefutable facts, students can neglect to develop a habit of critical questioning. In their study of the scientific literacy content of science textbooks, Chiapetta, Fillman, and Sethna (1991) observed, “many of the commercially available texts stress the facts and present science as a complete body of information that was derived in an errorless manner” (p. 713). A more balanced view of scientific work would include critical and collaborative peer evaluation. In truth, “science is one of the very few human activities—perhaps the only one—in which errors are systematically criticized and very often, in time, corrected ... In science, we often learn from our mistakes” (Popper, 1969, p. 216).

Elements of the Nature of Science (NOS) have been integrated implicitly and explicitly into science classrooms. Just as there is little agreement concerning the
elements of a definitive canon of scientific content, likewise the definition of NOS has multiple interpretations. Bell, Lederman, and Abd-El-Khalick (2000) define NOS as the “epistemology of science, science as a way of knowing, and the values and beliefs inherent in the development of scientific knowledge” (p. 564). They elaborated that scientific knowledge is tentative; empirically based; subjective; partly the product of human imagination and creativity; socially and culturally embedded. They also suggested that the NOS does not stand alone in any one of these categories, but rather, it overlaps and integrates these ideas.

An international review of NOS documents for K-12 settings cited by Zielder, Walker, Ackett, and Simmons (2001) summarized 14 characteristics of NOS, but these descriptions were both vague and subjective. Some of these included:

- Scientific knowledge, while durable, has a tentative character.
- Science is an attempt to explain natural phenomena.
- Science is part of social and cultural traditions.
- Scientific ideas are affected by their social and historical milieu. (from McComas, Clough, & Almazroa (2000) cited in Zielder, Walker, Ackett, & Simmons, 2001, p 345, emphasis added)

Zielder et al. advocate that a pedagogy that addresses the NOS must move away from a fact-oriented, content-driven focus and embrace the multiple perspectives and possibilities that are implied by these descriptors. In fact, their interpretation of scientific literacy aligns effectively with the Critical Thinking and Communication aspects of the Scientific Literacy Framework: “If teachers support the notion that scientific literacy
entails, at least in part, the ability of students to engage in active dialogue as they ponder evidence, apply critical thinking skills and formulate positions on various topics, then informal discussions and formal debates become central to a broader view of scientific literacy that explicitly included aspects of the nature of science.” (Ziedler et al. p. 344). If used incorrectly, the NOS could be presented as more content-laden facts for students to assimilate. If NOS is presented as it is intended to be, it provides the opportunity for reflection, evaluation, and application: many of the elements of the category of critical thinking. The connection between the classroom applications of NOS and the pedagogic scientific literacy framework also corroborate the links of the framework to Aikenhead’s (2006) ideas on humanistic approaches.

Current reform initiatives that promote an emphasis on scientific inquiry align with the category of critical thinking. Resources prepared for the National Institute of Health (BSCS, 2005) explicitly link the goals of inquiry with the goals of scientific literacy. They state that their curriculum supplement, that explores public health issues through a scaffolded problem-solving approach will provide a scientific inquiry experience. It will help students understand the basic elements related to scientific inquiry; experience the process of scientific inquiry and the nature of science; practice their critical thinking skills; and recognize the role of science in society (BSCS, 2005). They implement a 5E model for inquiry, where inquiry uses a model of Engagement, Exploration, Explanation, Elaboration, and Evaluation. This approach to scientific inquiry is supported by Bybee (2006), who also suggests a 5E approach. Bybee cautions that scientific inquiry is complex and cannot be reduced to a mnemonic or slogan. It should focus on the learning, not the activity. He refrains from even defining the term
scientific inquiry, other than “a teaching strategy that should capture the spirit of scientific investigation and the development of knowledge about the natural world” (p. 9). This supports the broad ranges of possibilities within the Scientific Literacy Framework and the category of critical thinking, in particular.

How logically do students frame their scientific positions by supplying justifications for their conclusions? Other than in written lab reports, they may have insufficient opportunities to practice these skills. “Individuals engaging in argumentation are making sense of phenomena, articulating those understandings and persuading others of their ideas. Meeting these goals requires that individuals construct and support claims using evidence and reasoning; and that they question, challenge and revise their own and other’s claims, evidence and reasoning. Students, however, seldom do these things.” (Berland & Hammer, 2011, p. 68).

Exploring open-ended issues through discussion, argumentation or debate uses skills that are seldom seen in a science classroom (Jimenez-Aleixandre, Rodriguez, & Duschl, 2000). “The discussion of socio-scientific issues is an uncommon practice in science classes” (Reis & Galvao, 2009, p. 164). Controversial topics are avoided due to concerns of parental protests or classroom management difficulties. Teachers might feel unqualified to undertake discussions of a sociological, political, or ethical nature. Time constraints can also hinder the depth in which these issues can be explored (Reis & Galvao, 2009). Consequently, facts are presented as true and unquestioned. Without the inclusion and instruction of critical thinking skills in classroom teaching, students get a skewed impression that neglects the multiple perspectives that can exist for many issues. Scientific developments are a complex combination of costs and benefits. Balancing
these positive and negative factors requires the integration of science with social policy. For students, this is a missed opportunity to explore science in its authentic social context.

**Connections to real world issues.** Connections provide the opportunity to put concepts in contexts. By providing real life applications for the ideas, it illustrates the ‘why’ and ‘how’ of science learning. It provides the opportunity for students to extend classroom concepts and apply them to the communities they live in. Jones (2012) cites research where students reported that contextual applications of their learning, such as earthquake monitors or baby monitors helped them to understand and remember the scientific concepts involved.

Many students recognize the lack of connection between their secondary science courses and their extracurricular interests or potential scientific career paths. A recent Angus Reid survey indicates that current Canadian secondary science students are not likely to continue in a science-related field. Although 82% of students surveyed appreciated the opportunities afforded in science-related careers, only 37% expressed interest in taking a science course at the post-secondary level (“Students say science isn’t cool: survey,” 2010).

Connecting student learning to issues at the community, national, and global levels provides an opportunity to extend student learning beyond the physical and temporal boundaries of the classroom. This concurs with the STSE ideas of social and environmental contexts in the Canadian Common Framework, and it also draws upon the ideas of stewardship, citizenship, and career planning. Local policy issues (e.g., those
relating to the environment) provide an opportunity to showcase science in an authentic context. Students want to link their learning to experiences beyond the classroom, connecting to either extracurricular pursuits or career aspirations. The international Relevance of Science Education (ROSE) project found that students are interested in science and “youth wish to be engaged in something they find important and meaningful” (Schreiner & Sjoberg, 2005, p. 21). In order to explain the areas of student interest, Sjoberg and Schreiner (2005) suggested “the most important challenges facing our society are related to health and environmental issues, and…these fields can offer meaningful jobs” (p. 15).

Issues provide a context and application to demonstrate the relevance of scientific concepts to students. Environmental issues, local industries, social justice concerns, and new innovations all provide an opportunity for students to engage with scientific concepts in authentic situations. Roth and Lee (2004) describe an environmental project’s where students got involved in doing real science while monitoring water quality. They were engaged and knowledgeable, contributing to their community, interacting with community leaders and taking pride and ownership in their work. Although the project may not have mapped directly onto the provincial curriculum document, in many ways the students went far beyond it, with interdisciplinary interaction and character-building results. This project highlights the issue that applications and issues seldom fall neatly within the confines of subject-specific boundaries.

[Scientific literacy] concerns lifelong participation in collective endeavors…If students learn to participate in a particular strand of collective life, such as
environmental campaigning, environmental stewardship, or hatching and raising endangered fish, their participation can continue beyond the spatial and temporal markers of school life. Participation in, and therefore learning about, issues where science can make relevant contributions, can become lifelong endeavors. (Roth & Lee, 2004, p.269)

By interweaving the authentic real-life context into the science education, the involvement and engagement could extend beyond the classroom walls or the school day. Classroom emphasis on scientific inquiry can be inadequate to simulate real life contexts. Schwartz and Crawford (2006) made a distinction between school-based scientific inquiry and authentic scientific inquiry (i.e., that conducted within the scientific community). They suggested that a “school community rarely promotes the complexity of reasoning and negotiation of meaning as it is expressed within the scientific community” (p. 337). They reported on a series of four case studies where students were observed in camps and internships. The case studies examined how the authentic contexts influenced the students’ reflection about the nature of science. The findings suggested that an explicit reflective assignment was needed to guide the participants to re-asses their understandings of the nature of science. Therefore, a hybrid of classroom and authentic contexts was most effective.

Many teachers do include current events from the media in their classrooms. A study by Kachan, Guilbert, and Bisanz (2006) surveyed Alberta teachers and reported that media items from newspapers, magazines and internet sources were regularly included in science lessons. Teachers raised concerns about the difficulty of keeping up with current developments in their fields and how quickly textbooks become outdated.
Their purpose was usually to illustrate or reinforce a curriculum concept. Students also often initiated these media-related discussions, usually for the purpose of sharing or clarifying scientific content. Unfortunately, at the grade 10 level, the survey results showed that teachers never used media reports to teach evaluation of the news, thus missing the opportunity to promote critical thinking. In this case, structured instruction on how to evaluate the arguments presented in a media report could have enhanced the scientific literacy of the students.

Connections to authentic applications allow students to see science in a genuine context. It also provides an opportunity to weave together many of the components of the Scientific Literacy Framework. It provides a context for the content, a topic for the communication, an argument to be critically assessed, and often a larger community with whom to work together. For teachers who do integrate such connections into their science lessons (e.g., Kachan, Guilbert & Bisanz, 2006; or Roth & Lee, 2004) some benefits are evident. Others could be revealed if intentional pedagogy integrated the course content with big ideas and students’ interests.

The Need for a New Approach

With the existing reform in the field of scientific literacy (e.g., AAAS, 1989; CMEC, 1997), why is it necessary to develop a new perspective on scientific literacy? The answer lies in the literature surrounding the work in Nature of Science (NOS) and Scientific Inquiry (SI). Nature of Science refers to the epistemology of science, or science as a way of knowing. It is the philosophical foundation of the field of science and it includes the values and beliefs inherent in scientific knowledge (Abd-El-Khalick, Bell, &
Lederman, 1998). However, there is much dissent regarding what exactly this includes and how it should be presented in science classrooms. (Abd-El-Khalick, Bell, & Lederman, 1998; Bell, 1999). Empirical studies of instructional practice shows that although teachers have a variety of ways to present NOS ideas in class, it is often neglected or presumed that students will acquire such ideas implicitly (Abd-El-Khalick, Bell, & Lederman, 1998; Akerson, Cullen, Hanson, 2009). The two studies investigated pre-service and experienced teachers who were participating in NOS professional development activities. Some teachers interpreted NOS as part of the scientific canon; others viewed it as synonymous with hands-on activities; others did not include it at all. The range of interpretations is indicative of the shortcoming in learning outcomes. The label of NOS did not result in the same quality of learning opportunities for the students in these classrooms.

Scientific inquiry has a similarly vague definition and a wide range of interpretations. The National Science Education Standards defines scientific inquiry as “the diverse ways in which scientists study the natural world and propose explanations based on evidence…Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world.” (NSES, 1997, p. 23) From this definition, an emphasis on understanding how scientists do their work merely provides students with more content; an emphasis on student activities, in which they pose questions, design experiments, gather evidence, and provide explanations is a different type of learning environment- one that emphasizes the critical thinking elements of the Scientific Literacy Framework. The ways scientists study the world could also be simplified into the
scientific method or group observations in a classroom demonstration. The potential risk of oversimplified activities could result in disengagement for students.

A resource document from the National Institute of Health (NIH) (BSCS, 2005) connects scientific inquiry and scientific literacy in an authentic hands-on format. Its goals align effectively with the Scientific Literacy Framework. They state that their four goals for students are to: understand basic elements related to the process of scientific inquiry (content); experience the process of scientific inquiry; hone their critical thinking skills (critical thinking); and recognize the role of science in society (connection). The lessons are structured to scaffold these goals sequentially and explicitly. The NIH document provides teachers with a specific list of behaviors of what both students and teachers should be doing during these inquiry lessons.

The difference between the two general science education initiatives above (i.e., NOS and Scientific Inquiry) and the Scientific Literacy Framework is the latter’s focus on student engagement and de-emphasis on content. In the Scientific Literacy Framework, inquiry or critical thinking is not an isolated topic, but instead, each of the process strands builds on the content in an active and interrelated manner.

**Summary of the Scientific Literacy Framework**

This section has examined scientific literacy from its practical and theoretical perspectives. It has synthesized the theoretical elements into a concise pedagogical framework. Each of the five components (summarized in Table 2) has been described and justified by connecting it to the literature. The key literature topics are specified in Table 3. This framework is intended for pedagogic use in a science classroom. It is an original
arrangement; however, there have been similar attempts to establish a scientific literacy framework. For example, the Canadian Common framework (Table 1) offered a framework that was overly complex with 16 subcategories. Aikenhead’s description of humanistic science education presented a more conceptual approach. There are clear similarities between Aikenhead’s summary of humanistic science and the scientific literacy framework presented here (see Table 4). There are also some subtle differences that prevent humanistic science from being the framework for this study. The references to western science imply that it is culturally limited. The emphasis on outcomes and student achievement may be misinterpreted as valuing assessment over engagement. The pedagogic scientific literacy framework works symbiotically towards both engagement and achievement. Therefore, it uses the Aikenhead’s humanistic perspective to support this framework, in conjunction with the other literature described in this review. This framework is not built upon a foundation of a single perspective any more than a building foundation can be successful on a single stile; a strong foundation relies on an integrated approach.
Table 2

Summary of the Scientific Literacy Framework

<table>
<thead>
<tr>
<th>5 Categories</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content</td>
<td>The scientific content provides a foundation for active learning. Trying to cover too much content often reduces the course to superficial treatment of facts &amp; formulae. Ideally, content should emphasize the big ideas of science and these should be interdisciplinary and emergent.</td>
</tr>
<tr>
<td>Communication</td>
<td>Communication refers the exchange of verbal and non-verbal information and ideas. These could include verbal, written, and multimedia formats with text, symbols, images, and video. Communication is a participatory action and students should both receive and contribute.</td>
</tr>
<tr>
<td>Collaboration</td>
<td>Collaboration describes the sharing of effort and expertise exhibited through teamwork, cooperative learning. It showcases the interpersonal skills of planning, delegation, and negotiation. It may involve elements of peer review.</td>
</tr>
<tr>
<td>Critical Thinking</td>
<td>Critical thinking is an umbrella term for questioning, argumentation, justification, logic, bias, metacognition and self-reflection. Critical examination will identify flaws in articles or advertisements in the media.</td>
</tr>
<tr>
<td>Connections</td>
<td>Connections provide the opportunity to put concepts in contexts. By providing real life applications for the ideas, it illustrates the ‘why’ and ‘how’ of science learning. It encourages students to extend and apply classroom concepts.</td>
</tr>
</tbody>
</table>
Table 3
The Scientific Literacy Framework Deconstructed to show Relevant Theories

<table>
<thead>
<tr>
<th>Scientific Literacy Framework</th>
<th>Included Theory (and Sources)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication</td>
<td>Vocabulary (Lemke; Osborne)</td>
</tr>
<tr>
<td></td>
<td>Oral, Written, Graphic, Visual, Multimedia Representations (Norris &amp; Phillips)</td>
</tr>
<tr>
<td></td>
<td>Conversational communications (Lemke)</td>
</tr>
<tr>
<td></td>
<td>Digital/ Multimedia literacy &amp; communications (Lankshear &amp; Knobel)</td>
</tr>
<tr>
<td>Collaboration</td>
<td>Collaborative attitudes &amp; skills (Lemke; Aikenhead)</td>
</tr>
<tr>
<td></td>
<td>Delegation</td>
</tr>
<tr>
<td></td>
<td>Peer Review</td>
</tr>
<tr>
<td>Critical Thinking</td>
<td>Metacognition (Hollingworth &amp; McLoughlin)</td>
</tr>
<tr>
<td></td>
<td>Reflection</td>
</tr>
<tr>
<td></td>
<td>Scientific Inquiry</td>
</tr>
<tr>
<td></td>
<td>Nature of Science (Lederman)</td>
</tr>
<tr>
<td></td>
<td>Ethical Issues &amp; Personal Responsibility (Hodson)</td>
</tr>
<tr>
<td>Connections</td>
<td>Contextual Applications (Roth &amp; Lee)</td>
</tr>
<tr>
<td></td>
<td>Citizen Science (Roth &amp; Lee)</td>
</tr>
<tr>
<td></td>
<td>Social Issues (Aikenhead)</td>
</tr>
<tr>
<td>Content</td>
<td>Facts, Laws, &amp; Theory</td>
</tr>
<tr>
<td></td>
<td>Knowledge (Life science, Physical science, &amp; Earth Science) (CMEC)</td>
</tr>
<tr>
<td></td>
<td>Skills (lab procedures)</td>
</tr>
</tbody>
</table>
Table 4
Overlap of Aikenhead’s Outcomes for Humanistic Science Education with the Scientific Literacy Framework

<table>
<thead>
<tr>
<th>Humanistic Science (Aikenhead, 2006, p. 84)</th>
<th>Scientific Literacy Framework</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. To make Western science more relevant to students</td>
<td>Connection</td>
</tr>
<tr>
<td>2. To help students become better critical thinkers and creative problem solvers</td>
<td>Critical Thinking</td>
</tr>
<tr>
<td>3. To increase students’ abilities to communicate with scientific communities (to listen, read, &amp; respond)</td>
<td>Communication</td>
</tr>
<tr>
<td>4. Social responsibility (citizenship)</td>
<td>Connection, Collaboration</td>
</tr>
<tr>
<td>5. To increase interest and achievement in the traditional curriculum or other sources of scientific knowledge</td>
<td>Content</td>
</tr>
</tbody>
</table>

The previous section has established the pedagogic framework for scientific literacy. The next task is to identify the tools that can be used to achieve this goal. Information and Communication Technology (ICT) offers a plethora of tools. The challenge is to select and implement them effectively.
Part 2: Applications of ICT for Science Education

The second part of this literature review considers how communication technology has been used in innovative ways. It will begin by defining the type of technology use that is intended in this study. This will ensure that the technologies are compatible with the scientific literacy framework; it will limit the scope of possible technologies; and it will assure a consistent teaching philosophy concerning the use of classroom technology. This study and this literature review focus on wiki projects and social media. These two technologies are frequently cited among the top social media technologies in both usage and potential (Cullen, 2011; Poore, 2013). Poore includes these two technologies on her educational social media list, The Big Four. Cullen highlights wikis and social networking in a chapter describing seven Web 2.0 tools that are effective in learning environments. Wikis and social networking sites (SNS) were observed in the case study classrooms. These technologies are accessible and user-friendly; they do not require special resources or training to implement in a classroom environment.

Learning from empirical studies that have investigated communication technology in science education classrooms is limited by the lack of published work in the field. Luehmann and Frink (2012) asserted that web 2.0 technologies are emergent and dynamic; empirical research on the topic is limited. In their literature review of 15 top-rated journals, they found only 89 articles on the use of web 2.0 technologies in school settings. They critiqued this list as most lacked empirical consideration of implementation or impact. This list was not specific to science education, nor were the articles focussed
on secondary students (i.e., many were used in a post-secondary setting or for teacher professional development).

An attention to student voice and perspective is also seriously lacking from the body of empirical evidence. Web 2.0 technologies encourage participation and decentralized control. Therefore the student experience which is the focus of these tools should be included in the research. In my review of literature, I found very few studies that included student voice, and the articles that did so described post-secondary students’ experiences (Glaser & Carson, 2005; Hume, 2004). This highlights the gap of empirical evidence to describe the student experience of participating in a secondary Web 2.0 environment and the impact of such technologies on their learning. Even Luehmann and Frink (2012), when they gathered data on student blogging in science classrooms, used teacher interviews, rather than student interviews. This highlights the challenges of access and timing for collecting data from the participants themselves.

Since the current philosophy is to reduce the amount of curricular content to encourage exploration of issues in greater depth (AAAS, 1989; CMEC, 1997), it would be counterproductive to add technology activities as additional content. Ideally, technologies should provide an alternative to the traditional classroom discourse patterns (e.g., initiate-respond-evaluate) and facilitate “natural extensions to the real world, whereby ideas are conceived [and] responded to” (Scardamalia & Beretier, 1994, p. 266). ICT provides a variety of tools that can motivate, enhance, and enrich the learning experience. However, they are only tools and not a miracle solution for achieving scientific literacy or meeting any other educational challenge. Thoughtful planning and creative integration are essential (Poore, 2013).
A Focus on Scientific Literacy Framework Compatibility

The variety of ICT and their applications are vast. However not all technologies correspond to a constructivist approach to learning (Scardamalia & Bereiter, 2008). The goal of this literature review is not to attempt to catalogue the technologies that exist, but rather to identify situations in which the implementation of the technologies corresponds to the process-oriented goals of scientific literacy (i.e., collaboration, communication, connectedness, and critical thinking, rather than content). Although ICT is proficient at storing and retrieving information (i.e., content), many of these tasks are outside the scope of the interactive social learning activities prescribed by the Scientific Literacy Framework. Therefore, the examination of the tools will specifically target communication technologies (CT). Internet search engines, spreadsheets, word processors, email, simulation applets, and interactive whiteboards are intentionally not included in this review. They are useful tools but they are usually utilized on an individual basis and the pedagogy often remains focused on a traditional content emphasis.

In this study, communication technology is defined as those technologies that promote and facilitate interaction and exchange of ideas. This matches with the Web 2.0 progression that encourages user participation rather than just transmission of information. It also coincides with the interpretation of literacy as a social practice, integrating social, institutional, and cultural relationships (Gee, 1997). This study focused on communication technology in an educational environment where student participation contributes to their learning experience. A specific device or program is not prescribed in this study, recognizing that such limitations are quickly transcendened by the development
of new products and the creativity of teachers and students who implement such
innovations.

**Other Technology Initiatives**

Although research involving wikis and social networking sites will be examined
in detail in this review, there are many other technologies with the potential to foster
scientific literacy. For example, online discussion boards have been used as a tool for
students working on a collaborative project that required elements of design, inquiry,
communication, and cooperation (Towns, Kreke, Sauder, Stout, Long, & Zielinski,
1998). Discussion boards also provide an opportunity for asynchronous conversations. It
has been reported that some students are more likely to participate in this reflective
format (Paulisse & Polik, 1999). However, it has been found that the discussion board
postings can often be superficial (Scardamalia & Bereiter, 2008).

Technology can be integrated into instructional activities that promote the
Scientific Literacy Framework. For example, cooperative email assignments link pairs of
students in a structured open-ended question assignment (Pence, 1999). Concept mapping
can be used, both with and without technology. The concept map provides a focal point
for peer conversation in collaborative and critical thinking activities (Sizmur & Osborne,
1997). Blogs have been used for personal reflection and as a structure for receiving
feedback from classmates (Billany, Hartnett, & Bhattacharya, 2007). In each of these
applications, the instructor initiated the project that used technology to support student
interaction, according to specific criteria. Ongoing instructions, supervision and
formative feedback monitored the students’ progress.
The exclusion of these other modes of technology does not imply that they are not useful tools. The focus of this study has been kept narrow for issues of practicality. The pedagogic choices surrounding implementation of technology is essential for using it to support engagement; to make it interactive rather than isolating.

This study needed to narrow the vast field of potential communication technologies to a short list that maximized benefits for learning and already enjoyed high usage by students. Poore (2013) lists the big four potential technologies for education: blogs, wikis, social networking, and podcasting (p. 41). Wikis and social networking sites were evident in the case studies. Not surprisingly, these two communication technologies reflect on two different emphases of collaboration. Collaboration was previously described as working together. The wiki technologies emphasize the ‘working’ aspects of the student experience and the SNS experiences highlight the elements of community and ‘togetherness.’ These two technologies also figured prominently in a European study compiled by the Institute for Prospective Technological Studies (IPTS) and cited by Cullen (2011). He lists the most common Web 2.0 tools used by students in Europe to support their learning. Blogs headed this list (41%), followed by social networking sites (40%), online discussion forums [sic] (29%), and wikis (29%).

Wiki Projects

Wikis are defined as a software platform that can be contributed to by many users. The origin of the name is attributed to both the Hawaiian word for ‘quick’ and to the acronym, ‘what I know is’ (Davies & Merchant, 2009). The most famous wiki is Wikipedia, an online encyclopedia with global contributors.
The wiki spectrum offers many additional opportunities for involvement. Wikis promote participation and collaboration among students, giving them a degree of independence within a framework of structure. Programs such as wikispaces or pbwiki make contributing to a wiki very user-friendly. Some teachers implement a class-based wiki project; others seize the opportunity for their class to collaborate with another school or another culture. Wikis allow the opportunity for publishing student writing, student questions, or student images. Access to the work is managed through privacy controls, so the scope of the group can match the goals of the project. Wikis foster student collaboration by providing an electronic medium that all group members can contribute to. Wikis allow students to publish their work (either polished or in draft form) and receive peer review comments and feedback. Wiki projects can be pre-packaged teaching activities, or they can be developed by the teacher to meet the needs and interests of their students.

Two empirical studies highlight the spectrum of research being done on wiki use in classrooms. Grant (2009) describes a qualitative case study in grade 9 technology class in the UK. Reich, Murnane, and Willett (2012) describe a mixed-methods study of wiki use in K-12 schools in the United States.

In the UK study, Grant (2009) describes students who had no prior experience with wiki use, and who were not given any guidance on collaborative learning skills such as teamwork, peer-editing, or delegation. As a result, although the students did complete the project, many opportunities were missed. The students focused on the content, not the collaboration. Students intentionally avoided peer editing, a task they did not perceive as useful or desirable. They expressed concern that peer reviewers might not be as well
informed as the original author. The benefits of peer editing (e.g., improving clarity, consistency, eliminating errors, and adding new ideas) had not been explicitly modeled in conjunction with the wiki project where it could have been useful. Although the teacher had tracking access to trace an individual’s history of personal contributions (i.e., postings, revisions, or comments to peers), the students expressed concern over their assessment as a group.

The students in Grant’s study were stuck in the paradigm of traditional classroom relationships where an individual student’s work is read only by an individual teacher. “In the absence of other models to draw on, it seems students imported the existing practices of school as they perceived them” (Grant, p. 111). Grant connected wiki activities to Wenger’s (1998) work on communities of practice, where knowledge is a social product, created by participation in the social, cultural, and historical practices of a community. The community provides the authentic context for the construction of knowledge. In a traditional classroom situation, where a transmittal model is utilized, (i.e., transferring factual knowledge from teachers to students), the various opportunities for collaboration and community building are not always realized; the transfer of learning from the classroom context to the world beyond the classroom is not encouraged; curriculum-related conversations seldom take place among students. This top-secret approach might be appropriate if the students were being prepared for careers in security or espionage, but not if the pedagogical goals are to foster scientifically literate citizens who are active and engaged in the real world. The objective of scientific literacy corresponds more effectively with a collaborative, community-based approach.
Reich, Murnane, and Willett (2012) stated their research goals were to determine the quality of wiki use in K-12 schools. They cited the Flat Classroom Project as an example of an engaging, international, multimedia wiki project that provides structure for students to work collaboratively with international peers. “Is this student-centered, global, collaborative project representative of typical wiki usage, or is it a relatively rare exception? Are such exemplary projects found in diverse settings, or do they exist primarily in schools serving affluent students?” (Reich et al., p. 7). They developed the Wiki Quality Indicator (WQI) instrument to carry out their assessment. Wiki quality was defined according to the opportunities to develop 21st century skills. The WQI tool was based on issues identified during interviews with teachers, focus groups with students and classroom observations to develop criteria. The WQI assessed information consumption; student participation; expert thinking; new media literacy; and complex communication.

The Reich et al. (2012) study considered how wikis can foster 21st century skills (e.g., problem solving, complex communication, and new media skills), but their assessment looked only at the wiki itself and did not have input from the students who produced it. Their study valued longevity and multiple purposes (e.g., combining academic writing, peer review, teacher feedback, student scheduling, uploads, images, multimedia, individual pages, and shared pages) in wiki projects, without considering if all these features were actually important to the participants. For example, their top-scoring wiki projects included a middle school novel study that included student responses and online discussions during the reading of the book, followed by a final project that included collaboratively scripting and creating a movie trailer for the book using multimedia editing resources. A research methodology that included input from the
participants could have indicated if the duration and depth of the project were intentional. However, this study did not. The teacher may have used the wiki in combination with another technology such as a class website for other parts of the project (e.g., multimedia). This would have resulted in a low WQI. In addition, some of the low-scoring wikis seemed to have been designed as delivery devices for course syllabi, class policies and homework calendars, with little or no expectation of interaction. The wiki served the intended purpose, but received a low WQI score because it didn’t match Reich’s criteria.

The findings of Reich et al. (2012) did show that schools in low-income neighbourhoods tended to have lower wiki quality scores and fewer opportunities for 21st century skill development. The wikis were used for a shorter duration and with a narrower scope of purpose. Reich et al. also found that the level of student collaboration on the wikis in general (i.e., from low-income and high-income schools) was quite low—that very few teachers were making full use of the technological opportunities that wikis offer. As previously mentioned, teachers may have been using different platforms for different purposes. Reich et al. reported that 40% of the wikis they surveyed were failed or trial wikis. Thirty-four percent were teacher-centered content delivery devices. Twenty-five percent were individual student assignments with minimal collaboration and only 1% were collaborative multimedia spaces that received the highest ratings of the WQI. However, Reich et al. failed to consider that a trial wiki, a teacher-centered platform, or an individual student assignment may have been the desired outcome of those projects. They may have been a learning step, scaffolding student and teacher understanding of wikis.
Attitudes towards wikis in classrooms continue to be mixed. Although they offer a variety of educational opportunities for group work, collaboration, social participation, online scholarship, and student publishing in a structured or unstructured environment, the prevalence of wiki use in schools is remarkably low (Davies & Merchant, 2009). Empirical research into the benefits of wiki activities in science classrooms was also scarce. Perhaps the documentation of wiki activities in this study will identify opportunities for wiki use and contribute on an ongoing uptake of this Web 2.0 platform. Additionally, this study will examine wiki use through qualitative methods, giving voice to the experiences of students and teachers (in contrast to the study by Reich et al.) and will examine the connections between SES, resources, and wiki use (as proposed by Reich et al.).

Social Networking Sites

Social software refers to online applications that support interaction between members of groups (Selwyn & Grant, 2009). This is an umbrella term for social networking, blogs, virtual societies, multi-player online gaming, wikis, and more. Social software represents a shift in the way people interact on the internet, from passively consuming information to being active and creative contributors in a Web 2.0 format. This change will also affect learners and learning activities.

The educational potential of such internet use is considerable....[There are] strong links between the nature of social software use and social-cultural perspectives on learning which see knowledge as constructed active by the learner within
communal social settings ... Social software is also implicated in notions of the changing nature of contemporary learners – with schools, colleges and universities faced with incoming cohorts of ‘digital natives’ said to be characterized by habitual use of social software in most areas of their day-to-day lives. (Selwyn & Grant, 2009, p. 80)

Social media such as social networking sites (SNS) have a growing impact on learning outcomes whether they are used formally or informally to support student interaction and classroom communities (Poore, 2013). Four main themes were evident in the literature on social media. This section considers a) the patterns of usage of SNS; b) how SNS foster communities of learners; c) how SNS help form an adolescent sense of identity; and d) how SNS contribute to a decentralized classroom environment. Each of these topics will be discussed in the following sections.

a) **Patterns of Usage.** Many students have developed diverse skills with digital technology (see Tapscott, 2008; Prensky, 2001). Some studies have found a ‘digital disconnect’ between the ubiquitous wifi technology that many tech-savvy students have available at home and the regulations, restrictions, filters, and controls that can inhibit their internet access at school (Levin & Arafeh, 2002; Selwyn, 2006). Selwyn (2006) reported that some students commented that the school’s restrictions impeded their educational use of the internet. Often these restrictions were designed to block access to SNS and other sites. Selwyn also reported that other students described methods of circumventing the rules by using teacher’s login codes or other hacking options.
Consistency between internet accessibility in home and school environments and between various schools was often lacking due to differences in resources or regulations.

A 2008 study by Luckin et al. (cited in Passey, 2011) examined technology access by adolescents. They found that student access to technology inside and outside of school was very high, but that technology usage was much higher outside of school. Students reported on both quantity and quality of technology usage. They reported they spent more time using computers at home for school-related activities than they did at school and that collaborative activities were more prevalent outside of school.

In addition to differences in ease of access at home and school, studies have shown a distinction in how students use the internet in these locations. Madge, Meek, Wellens, and Hooley (2009) reported on a study of the Facebook usage of British undergraduate students. The students in this study concurred that Facebook was a social media platform and should not be used for formal teaching. It was clear that they had established boundaries in their technological platforms and did not envision the benefits of integration. However, these same students did use Facebook for informal, student-directed learning purposes – usually for clarifying logistical questions with peers (e.g., due dates for assignments or room locations of classes), asking academic questions of peers, arranging for group project work, or revision of their work. The students perceived Facebook as an extracurricular context where they could express themselves privately (among their peers) without the professional expectations or intrusion of teachers. The type of task determined whether these students considered it appropriate for a SNS environment. In another study, Cullen (2011) stated that the weekly time devoted to SNS activities of adolescents rivaled their duration of television viewing (nine hours versus ten
hours). The majority of participants in Cullen’s survey who use SNS also reported that they use this technology for educational-related topics.

b) **Community.** Social software facilitates relationships in an online community. The members of such a community choose to participate in the virtual group for a number of reasons: it can be to establish social networks at university before physically arriving on campus (Madge, Meek, Wellens, & Hooley, 2009) or it may be to maintain strong links with people that one already has a close connection with (i.e., people in the same class, friends from a hometown, or individuals with a common interest). Selwyn (2009) identifies two types of SNS patterns: an ‘online to offline trend’ and an ‘offline to online trend.’ ‘Online to offline trend’ refers to those people that initially meet online and then progress to a face-to-face meeting (e.g., online dating sites); the ‘offline to online trend’ includes individuals who know each other before connecting through a SNS and who chose the SNS as a convenient method to stay in touch with friends they already know.

Facebook connections tend to involve the latter type – individuals meet in person first and then use the SNS to facilitate their communication. Choice is a key element in this distinction – individuals have a multitude of media options (in addition to their face-to-face interaction), but SNS such as Facebook tend to be a convenient popular choice. The SNS allows participants to maintain and strengthen the relationships that they have already established in a more traditional format by using popular online media.

Wenger (1998) described the characteristics of a community of practice to be mutual engagement, joint enterprise, and shared repertoire. A SNS community allows
students to interact with one another in a participatory manner towards a shared goal or common purpose. Participants will not be homogeneous in nature, but they will share a common purpose and contribute diverse abilities, interests, and experiences to the group. This range of perspectives provides enriches and informs. The shared repertoire refers to the prior experiences that bring a group together. Interaction around a central issue gives a community identity and purpose.

c) **Identity.** Social Networking Sites can contribute to a sense of identity, both individually and as a member of a group. For adolescents who are forming their own personal identity and for whom peer recognition and affiliation is important, SNS provide a medium to express themselves through their profile and for others to contribute to this evolving self-image as well (Greenhow & Robelia, 2009). The online profile allows an adolescent the opportunity to develop an image of herself. Through self-reflection, experimentation, and the contributions of others, this virtual image can adapt and change. “The process of identity formation is an individual cognitive process and a social process, carried out among and in negotiation with others” (Greenhow & Robelia, 2009, p. 123). The use of a SNS provides a media for this presentation and interaction to occur.

Identity is a socially organized status. The identity of the community as a whole is a negotiated process (Wenger, 1998). Within the community, individuals also establish their identities, often reflecting their involvement within the larger group. Wenger suggests that individuals identify most strongly with the communities in which they develop ownership and power. Identity is not static; it is a dynamic process, reflecting the
ongoing development of the individual. Therefore, participation within an active SNS can contribute to one’s individual and collective identity.

One’s sense of identity has a contextual component. Solomonides and Reid (2009) defined identity as a “sense of being,” an ontological expression that included confidence, happiness, imagination, and self-knowledge (p. 390). If one’s identity includes interaction with peers via social media, then it is authentic and consistent to include such interactions in a classroom context as well.

Gee (2000) described identity as one’s “performances in society” (p. 99). He concurred that identity is influenced by the context and one’s role within it. He suggested that there were four ways to view identity: as a nature or state (e.g., a twin); according to one’s position in an institution (e.g., a graduate student); as a participant within a discourse (e.g., a role of leadership or encouragement); or as a member of an affinity group (e.g., Friends of Charleston Lake Provincial Park). The first two options tend to be external labels; the last two are more participatory in nature and reflect more of an individual’s ideas and personality. The last two perspectives on identity also align well with SNS interaction: individuals can participate in discussions of interest and importance and identify with like-minded individuals on contextual issues of personal importance. Three of Gee’s four perspectives on identity require interaction within a social context, highlighting the importance of providing a structure for student interaction either in a face-to-face context or a virtual online environment.

**d) Supporting Decentralization.** Social software allows for decentralization of participation (Poore, 2013). A traditional classroom can impose pre-defined roles for
teachers and students. The lesson is usually prepared by and delivered by the teacher; the teacher asks the questions and the students respond. Social media facilitates a more authentic inquiry-based environment that parallels the work of scientists: asking questions and responding to peers in a professional conversation. Students can ask questions that are of interest and importance to them and their peers. Answers can be proposed from a variety of sources. Students can develop twenty-first century skills to seek, assess, and analyze information. Participants can contribute according to their own comfort level, participation by all members of the group can be encouraged and accommodated, and multiple perspectives can be considered.

The current trend of flipped classrooms supports both decentralization and interaction with technology. The term flipped classroom refers to a pedagogic approach where the presentation of material is done individually as homework and the class time is used for working with the material. In a flipped classroom, the lesson may be available online so the students can view it independently. Class time makes use of the human capital for discussion, activities, and opportunities for students to interact with one another. Advocates of such pedagogy suggest that it makes effective use of the students’ time and promotes engagement.

Social media has the potential to revolutionize how students perceive their roles as learners. As McLuhan (1964) coined, “the medium is the message,” so can SNS re-envision the role of students from being passive receivers of online information, to active Web 2.0 participants with responsibilities to contribute, create, and critique.
Section Summary

The examination of two applications of communication technology—wikis and social networking sites—highlighted the pedagogic richness these technologies can offer. Although each technology contributes a particular strength, neither one is a panacea. Wiki projects are promising in the dimensions of collaboration, communication, and the critical thinking element of evidence-based decision-making. Student publishing for peer review has the potential to foster communication, collaboration, and the critical thinking element of evaluation. The peer review aspect authentically emulates the actions of the professional scientific community.

Effectively Linking Communication Technology with Scientific Literacy

“There are many ways to be scientifically literate” (DeBoer, 2000, p. 597) and the route to teaching scientific literacy is neither a single path nor a short one. There are many ways to successfully experience the 5C criteria of the Scientific Literacy Framework (collaboration, communication, critical thinking, connection, and scientific content). Ideally it will foster an interest and engagement that will extend beyond the scope of a school curriculum or course syllabus. The pedagogic choices by an informed science teacher will meet the needs and interests of the students; assimilate the available technology; and integrate current issues and ideas. The rapid rate at which technologies change suggests that these innovations are best managed at a local level, rather than as a national program to allow the implementation to be process-oriented and flexible enough to allow for local interests and resources.
Other International Initiatives

As shown previously, there are many interpretations and visions for scientific literacy; the pedagogic choices for implementing student-centered reform are vast. There are also numerous technological choices for supporting such measures. The challenge for educators is to select the appropriate choices and to integrate them effectively.

Examples with Alignment. The research literature documents many international reform initiatives that provide models to consider. They substantiate the importance of promoting such reforms. Educational reform from South Korea (Choi, Lee, Shin, Kim, & Krajcik, 2011), Turkey (Cavas, Cavas, Karaoglan, & Kisla, 2009), and Taiwan (Chin, 2005) has emphasized the importance of scientific literacy and the affordances of communication technology to achieve it. Each international initiative supports the importance of scientific literacy innovation in a global community where the science plays an influential role. The culture and curriculum of each reform location is unique; therefore, their findings can inform this work, but not remove the need for it. The work of Choi et al. (2011) parallels the development of the scientific literacy framework in this study. Their framework was developed in response to a perceived decline in international achievement scores (i.e., PISA). It was developed in part from a quantitative survey, but it resulted in very fluid and affective goals. It consisted of five dimensions: content knowledge; habits of mind; character; science as a human endeavor; and metacognition. Their framework was designed to extend from a personal context to a more general global perspective. The main difference between their framework and the one developed in this study is that theirs’ was very conceptual and theoretical; this framework is
designed to be more practical so it can be applied in a classroom context. A key similarity between the two framework is that they both recognize the need to “rethink current views of scientific literacy and to propose an expanded vision that includes more global perspectives and competencies…in response to the increasing rate of scientific and technological advancements” (Choi et al., 2011, p. 671).

**Examples of Dissonance.** Communication technology can contribute to the development of scientific literacy. However, with the wide range of available technologies, instructional choices must be carefully balanced to achieve the greatest positive effect. The Second Information Technology in Education and Study (SITES) data indicated how ICT can be used in innovative ways (Voogt & Pelgrum, 2003). However, it also demonstrated ICT applications that do not foster scientific literacy. Both extensive and non-extensive ICT-using science teachers rated hands-on materials, general office suite programs, and the Internet as their top three ICT learning resources (Voogt, 2009). Using a word processing program to produce a traditional lab report or using the Internet to access information is only a substitution of a content delivery method rather than an instructional innovation to promote engagement and deep understanding. This indicates that even science teachers who consider themselves technologically savvy were either unaware of the ICT options that existed or were unfamiliar with the potential contributions they could make to student learning. Examples like these are important to illustrate the superficial integration of technology in which potential opportunities are missed. Intentional pedagogy is essential to create rich learning activities.
This literature review has synthesized the significant ideas of scientific literacy into the Scientific Literacy Framework which considers scientific literacy to be an active process. The Scientific Literacy Framework engages students in contexts that are authentic in scientific ways of thinking and in social interaction. It consists of communication, collaboration, critical thinking, connectedness, and content knowledge. The Scientific Literacy Framework advocates encouraging students to read, write, and critique scientific texts; to develop and discuss evidence-based decisions; to assess the validity of scientific claims made by others; and to work cooperatively on issues of common interest. It also encourages students to critically examine the scientific issues that they encounter in their communities or in the media as a habit of mind.

Communication technology can contribute to student experiences in the interrelated aspects of the Scientific Literacy Framework. The second part of this literature review has examined a number of applications of educational technology to illustrate how communication technology can, with proper selection and integration, support higher-level thinking skills in a community of learners.

Technology is a tool that must be pedagogically integrated with classroom activities to ensure an effective match of culture and curriculum (McFarlane & Sakellariou, 2002). Likewise, the research that describes these activities must match the targeted audience and the interactive style that the activities engender. The effective description of these teaching innovations requires listening to the voices of students involved in such experiences.
Chapter 3

Research Design

This chapter describes the research design for this study. It begins by restating the research questions. It then describes an overview of the study. It includes a discussion of the methodological foundations for the selection of a case study methodology to answer these questions. Then it gives the details of the method, including the site selections, recruitment, data collection and data analysis. It describes the triangulation included in the research design. The final section of this chapter describes the coding used in the data analysis. It defines all of the codes used and provides examples of them from the data.

Research Questions

This section revisits the research questions of this project, before elaborating on the details of how they will be answered. The central research question is: What kind of learning experiences aimed at promoting scientific literacy are evident in classrooms where teachers integrate communication technology? In order to investigate this question I have developed the Scientific Literacy Framework in the previous chapter to deconstruct, define, and describe what is understood as scientific literacy. The second research question explores the link between communication technology and scientific literacy: How does communication technology contribute to scientific literacy in classrooms where teachers use these technologies?
Overview of this study

This study is a multi-site case study. It examines the classrooms where innovative communication technology is used or alleged to be used. It explores how this impacts the scientific literacy of secondary students. In this study, scientific literacy is defined by the framework developed in chapter two and it incorporates communication, collaboration, critical thinking, and connections, within a context of scientific content. This study acknowledges that students create meaning in scientific contexts through their interactions with teachers, peers, and a variety of formal and informal resource materials. Therefore, it seeks an active and engaging pedagogy that will encourage students to understand and to apply their scientific knowledge; participate in discussion and debate; and share responsibility for their learning (Yore, 2001). This interaction can occur through the affordances of communication technology; this study seeks to examine how such resources can impact a learning community. This research recognizes technology-based communication as a medium of interaction for the sharing of both content and social connection; it appreciates the complexity of interplay that exists between the learners and the curriculum. Inclusion of technology can include students’ prior knowledge, experience, interests, and social influences. In order to triangulate the data in the study and gather multiple perspectives on the experiences of students and teachers who use communication technology in their science activities, data was collected using a multiple methods approach that was informed by the experiences of the teacher and the students. This included interviews with the teachers, conversations about student experiences in a focus group setting, anonymous student surveys about technology usage, and classroom observations to give context to the data.
The study examined four sites, representing private and public schools. The sample size was small enough to allow for data collection that provided detailed descriptions from each site, and large enough to allow for cross case analysis and comparison of common themes.

Data analysis followed a qualitative approach. Nvivo software was used to code and analyze the interview and focus group transcripts. Content analysis (Patton, 2002) explored the transcript data. Emic and etic patterns emerged and a cross case analysis was completed.

**Methodology**

This section describes the methodological foundations behind the choices that will be further described in the methods section. In particular, it considers the selection of a case study as a research method and the sampling techniques. It provides the theoretical rationale for these choices. The specifics of data collection are described in the method section of this chapter.

**Selection of a Case Study Methodology**

Yin (2009) describes a case study as an inquiry that “investigates a contemporary phenomenon in depth and within its real life context, where the boundaries between the phenomenon and the context are not clearly evident” (p. 18). He cautioned that complex real life situations present a plethora of variables and he stated that case study inquiry relies on multiple sources of evidence that need to converge via triangulation. The teachers and students involved in innovative classroom activities fit this profile of a
contemporary phenomenon that defies boundaries. The complexity of these cases is influenced by a variety of variables that can be acknowledged, although not emphasized. This study examined science classroom activities that integrated communication technology. Resources, prior technical experience of students, the teacher’s teaching philosophy, school policy, will all impact the interactions of the teachers and students. This influence was acknowledged, but it was not the central focus of the study.

Stake (1995) described a case as a bounded system. It may be people or programs of interest, and telling their story will increase the researcher’s understanding of their unique and common features. The story told in a case study should include a thorough description of physical details to develop “vicarious experiences for the reader...a sense of being there” (p. 63). The need for rich descriptive details justifies the use of data collection using classroom observations to describe the physical context as both unique and ordinary (Stake, 1995) so that the reader can create meaning, visualize the events described, and create mental comparisons with other locations. The bounded system for each case was the science class, including the teacher, the students, and their technology-based learning activities, including their interactions with one another, the technology, and with the material. The study included teacher interviews and student focus groups that provided experiential descriptions to present a more complete story of these interactions.

Merriam (1988) described the range of applications of case study research (descriptive, comparative, and evaluative). This illustrates the versatility of case study approaches. However it also indicates a possible weakness in the design of the study: it may be tempting to describe the educational experiences and then attempt to compare and
evaluative them. This is not the intended goal. Each context is unique. This study was
designed to gather descriptions of educational experiences that integrate innovative
communication technology into science learning activities. It will include a description of
the communication technology activities, the context, the perspective of the students and
teachers involved. It is not designed to systematically compare or evaluate them (criteria
have not been established that would facilitate participant selection in an inclusive and
unbiased manner). It may be tempting for the reader to expect an evaluation or
recommendation of a communication technology application that can be integrated
universally into all science programs. This is not feasible when considering the unique
characteristics of learners and the teachers, resources, media influences, and personal
interests that influence them. To avoid developing inappropriate expectations, the study is
clear in its objectives and its limitations. The descriptive portion of the case study will
highlight the interactions of a teacher and learners in an authentic classroom context. All
classrooms are unique.

Four unique cases were examined, described, and analyzed. Subsequently, cross-
case analysis allowed comparison of the group of cases (or quintain) to find common
themes or opportunities for shared success (Stake, 2006). Four cases are not enough to
establish a population of cases, but they do allow for comparison within the scope of this
study.

**Sampling Techniques**

Intensity sampling examines “information-rich cases that manifest the
phenomenon intensely, but not extremely” (Patton, 2002, p. 234). Intensity sampling
permits the examination of exemplars of good classroom practice that are accessible and repeatable at different sites. This study relied on intensity sampling, rather than extreme sampling in order to strive for findings that were transferable and not attributed to unique resources or expertise that could not be found elsewhere. The phenomenon of interest was the inclusion of communication technology in science education classes. Appropriate sites were identified through information on school websites that described extensive integration of communication technology or through personal referrals that knew of technology projects happening in these classes.

Data collection used a multiple methods approach. The variety of data collection approaches was informed by the various participants in these classrooms and supports the triangulation of data. Data was collected in four ways: interviews with the teacher, surveys of the students, focus group with the students, and classroom observations. Data collection methods are described in detail in the next section.

Method

This section will describe in detail the methods used to collect and analyze data in this study. It will include the site identification and recruiting at private and public schools; data collection, including teacher interviews, student surveys, classroom observations, and student focus groups; and data analysis.
Site Identification

As previously stated in the methodology section of this chapter, this study used intensity sampling. The identification of information-rich cases was essential. This was done in two ways and two private schools and two public schools were chosen.

The private schools were selected by systematically examining the school websites to identify schools that had an educational philosophy and practice that included communication technology. A top five list was compiled and headmasters of these schools were contacted to request permission for their schools to participate.

The public schools were selected by a process that began by identifying two public boards: one had a reputation for implementing innovative technology and the other that was both conveniently located and had a reputation for using technology to solve problems involved in the demographic of small schools. I had previously attended a science teaching conference and observed which presenters represented schools and school boards where innovative technology was highlighted. After identifying a perspective school board and obtaining ethics approval, I met with the board’s science program consultant and his associates to get their recommendations of innovative teachers to invite to participate. These potential teachers then formed a shortlist of schools to contact for permission to invite. Identification of a teacher at the second public board was expedited when one of the teachers in the board won a national teaching award, in part for her integration of communication technology in her classroom. A local newspaper article described the teacher’s practice and it aligned closely with the goals of this study. In both of the public boards ethics approval was applied for and received, then the principals were contacted for approval, and then the teachers were invited.
Recruiting

At each site, once the required permissions had been granted (either from the headmaster or the principal) the teacher was contacted. I contacted three teachers by email and spoke to the fourth in person while I was visiting his school. I outlined my project and invited the teachers to participate. In this communication we planned the optimal scheduling for me to come to the class to explain the study and distribute the Letters of Information and the Consent Forms.

When I visited the classrooms, explained the study to the students and distributed the Letters of Information and Consent Forms for the three student segments of this study (i.e., the classroom observation, the survey, and the focus group). I answered any questions the students had. The students returned the signed consent forms to their teacher who collected them on my behalf.

This recruiting strategy resulted in the participation of four teachers and their respective science classes. The teachers will be briefly introduced here; more details about their teaching, the activities, and the students’ experiences will be described in the data chapters that follow.

Introduction of Participants. At Atlantic View Academy, Mr. Martin is a chemistry teacher with more than thirty years of teaching experience. He is teaching at a private school that offers the International Baccalaureate (IB) program. The class at Atlantic View Academy is small and Mr. Martin’s teaching methods tend to be traditional. The school requires students to have MacBook computers, it uses FirstClass platform for course websites and school email.
At Berryfield High School, Ms. Dalton is a relatively new teacher with five years of teaching experience. She is teaching biology at a small public high school that offers the IB program. She has won a national award for her teaching. She uses Edmodo, an educational social networking site for the course website and course communication. The students are not required to have a particular computer, and they access Edmodo through a variety of smartphones, iPads, and laptops. Flexibility and convenience are key ideas in her integration of technology.

The IB program provides an internationally-recognized, rigorous, standardized curriculum. An IB course usually consists of an additional semester of study in comparison to a regular Ontario university level course and it may be recognized for advanced standing at the post-secondary level. In addition to their course work, students in the IB diploma program also participate in the three main facets of the IB program: Creativity, Action, & Service (CAS) encourages involvement in arts, physical activity, and civic-mindedness; the Theory of Knowledge course provides a foundation in critical thinking; and the Extended Essay (EE) encourages independent learning on a topic of the student’s choice. Two of the teachers who participated were teaching at IB schools.

At City High School, Mr. Saunders is also a new teacher, with three years of experience. He is teaching chemistry in a large urban public school and he is taking a leading role in supporting other teachers to implement technology projects in their classrooms. The department has a class set of netbooks and he has used these to participate in an international wiki project that has allowed his students to work collaboratively with students from around the globe. Mr. Saunders’ teaching is guided by a big idea that allows him to provide context to the course content. The wiki topic is
sustainability and this aligns with the big idea for his chemistry class which is green chemistry.

At Deepwater Academy, Mr. Rutherford is an experienced teacher, with over 10 years of experience, in two countries. The school is a private school and the technology policy allows the students to choose either a MacBook or a Lenovo tablet computer. The dual platform policy allowed the students to experience the strengths and weaknesses of both systems, although it did create some confusion with incompatible software. The school used Moodle as a Learning Management System (LMS). I observed both the grade 11 and 12 chemistry classes because the grade 12 group is very small. Mr. Rutherford created his own Flash animations to demonstrate certain scientific phenomena.

Each of the four sites was well suited for this study; the teachers each integrated technology into their teaching and learning on a regular basis. The frequency of usage varied by school and by topic of study (e.g., at Berryfield High School, Ms. Dalton used Edmodo daily; Mr. Saunders’ class at City High School used the netbooks in class on a weekly basis, (although the students accessed other technology more frequently for their wiki project); and students at Atlantic View Academy accessed their Facebook group almost daily) The classes were using hardware and software consistently and effectively. However, there were also clear differences observed at the four sites, including pedagogy, resources, teaching philosophies, and student experiences. These sites, with their similarities and differences provided rich data for individual analyses and a cross case analysis.

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**Data Collection**

Data collection came from four sources. The variety of sources was designed to facilitate triangulation and provide data from multiple participants.

At each site there were multiple interviews with the teacher. These provided the opportunity to conduct a combination of scripted interviews (at the beginning of the project), informal clarifications during the study, and a summary interview at the end. The interview was designed to answer the central research question and the secondary research question.

A student survey gathered information about their use of technology, in both academic and extracurricular contexts, from all participating members of the class. A Likert-type scale was used to gather data about the frequency of various technology usages. Open-ended questions provided the opportunity for the students to describe, in their own words, how the technology was used and how they benefited from its integration. The survey was designed to answer the central research question and the secondary research question, and to provide a conduit to gather data using closed questioning that would be a non-productive use of focus group time, and to provide background material for the focus group conversation.

Classroom observations conducted by the author provided an opportunity to observe the technology activities and classroom routines from an objective, outsider’s perspective. At each site three observation classes provided the opportunity to see some of the learning activities described by both the teachers (in their interviews) and the students (in their surveys) and to provide a context in which to frame the questions for the final teacher interviews and the student focus group. The inclusion of classroom
observations was designed to contribute to the central and secondary research questions and provide background material for the interviews and focus group.

The student focus group, held near the end of each study, provided an opportunity to speak with the students in a conversational format and gather data about their experiences with communication technology. The focus group was designed to answer the central research question and the secondary research question. The following sections will describe the logistics of each of these data collection activities.

**Teacher Interviews.** The purpose of the teacher interview was to describe the classroom context and pedagogic intentions of the teacher. Merriam (1988) stated that in case study research some or all of the data is collected through interviews. Interviews allow the participants to describe their experiences and express their opinions in their own words (Patton, 2002). Interviews provide an opportunity to gather rich, descriptive data. Patton describes three different approaches for structuring interviews: the informal conversational interviews; the general interview guide approach; and the standardized open-ended interview. These can be combined or overlapped where appropriate. The general interview guide approach used prepared questions and issues that are to be explored during the interview. The order and wording of each question is not as rigid as the standardized interview, which is conducted when each interview requires a precise and consistent protocol. Merriam (1988) described these same approaches, but arranged them as a continuum, highlighting the benefits of using the strengths of each method. In this study, a combined approach is methodologically appropriate: the general interview guide provides the questioning framework for the data collection. The questions and
prompts are prepared in advance to ensure that the key ideas are covered. Some of the questions can be adjusted from site to site as necessary to best fit each context. The order of the questions can be flexible so that the conversation can flow naturally.

The teacher interviews took place at each school, either during the teacher’s spare period or after school. The interview was less than one hour in duration. In each case I had previously met with the teacher informally in person or by email, to obtain some background information about their classroom practices and technology usage. This allowed the use of a prepared interview guide of consistent questions, but also to tailor some of those questions to the specific context at each site. The interview was audio recorded and transcribed verbatim. The transcript was member-checked by the teacher for accuracy and clarification. The transcript was then analyzed with Nvivo software to identify themes or patterns.

**Student Survey.** The purpose of the student surveys was to gather anonymous data that gave an overview of how students use communication technology: the type of communication technology used, frequency of its use, and the perceived benefits. This source of data collection meant that the student focus group could emphasize describing their experiences rather than listing them. The surveys also gathered data from a larger group of students than the focus group could, so the profile of student usage that it provided was more generalizable. A mix of closed and open ended questions was used to facilitate student responses and to facilitate data analysis. Closed ended questions allowed easy compilation of the frequency responses. Open ended questions allowed students to respond in their own words to describe the benefits of communication technology.
The student survey was designed to gather background information about what types of communication technologies are used by students; what milieu they use them in (i.e., academic or social purposes); how often they use them; and what benefits they perceive from the use of communication technology in learning activities. The questions on the types of technology used employed a 3 point Likert-type scale (to indicate whether they used them frequently, occasionally, or never). The question on frequency of usage used a six-point scale (i.e., never; several times per month; several times per week; about once a day; several (2-4) times per day; or many (5 or more) times per day). The open-ended questions asked the students about the reasons they use communication technology for academic purposes and how the communication technology improves their school work. Finally, the students were asked to rate their technical ability and their interest in science. These questions gave an indication as to the level of technical confidence and experience and their engagement in the subject material.

At each site, the survey was distributed to the students who had returned the signed consent form. They were given time in class to complete the survey; it took less than 10 minutes to complete.

**Classroom Observation.** The purpose of the classroom observations was to provide a descriptive context for the case study. Observations are an appropriate technique when a fresh perspective is desired (Merriam, 1988). In this study, the teacher and students at each site were providing their own accounts of their experiences. A neutral observer could notice details not mentioned by any participants. Observational experience can also help interpret participants’ descriptions of their experiences. Merriam suggests a list of essential elements to observe in a case study observation: the setting, the
participants, the activities and interactions; the frequency and duration of situations; and subtle factors such as informal or unplanned activities. Observation is a major means of data collection in case study research; when observation is combined with interviewing it facilitates a holistic interpretation of the phenomenon being investigated (Merriam, p. 102).

Classroom observations provided the opportunity to observe the students interacting in the classroom. Although it was not possible to observe every possible technology activity and every student interaction with the technology, this selection of observations provided an overview of how the technology was used in the classroom, some of the logistics and routines involved with the technology, the rapport of the teacher and students, and the engagement of the students. These observations helped build the rich descriptions needed for a case study narrative. The field notes of the classroom observations also helped to frame some of the interview questions for the teacher interviews and the student focus group.

**Student Focus Group.** The purpose of the focus group was to explore in depth the students’ perspectives on the inclusion of communication technology in their learning activities. The focus group format was methodologically appropriate (Patton, 2002) because it allowed interaction among the students, thereby establishing a conversational social context similar to the situation being studied.

According to Knodel (1993), the selection of participants for focus groups can be classified by two broad types of group definitions: control characteristics are those that are common to all groups and break characteristics are those that distinguish groups from
each other. In this study, the control characteristics involve the selection of senior science students. Common characteristics for all participants will be their enrollment in a senior science (i.e., grade 11 or 12 chemistry or biology). The identification of such control characteristics was important on several occasions when participating teachers suggested that I include their intermediate students. Focusing on senior students ensured that they had more science classroom experience and that the curriculum emphases were consistent.

Break characteristics that distinguished one group from another (and highlighted differences in the practical integration of communication technology) included: teachers’ pedagogic preferences for the integration of communication technology in regular learning activities; communication technology resources specific to a school; project-based activities that incorporate communication technology that are specific to a school or a teacher’s program; urban/suburban differences in community-based resources; and differences in the curricular emphases in public/private school settings. Due to the differences in these break characteristics, some of the interview questions and focus group questions were tailored to each situation. The focus group questions contained a common core at each site, but also reflected the unique characteristics demonstrated by the observation sessions, the teacher’s comments, and the information from the student surveys.

The focus group is a panel interview; therefore the questioning aligned with the methodological structure of the teacher interview. It was a guided interview, with prepared questions that were explored during the session (Kruger & Casey, 2000). Within this framework, the order and wording of questions was not rigidly structured as it would
be in a standardized interview. This allowed for probing and elaboration on a particular topic that may be site-specific.

A one-hour focus group was held with students at each site. These sessions were conducted at the schools, to ensure it was a safe, convenient, familiar location for the participants. The first two sessions were held after classes. The second two were scheduled at lunch time (to accommodate the availability of the students) and were slightly shorter in duration. These conversations provided a description of the student perspective of their experienced curriculum. Questions explored the impact of classroom initiatives that use communication technologies and how they impact science learning and enhance engagement. How did communication technology contribute to the students’ learning experiences (e.g., what was the mode of communication, the frequency, the topic, the amount of collaboration, and the perceived benefits).

Recruitment for the student focus groups was done on a volunteer basis. A description of the focus group was provided orally and in the letter of information at the beginning of this study. Students were invited to participate by returning their completed consent forms. It was recognized that this recruitment strategy would incur bias into the study because the participants would likely be extraverted, technology-savvy individuals. If there were more students interested than could be accommodated in the focus group, participants were selected to achieve a balance of gender and ability. Consultation with the teacher provided a referral list of potential candidates who would be good contributors. Morgan (1998) described referrals and a recruitment method that is well-suited to focus groups. Individuals with insider information may be excellent resources to identify potential candidates. However, the focus group participants will also help ensure
data in this study is rich and descriptive because these students will have experiences and opinions to share. The possible bias of participants will be noted and the missing voice of introverted students or those dissidents towards technology will be queried during the teacher interview. An indication of the students who do not appreciate or frequently use communication technology will be evident from the anonymous student surveys. (At each site this segment of the class was represented in some degree by only one or two students.)

The focus group was planned to consist of 6-8 students at each site. This is considered a medium sized group (Krueger & Casey, 2000) which is beneficial for promoting participation among the adolescent group members and eliciting richly detailed stories.

The focus groups were digitally audio-recorded. The transcripts from the focus group were transcribed verbatim. Moderator recall and reflection summarized main ideas from each focus group. The data from each site was analyzed using a qualitative data software analysis program (i.e., NVIVO) to determine common themes or unique characteristics. Cross case analysis examined patterns of experiences or implementation.

This completes the description of the data collection activities for this study.

**Data Analysis**

The purpose of data analysis was to uncover patterns and themes in the data. Although each site was unique, the various types of communication technology were distinct, and the applications were particular to each context, the analysis hoped to uncover commonalities regarding how these attributes impacted the scientific literacy
outcomes of the students. Coding and classifying of the transcripts using Nvivo followed a pattern of microanalysis, open coding, and axial coding (Patton, 2002). Analysis included an Nvivo-based examination of the coding frequency according to the major categories and themes (which are described in detail at the end of this chapter). Since numbers alone do not capture the richness of qualitative data, a holistic overview of the key ideas at each site was also included.

**Triangulation**

The following section will describe the triangulation that is integrated into the design of this research study. Patton (2002) describes triangulation as an important research strategy that uses multiple kinds of methods and/or data. Patton cites Campbell in the importance of using multiple methods because any one method is imperfect; but “multiple methods, both quantitative and qualitative are needed to generate and test theory, improve understanding over time of how the world operates, and support informed policy making and social program decision making” (p. 92). There are multiple types of triangulation and they are evident in this study in several ways. Data triangulation uses a variety of data sources; methodological triangulation uses multiple methods to study a single problem; theory triangulation uses multiple perspectives to interpret a set of data; and investigator triangulation uses several researchers or evaluators. This study presents elements of all four types of triangulation.

Data triangulation was achieved in this study by using data obtained from the teachers’, the students’, and the researcher’s observations. The various perspectives
highlighted what was important to the participants and the classroom observations provided an objective outsider’s viewpoint.

Methodological triangulation is evident in the multiple methods of data collection tools. These included personal interviews, both individually and in group settings. Data collection methods also included objective observations and anonymous surveys. By using survey data to gather background information about technology usage, I can develop a general profile about the usage patterns at each site. These can be used to better understand the students’ experiences. The survey method for this data is efficient, although more superficial. It is complemented, however, by the focus group interview that allows the students to elaborate in greater detail on their experiences. “Using multiple methods allows inquiry into a research question with ‘an arsenal of methods that have non-overlapping weaknesses in addition to their complementary strengths’” (Bower and Hunter, cited in Patton, 2002, p. 248). The teacher interviews give detailed accounts of the teaching context, the pedagogic intentions, the technologic logistics, and the classroom demographics. The various methods for obtaining data are not intended to yield identical results, but rather they provide the opportunity to test for consistencies and offer a window into the “real-world nuances” that are evident, such as the different experiences or priorities of the participants involved (Patton, 2002, p. 248).

Theory triangulation uses multiple perspectives to interpret data. These four cases are examined from the perspectives of theory and practice. These two perspectives can complement each other. Considering both sides of the theory-practice continuum can also indicate where gaps occur.
The recording of each interview and focus group was transcribed verbatim. The document was checked by the researcher for accuracy with the audio file. The transcripts of the teacher interviews were sent to the teachers to be member checked for accuracy and clarification if needed, and with the exception of minor grammatical changes they were approved. The transcripts were cleaned: all names and identifying features were replaced with pseudonyms. An organizational strategy was developed to identify sites by letter (i.e., A, B, C, and D) and this anonymous identification system was used later to cite references in the data.

**Coding of Data**

The following section will describe the definitions and interpretations of the codes that were used in the data analysis.

Preliminary analysis deconstructed the data into very detailed specific codes. The purpose of this was to pull apart the data and examine what was contained within. This step was performed using Nvivo software and open coding (Patton, 2002) was used to identify and label specific details in the data. This generated between 67 and 74 codes for the four sites (see Table 5). The next step was to consolidate these very specific codes into usable categories. The codes were sorted and grouped according to shared characteristics. The labels for these larger corresponded to the five categories of the scientific literacy framework. The more detailed codes provided insight into the details and minutiae that were encompassed in the category.
Table 5

Total Number of Descriptive Codes during the first step of Data Analysis

<table>
<thead>
<tr>
<th>Location</th>
<th>Number of Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site A</td>
<td>74</td>
</tr>
<tr>
<td>Site B</td>
<td>67</td>
</tr>
<tr>
<td>Site C</td>
<td>67</td>
</tr>
<tr>
<td>Site D</td>
<td>74</td>
</tr>
</tbody>
</table>

These codes were then consolidated in categories of associated ideas. This resulted in five categories. The overall theme was scientific literacy, and it comprised the categories of Communication, Collaboration, Critical Thinking, Connections, and Content. Within each category, there were several subcodes which resulted from the combination of the specific codes in the preliminary analysis. The relationship of theme, category and subcodes used in the secondary analysis is shown in Table 6. These labels parallel the categories in the structure of the Scientific Literacy Framework (as shown in Table 3) but these were the ones that were generated by data. There were minor differences between Table 3 and Table 6. These differences were attributed to some ideas in the framework that were not explicitly evident in the data (i.e., there was no mention of specific lab skills or the Nature of Science in the conversation; ethical issues and personal responsibility overlapped with reflection and was coded as such; and labels such as citizen science were abandoned in favour of more descriptive labels that indicated whether the topic involved the environment, the economy, or social justice issues). Overall, the list of included theory from Table 3 was focused to match the practical aspects of the classroom data, which produced the list of codes and subcodes in Table 6 that were relevant to the data.
When the transcripts were analyzed holistically, without the use of Nvivo, content analysis looked at the text for recurring themes in the conversation (Patton, 2002). These themes were also the main categories from the framework. It allowed an analysis of the key ideas of the conversations and it provided triangulation with the deconstruction analysis that used Nvivo software.

Table 6
Themes, Categories, and Subcodes used During Data Analysis

<table>
<thead>
<tr>
<th>Theme</th>
<th>Categories</th>
<th>Subcodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific Literacy</td>
<td>Communication</td>
<td>Student-student communication</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Student-teacher communication</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Class Discussion</td>
</tr>
<tr>
<td></td>
<td>Collaboration</td>
<td>Teamwork</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Peer support</td>
</tr>
<tr>
<td></td>
<td>Critical Thinking</td>
<td>Metacognition (including Reflection and Learning styles)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Justification</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Evaluation (including Resources and Comparison of policy or methods)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Personal Application</td>
</tr>
<tr>
<td></td>
<td>Connection</td>
<td>Environment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Economy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Social Justice Issues</td>
</tr>
<tr>
<td></td>
<td>Content</td>
<td></td>
</tr>
</tbody>
</table>

**Coding Definitions for the Theme of Scientific Literacy**

The following section will define the coding categories and subcodes for the theme of scientific literacy and give examples of how they were represented in the data. It
will include the categories of communication, collaboration, critical thinking, connections, and content. The subcodes within each category were shown in Table 5. Each of the examples references the data document from which it originates with the participants pseudonym name, the document identifier, and the line number. In the document identifier, A stands for Atlantic View Academy, B for Berryfield High School, C for City High School, D for Deepwater Academy, FG for Student Focus Group, T1 for the first teacher interview at that site, and T2 for the second teacher interview.

**Category: Communication**

Communication refers to the exchange of verbal and non-verbal information and ideas. These could include verbal, written, and multimedia formats with text, symbols, images, and video. Communication is a participatory action and students should both receive and contribute. Coding references of communication included those that emphasized exchanges between teacher and students or among students. It included questions, answers, ideas, and suggestions; the interactions could either be online or via a face-to-face classroom context.

The umbrella of communication included the subcodes of student-student communication, student-teacher communication, and class discussion. This allowed for the analysis of the type and the participants in the conversation, identified as either the students or the teacher. Examples of student-student conversation included: “I’ll ask people on Facebook if they know what we’re supposed to be doing, what pages, or I’ll text them” (Natalia, FG C, line 69) or “it [Edmodo] facilitates group work between students. It eliminates that ‘oh, we couldn’t work on our project because we couldn’t get
together,’ because they can communicate back and forth through Edmodo” (Dalton, B T1, line 221). The student-teacher communication involved references to the variety of ways that students and teachers connect. For example, “it’s easy to talk to Ms. Dalton beforehand or quickly message her on Edmodo” (Sandy, B FG, Line 409).

You can check the school board website and all the teachers have their email information, and you can see what you don’t know for homework, what you are supposed to do, or you miss out on something at school and you can always contact your teachers by sending them email. (Daniella, B FG, line 40)

Class discussion refers to conversations that occur amongst the whole group (not just a select pair of individuals) in which participants can listen and contribute. Discussions may occur face to face (e.g., in class), or they may take place in a virtual environment, such as a discussion board or Facebook group.

I’ve seen an increase in student participation...they get into the discussion, and often their discussion will be really, really good. I’ve started a lesson and gotten three slides in, and I don’t get any more done because I don’t want to stop them from thinking. Even if it strays a little bit from what I’m doing in the class, if they’re engaged, and they’re thinking, and they’re interested – I just want to keep that going. (Dalton, B T1, line 334)

There were 124 references to communication; 55 involved student-student
communication, 53 involved student-teacher communication, and 23 involved class
discussion. (Some references included more than one of the subgroups under
communication.)

**Category: Collaboration**

Collaboration describes the sharing of effort and expertise exhibited through
teamwork or cooperative learning. It showcases the interpersonal skills of planning,
delegation, and negotiation. It may involve elements of peer review or peer editing. The
sub-codes for this category denoted either teamwork or peer support. These differentiated
whether the collaboration was in a formal group project (as a team) or an informal
opportunity for students to assist one another.

**Collaboration Subcode: Teamwork.** Teamwork was shown in references to
formal, structured group projects, from both the student perspective: “the fact that the
whole delegation process for that project was all us. I think we were more excited about
doing this because of the fact that we got to use netbooks ...and collaborate with schools
around the world. So it was kind of more interesting than normal projects where we just
go find some research and do an essay on it and then hand it in – it was more fun.” (Gina,
C FG, line 164) or the teacher’s viewpoint: “they did this insane infomercial...and went to
the next level and they had a website with their YouTube video. And it was kind of neat
cause then they involved other students in the school and other students from the school
were in the video.” (Saunders, C T1, line 425).
Collaboration Subcode: Peer Support. Peer support highlights the opportunities that students have to work together on a more informal basis. This informal network of support may include online interactions: “I was studying one night, and a guy from our class sent me through Facebook a link to a video that explained, in depth, one of the subjects we were talking about” (Mary, B FG, line 568) or a reference to face-to-face peer tutoring:

Yeah, if we are doing something and we don’t understand, we’ll try to help each other. My computer is a tablet so I can write stuff on it, so for explaining something to someone, you just write it out on a word document, it’s like writing on pen & paper – it’s a lot easier. (Brianne, D FG, line 49)

There were 40 references to collaboration; 19 involved teamwork and 20 involved peer support.

Category: Critical Thinking

Critical thinking is an umbrella term for questioning, argumentation, justification, logic, identification of bias, metacognition and self-reflection. Students will ask questions of interest or concern to them and their community and they will seek answers. Students create and critique arguments with rigorous and logical justification. Students can identify flaws in the articles or advertisements in the media. Metacognition provides the opportunity for self-reflection, to identify issues that lack clarity, make connections with prior knowledge, and potential applications.
The range of possible applications in the critical thinking category resulted in a greater number of subcodes than was seen in the other scientific literacy categories. After analysis with these subcodes, it became evident that there was overlap (e.g., usually the metacognition involved either reflection about the learning experience or about the learning style. Subcodes were therefore merged to reduce duplication made the following groups and: metacognition (including reflection and learning styles), justification, evaluation (including resources and comparisons), and applications. The following section will provide definitions and examples of these coding subcodes.

**Critical Thinking Subcode: Metacognition.** Metacognition referred to individuals expressing their level and depth of understanding. The participants often commented on how the format of information impacted its usefulness and their comprehension. Students from multiple locations commented on the benefit of using PowerPoint notes instead of copying notes from the board. The students identified that it allowed them to focus on the material rather than the transcription, to prepare before class, and to be better organized after class:

It’s a lot easier to follow along because a lot of times when you are copying something off the board, writing a note, you’re writing it but you’re not understanding what you’re writing, you’re too busy trying to focus on getting the whole note and keeping up so when it comes to having the PowerPoint you don’t have to be writing because you have it at your disposal, you can have it printed off and have it in front of you, you can already have looked over it the night before to get a better understanding of it, and then you get that opportunity to listen to what
extra things Ms. Dalton wants to add into it, if she has an extra comment that isn’t in the slide show you can add that into your notes cause that’s really helpful to get a better understanding of what you’re learning. (Alicia, B FG, Line 148).

“The students have said to me, that they find it so much easier to not have worry about scrambling to copy down notes and to actually be able to listen.” (Dalton, B T1, line 331).

I think it’s easier to understand when it’s digital, like with your notes you can write in different coloured pens and stuff, but on PowerPoint you can have certain information that kind of pops out and it’s like, yeah I need to remember that...you can go back and review it later...whereas with your papers, everything’s just in the way. (Brianne, D FG, line 26)

It was a logical association to align self-reflection and learning styles in the metacognition subcode. Self-reflection was evident when participants described past experiences and made new insights or revelations (as opposed to direct recall of facts). Teachers and students described learning experiences where the self-reflection uncovered unexpected learning opportunities.

Along the lines of the global teenager project, as we were doing it, we may think...that the environment in our area is probably the same as in other parts of the country. Personally, until we did that project, I thought the same way. But
when the students from other parts of the world, they gave the status of their environment, you really get to understand how different it is. How the social structure works in different areas. (Mattias, C FG, line 105)

Teachers and students commented on different learning styles, recognizing that a variety of approaches can meet the needs of more students and it can reinforce concepts. The benefit of the flexibility provided by technology was highlighted.

Everybody learns differently. When it comes to the PowerPoint, we can either have our iPads in front of us & we can be on Edmodo, we can just follow along the lesson or we can take out a piece of paper and listen to her as she speaks and write it down or take quick notes from the PowerPoint – it’s a big variety and it kind of gives us more of a choice. Instead of just having to copy it down. (Sandy, B FG, line 156)

The option of including visual representations (i.e., images, diagrams, or videos) provided students with multiple ways to learn and understand.

Also, sometimes visuals are reassurance of what you’ve learned. Like, let’s say you’ve learned mixing two chemicals together, and you know how to do it looking at the equations, but if you see the experiment and you see how it precipitates and everything, you get a more clear understanding of how the chemicals balance out and everything. (Charlotte, C FG, line 263)
Critical Thinking Subcode: Justification. Justification was the subcode of critical thinking where students were challenged to present their ideas in a convincing argument, with logical justifications. It is an element of critical thinking that clearly overlaps with communication (expressing the ideas) and with collaboration (interacting with others) and connections (providing a context for the issue). However, the developing of a coherent and cohesive explanation for the argument is a skill that requires practice and support. One school actually integrated explicit critical thinking into their science goals. Justification with data was a key element of this goal.

Most [“Thinking Like a Scientist” activities] involve overall question or scenario, and then having the students come up with pertinent research questions to help them answer the overall question, and knowing what to do with data, such as graphing, ignoring peripheral data that is not useful for answering the question etc. Most students are still obsessed with memorizing or wanting to be able to look up the answer directly. Our school, as a whole, is going to start moving towards more critical thinking approaches starting next year, and teaching the students the different between knowledge, understanding, application of knowledge, and critical thinking. (Rutherford, D T2, line 26)

Students recognized that various media sources and formats could be used to support an argument. They acknowledged the difficulty in developing a clear and convincing
argument.

If you show a video, it’s easier to explain to someone, rather than putting out a whole bunch of words. When I’m writing an essay and I realize that it makes no sense – to have a video to help me support my idea – works so much better. (Cheryl, C FG, line 286)

**Critical Thinking Subcode: Evaluation.** Evaluation was a subcode that identified when students were making an assessment of an argument, resource, or practice. The subgroups of evaluating resources and making comparisons were merged into this subgroup because they all involved similar assessment practices. Examples of evaluation included, “when I read articles online on science, I like reading the comments section, too. Everyone has a slightly different opinion. Some of them aren’t as reasoned as others, but some of them are really interesting…it helps…it’s a more open-minded perspective” (Brittany, A FG, 189). “I have them read particular articles and discuss what they think. Who is the author or authors? Do they think there is bias? Because I think it is important for them to learn how to distinguish unbiased” (Rutherford, D TI, line 224). There were 25 references to evaluation. The subgroup of evaluating resources involved assessing the strengths and weaknesses of resources. These often involved technological resources or learning materials. For example,

Textbooks get outdated really quickly. This textbook here is from 10 years ago. There could be new information… With the internet and with new technology we can know what’s happening with the environment right now. (Gina, C FG, 238).
I prefer videos to images. In biology, it tells you about a process like osmosis. When you use pictures, it’s not a process, but a video is a series of images, connected together. You can understand what is going on. (Daniella, B FG, line 573).

Making comparisons was a subgroup within the subcode of evaluation. It involved identifying difference, although sometimes it was not relevant or appropriate to determine which choice was better. These included, “because of the internet, you can look at the contradictory sides of science and it helps you to develop, to be able to decide what you believe” (Kay, A FG, line 186).

But when the students from the other parts of the world gave the status of the environment, you really get to understand how different it is. How the social structure works in areas, for example versus the place where we live. (Mattias, C FG, line 115)

**Critical Thinking Subcode: Applications.** Applications of critical thinking involved students extending scientific concepts to practical, personal applications. It was closely aligned with connections, with the main difference that the associations were identified by the students. One teacher describes a project where the students were required to summarize a news article and then elaborate on the implications for the individual and the local community.

To give them examples of local community issues, and again, thinking of
what’s important to them. Every Friday a different student is assigned a different article, from either... they can look it up in the newspaper, or Wired, or some science magazine, and what they have to do is read the article and give the basic ...between the lines, and on the lines and beyond the lines...they have to look at what the main part of the article is, what is the information that’s given, and then the second part is how does that affect a local community. So that’s the part of it where they look at how is this affecting me or how is it affecting my community? (Saunders, C T1, line 329)

Students expressed the need to act on their knowledge. Information that was current, relevant and had an implication for their community needed to be acted on.

I think that because we have access to this information, we sort of have the ability to act on it. So if we know that something is going on, then maybe we have the chance to prevent it or try to stop. (Tonya, C FG, line 203)

There were 120 references to critical thinking. These included 41 references to metacognition, 13 references to reflection, 48 references to learning styles, 8 references to justification, 27 references to evaluation, 42 to resources, 13 to comparisons, and 10 to applications.
Category: Connections

Connections provide the opportunity to put concepts in context. Providing real life applications for the ideas illustrates the purpose of science learning. It provides the opportunity for students to extend classroom concepts and apply them to the communities they live in. Some teachers described this as the ‘big idea’ behind their science curriculum that gave it cohesiveness and context. Some theorists refer to this as citizen science – the science that reaches beyond the classroom to the experiences of daily life. Preliminary analysis indicated that the data tended to associate a connection to such issues as the environment and marketing. Teachers occasionally made reference to Science, Technology, Society and the Environment (STSE) connections. This category was initially deconstructed into three subcodes that identified whether the connection was to the environment, the economy, or to STSE issues. However, after coding was done, it was clear that although STSE was a very broad category, most of the occurrences of STSE were of an environmental nature. These STSE references were merged with the environmental sub-code. The remaining reference was to social justice, so the code was renamed social justice issues. Environment included references to green chemistry, the environment, sustainability, and pollution. It was the dominant sub-code, indicating that teachers connect science curriculum to environmental contexts almost exclusively. Economic concerns often overlapped with the environment, if they were mentioned.
Connections Subcode: Environmental Issues. Environmental issues were raised by both teachers and students, at all four locations. They represented an overall pedagogic emphasis on big ideas as well as specific student projects.

I think having a big idea is much better. It allows you to connect it beyond the walls of the classroom right into the community, country, or even world. It places the student within the problem and not just some issue not important to them. For green chemistry they have high stakes involved as they are consumers, they are the ones drinking the water and breathing the air and maybe they will be the chemist to make the next product greener. (Saunders, C T2, line 45)

“We had to research a world issue and talk about it. I had... the oil tank [rig] that exploded in the ocean [Gulf of Mexico] and the oil was going out... (Carla, D FG, line 249).

Connections Subcode: Economic issues. Economic issues were usually raised by teachers and usually involved issues of purchasing and advertising. For example, they involved the purchase of bottled water and making informed decisions about the plastics used in consumer products. “We did discuss water quality again, as well as how knowing science does help us evaluate claims of vendors, governments, private companies, etc.” (Smith, D T2, line 53).
So students, a lot of them chose different types of plastics [to research] and they were looking through a grocery store and they were seeing which products and how many, are made of this plastic that is supposed to have different negative side effects. (Saunders, C T1, line 319)

**Connections Subcode: Social Justice Issues.** Social justice issues were more often raised by students. They included references to understanding conditions, policies and practices from different cultures.

Knowing about the problems in the other part of the world, and if you see it on video, you understand more. Because you’re more interested in all the things, you are not just hearing about it and seeing pictures, it’s like if you were there. (Dianne, D FG, line 269).

There were 24 references to Connections; 11 emphasized the environment, three referred to economic issues, and four references involved social justice issues.

**Category: Content**

The final category of the scientific literacy framework is content. Content refers to the curriculum material. It includes the scientific information, the knowledge and skills that are both explicit and implicit in the curriculum. It does not include attitude or disposition; those temperaments require reflection and consolidation with personal values they align better with critical thinking. Examples of references to content included:
“I showed them a titration today and in the next few weeks they’re going to be titrating weak acids and things like that to see if they notice any differences between strong acids/strong base titration” (Rutherford, D FG, line 44).

[In a design lab] I give them [the students] a topic, for example: investigate the factors that affect the rate of enzyme activity. So they have to research the enzyme, the substrate, their testing methods, they have to write a procedure (they have to have it approved by me), they have to outline their variables, they have to perform many trials, then they have to write up the whole lab report. (Dalton, B T1, line 90)

There were 15 references to content in the data; 14 of these references were in the teacher interview data.

**Coding Clue Structures**

The previous section has defined and provided examples of the coding categories and subcodes. During the coding process, I was aware of these coding definitions and subcodes. I was also conscious of the significance of each comment. My observation time and conversations gave me insight into the intentions and activities of these participants. Clearly, if a participant was speaking that alone was not enough to be classified as communication (or every comment would be coded as communication). I considered whether the intention of what they were describing was to transmit information (i.e., in a classroom teaching context) or to ask and answer clearly-defined questions (i.e., student
to teacher or among students) and these were coded as communication. Class discussions with participation by multiple students and supervision from the teacher were also classified as communication.

Collaboration described situations where students were doing official group projects (subcoded as teamwork) or informally working together (subcoded as peer support). Collaboration involved small group interactions and often included helping one’s peers with explanations of ill-defined questions. Clearly vocal or textual interaction was involved in these collaborative activities. What set collaboration comments apart were the intentions of the participants. Especially with peer support, these were situations involving ill-defined questions where students came together to better understand a topic of confusion, assisting one another and recognizing that each individual presented unique academic strengths. When students described using Facebook to pose the question to clarify what homework questions had been assigned, or what was the definition of Protista, these were coded as communication; when they described tutoring a classmate who didn’t understand the concept of titration curves, this was coded as Collaboration (i.e., it required the tutor to assess where the misconception existed and how best to remedy it). Collaboration was also reflected in open-ended study sessions where students gathered in person or online to work collaboratively to prepare for tests and exams by study asking and answering a variety of questions.

Although critical thinking was a challenge to observe, the student descriptions of their learning activities provided clear clues. The definition and subcodes described metacognition (as evidenced by discussion of self-reflection or learning styles); evaluation of resources or policies; justification of arguments or explanation of choices.
Often the comments coded in this category involved students commenting on their understanding of their own personal learning, explaining their reasoning, and considering how their classroom learning applied in their personal lives. Teachers commented on how their choices of learning activities corresponded to students’ learning styles (e.g., Mr. Martin) and encouraging students to reflect on their learning and make it personally meaningful (e.g., Mr. Saunders).

The subcodes of connections referred to aligning the curriculum with authentic contexts or big ideas. When I was coding for the category of connections I was looking for explicit references to linking classroom learning to real life situations. The teachers were more likely to connect the curriculum to environmental or economic issues and the students were more likely to social justice issues.

The category of content had no subcodes. These comments involved references to science concepts. They included identifying functional groups in organic compounds, analyzing factors that affect the rate of a reaction, balancing equations, and comparing the titration curve of weak acids with strong acids. In each of these comments, the speaker was referring to the concept itself, not to interaction or collaboration with others.

**Coding Challenges**

In a couple of circumstances comments in the data seemed ambiguous because the comment appeared to demonstrate elements of multiple categories. Sometimes this could be dealt with by separating the comment into two distinct comments, each with its own coding. At other times, where the comment could not be easily subdivided, it was important to consider the context and the intentions of the speaker. For example, the
students at the Berryfield High School described the difference between their teacher’s hand-waving explanation of osmosis and diffusion which left them confused and then they viewed an animated video which showed it more clearly. The section was coded as Critical Thinking, with a subcode of metacognition. The students were not emphasizing the teacher’s communication to the students; rather, they were describing effective and non-effective teaching strategies to explain complex, dynamic biologic systems. The contrast between the two teaching approaches was clear and the students’ argument was well justified.

Ms. Dalton will try to explain it, but with diffusion and osmosis, she would say ‘the solvent goes from this side to this side’, using hand movements, and it doesn’t help much – your hand isn’t a membrane and it doesn’t help us see what’s going on. But then she posts a video and we’d be like ‘oh, so that’s what actually happens – it’s not Ms. Dalton’s finger, it’s the channel membrane sending it through’ and then there’d be a voice in the background explaining what’s going on. I find the videos are way more helpful that the pictures cause as much as the pictures are there, they’re not moving, showing you what’s going on. (Kate, BFG, line 582)

The context of the comments provided an indication as to the participants’ intentions. The following comment described the sharing of resources on Edmodo. “I know somebody in the class, like when they do homework, they’ll come across a website
– ‘oh this is a good website’ and they’ll post the link on the wall and it’s there for everybody else to use, too” (Kate, BFG, line 125). In this case, it was coded as Collaboration rather than Communication. The rationale for that was that it was not an interaction between two students or between a student and the teacher (which were the subcategories of Communication. This comment described the actions of a student, anticipating that his peers would benefit from a resource that he recommended. He made the resource available to all of his classmates through Edmodo, perhaps addressing a question that had not yet been asked, but anticipating a likely need.

When Mr. Saunders was asked if he ever involved his students in peer review activities, he described an experience where the students had to be coached in how to provide effective constructive feedback. The students were required to do this as part of a classroom activity (it wasn’t by choice) and they needed practice in achieving a balanced approach that was not socially influenced. Although I had anticipated that peer review would align with collaboration, what Mr. Saunders was describing was more of an activity to learn to be proficient at providing constructive feedback. This comment was coded as Critical Thinking with the subcodes of evaluation and justification because the purpose of the activity was to help students to become better at critiquing the work of others.

I think sometimes when they are given the authority to [peer] review they don’t know how to handle it very well, sometimes they are very tough or sometimes they’re like ‘oh it’s my peer – give them 100%’ And so sometimes I find that was challenging. When it was more of just a formative piece, I think ...I didn’t tell them to give a grade number, I said give them positive comments and what things
did you learn, and maybe some constructive comments. It would be more of a formative assessment rather than `this is what you are getting here`. Because if you assign a number – you got 8 out of 10 - that doesn`t really help you improve.

This ends the section describing the categories and subcodes within the theme of scientific literacy. These codes were used in each case to analyze the prevalence and priority of each category at that site. Overall, coding of the data (both using Nvivo software and considering the conversations in their entirety) provided insight into the activities and teaching philosophies in these classrooms. This analysis and the results will be described in detail in the case studies of the following chapters.
Chapter 4

Data Collection & Analysis – Atlantic View Academy

This is the first of four data chapters. Each data chapter will describe the location and school context; the data collection activities (i.e., the teacher interview, classroom observations, student survey, and student focus group); and the relevant observations at each site. Analysis of the data, specific to each site, will follow. After all four data chapters are presented, a cross case analysis will compare the similarities and differences observed in the four sites.

This chapter describes the teaching and learning activities in the classroom of Mr. Martin at Atlantic View Academy. In the first section I describe the school setting and the data collection, including the two interviews with this teacher, the three classroom observations, student survey, and a student focus group. In the second section of this chapter I highlight the analysis of this specific case in relation to the theme of scientific literacy. I consider what kinds of learning experiences aimed at promoting scientific literacy are evident in classrooms in response to the first research question. I then consider how communication technology contributes to the students’ scientific literacy in response to the second research question. The categories in this theme were previously described and defined in chapter three.

Data Collection

This section will describe the data collection at Atlantic View Academy. All of the names, including the institution and the individuals are pseudonyms throughout this case study.
Location

Atlantic View Academy is a small private school in a large city. Although the size of the city is represented by the variety of industries, businesses, government offices, and academic institutions, the school itself is located in an older, established, wealthy neighbourhood that suggests a small-town, residential atmosphere. The student population reflects the multicultural nature of the city. The school delivers the International Baccalaureate (IB) curriculum, although some classes are blended and contain IB and academic students due to the small student population. The students all have MacBook computers and a school-wide system, FirstClass supports school email and course websites. I have chosen this school because its’ website promotes their technology programs and their success in science education, citing that 50 % of their graduates go on to study science, math, or engineering at university. Their technology program is described as a 1:1 Macbook program where laptop usage is integrated into all classes. Students are encouraged to enhance their learning by using digital technology. The website describes the many projects and group-based student activities that emphasize problem-solving and critical thinking. The school website also highlights the importance of sharing of ideas, creativity, and expertise.

First Teacher Meeting

I first met with the teacher, Mr. Martin, after school on Sept 23, 2011. This was not a structured interview but rather an opportunity to meet him, explain the project, and determine a convenient time to schedule classroom observations. At this meeting, Mr. Martin explained that the main use of the laptops in his classes was for data collection.
and data analysis. They often use data logger software. He described his current class size as small (five IB students were in the grade 12 class, which was taught concurrently with the academic chemistry course). The students usually worked individually. He recommended that the best opportunity to observe them working together collaboratively would be during the group 4 project, which is an interdisciplinary science project for the IB students. In this project, they work with a partner to design an experiment to investigate a topic from the perspective of multiple scientific disciplines (i.e., biology and chemistry). This would take place later in the autumn. They would work after school in the lab on Wednesday afternoons from 4 to 6 pm for three sessions and then they would present their findings.

**First Classroom Observation**

My first observation session occurred on November 24. I arrived at the school early to meet with the headmistress; however, she was detained by an unexpected meeting with a student and was unavailable. At 4 pm, I went to the chemistry lab and there were 4 students present. (One pair had a scheduling conflict on this particular day). Mr. Martin had previously informed them of my visit. I introduced myself and distributed the letters of information and consent. The Group 4 project work had begun the previous week, so the teams of students were underway with their lab work.

**Physical Location.** The school is a blend of traditional and atypical features. The exterior architecture of the building resembles a residential mansion, rather than a high school. The halls are lined with lockers, typical of most secondary schools, but they are
interspersed with the personalized touch of professional-quality, poster-sized photos of Atlantic View Academy’s students engaged in learning activities and extracurricular events. Outside the science room the picture shows the teacher and a group of students clustered around a microscope.

The science lab continues the blend of predictable and uncharacteristic elements: the white cabinets and black lab benches it contains are typical of most high school labs. A modern SmartBoard is positioned beside a traditional fume hood and a small trolley cart of lab equipment. The horseshoe configuration of tables is surrounded by comfortable office arm chairs that would be more typical in a conference room. The arrangement of the tables indicates a potential interactive tone for the class. The arrangement of tables faces the blackboard, not the SmartBoard, indicating the design emphasis of the room. On the walls are two large original portraits, perhaps more normally seen in an art room or gallery. These paintings, which depict Albert Einstein and Marie Curie, were painted by the teacher. Tall windows behind the student lab benches allow lots of natural light. Cast iron, hot-water radiators provide uneven heat to the room.

The Group 4 project involved three pairs of students. They were working on projects on topics that they had chosen. I observed the second and third lab sessions and the day of student presentations. Three science teachers shared supervision of the lab sessions and all three teachers evaluated the final presentations.

The following section will describe the classroom observations of each pair of students during the two laboratory sessions and the presentation day. On the first observation day, there were only two pairs, since the third team had a scheduling conflict.
Although these activities were not a typical classroom setting, collecting observational data of this project was the recommendation of the teacher as the best situation to observe the students in a collaborative activity.

**Team 1.** These two students were experimenting with yeast reactions to explore its production of alcohol and carbon dioxide. They were reacting different concentrations of yeast with sugar and using a potassium dichromate indicator to show if alcohol was present. They wanted to determine if changing the concentration of the yeast would change the amount of alcohol. They were collaborating effectively: one was taking leadership of the lab procedure and the other student was recording data. During this time, I observed both of their MacBook laptops sitting unused on the classroom desks.

Mr. Martin came over to discuss their intended lab procedure with them. This conversation highlighted the lack of detail of their lab procedure. They knew that they would weigh four different amounts of yeast and place each one in a separate Erlenmeyer flask with a constant amount of water and sugar. They would seal the flasks to ensure an anaerobic reaction and check the indicator color later that period and the following week. However, the conversation highlighted that the students were not quite sure how to quantify their color change. The teacher suggested the colorimeter could measure the light intensity through the four test samples. However, the colorimeter was currently being used by the other group. The teacher suggested a hygrometer could be useful and authentic because it would be the device used in beer brewing and wine production to determine the alcohol concentration. The students asked if the device that the police used for checking alcohol content (i.e., a breathalyzer) would work. It would not. They
students went to their computers and searched Google for websites about testing for the presence of alcohol. The top results involved home brewing and the use of a hygrometer, supporting their teacher’s suggestion. They realized that a hygrometer might be a solution but weren’t sure how to contact a brewer to use one.

After they had prepared the four flasks for the anaerobic portion of their project, they began the test for the production of carbon dioxide. They did not know how to measure the gas Mr. Martin suggested using the manometer. The students were unfamiliar with this equipment so the teacher showed it to them and explained how to use it to measure the pressure of the gas. He also gave them a tutorial on how to use the ideal gas law to convert the pressure into a volume. The students prepared the sample. They wanted to put it on a warm hot plate, but they had difficulty measuring the temperature of the hotplate with a lab thermometer (and they could not put the thermometer in the flask because it was attached to the manometer).

At the end of the session they borrowed a cell phone to take a picture of the four samples of solutions with the indicator in test tubes to document the results from the first part of the lab. They planned to get the photo by email.

**Team 2.** Meanwhile the second pair was working on an experiment that compared various skincare products at either end of the price spectrum. They wanted to determine if there was a difference in the chemical properties of the expensive and inexpensive products. They were testing conductivity, pH, and the concentration of nitrate, phosphate, and sulfate ions. They were using the Hach colorimeter to determine the ion concentrations, a conductivity tester, and a digital pH meter. Their first challenge
was to dilute the skincare products. Mr. Martin gave them a brief tutorial on dilutions on the blackboard. Their lack of confidence was obvious, but once they had a procedure to follow, they did so. They were diluting one mL of the cream in 20 mL of water and then taking 1 mL of that solution and diluting it to 100 mL. They were following the dilution procedure provided for them by their teacher. I observed that they were not cleaning equipment well between trials and not labeling their solutions; it had not been included in the brief tutorial session. At one point they were not sure what solution they had in their cylinder, so they had to discard it and start again.

The skincare team realized that preparation of the dilutions was a time intensive factor in their experiment. They planned to come in on their spare period on the day of the next lab session to prepare some of their samples in advance.

In my first observations I had observed multiple instances where the students were unclear about the vocabulary and terminology of the basic equipment they were using (e.g., flasks, pipettes, manometer, beakers, and test tubes). The contrast was evident: the students had weak lab vocabulary, but they had somewhat well-developed experimental designs.

**Second Classroom Observation**

On my second day of observation, the Biology teacher, Ms. Thomson, was supervising the work period. Ms. Thomson is new to Atlantic View Academy, but had taught in an IB school in England for a number of years. This lab session was taking place in the same lab as before. All of the students were taking chemistry and biology concurrently and seemed unperturbed with the change of supervisors. This session
seemed more conversational. Ms. Thompson began this final lab session by talking with
the group and describing an overview of the oral presentation that they would be
expected to present the following week. Each group would prepare a 15 minute oral
presentation with approximately 5-7 slides describing the chemical relevance, the
biological relevance and a summary of their results. They did not have to produce a lab
report from their work. She advised the students to complete their test work during this
session and begin to work on their presentation.

As the students began work during their last lab session, there was some
disorganization. The team working on skin care products had not come in early to prepare
samples. They could not remember the recipe for their dilution and they had not recorded
it in their notes. The team working with yeast remembered that they had not received the
photo of their lab work from the other student. Unfortunately, it was no longer on her
phone.

**Team 1.** The team working with yeast had a plan. They were going to run several
trials to measure the amount of carbon dioxide produced by varying concentrations of
yeast. They had done one trial the previous week, using the manometer. As they
measured out the yeast with the digital scale, they spilled it on the lab bench. As they
measured the amount of sugar to match the previous trial, they realized that they needed
to keep the amount of water in the flask constant but they had not recorded how much
they had used the week before. They relied on memory. When they were ready to run the
trial, they began heating up the hotplate, knowing it had to be warm, but not hot.
However, the hotplate had a relative scale of 1-10 and it was difficult to know what the
actual temperature was. Fifteen minutes into their first trial the manometer seemed to stop changing so the students took this as the endpoint. They took a picture with their laptop webcam and recorded the data on paper in their notebook. They had misplaced the paper with results from the previous week.

**Team 3.** A third group was present in the lab this day. They were working on an experiment to test various concentrations of enzyme tablets to test how well they broke down carbohydrates, proteins, and lipids. The enzyme tablets were commercially available in drugstores and health food stores; the students wanted to test their claims. In the carbohydrate test, they were using soda crackers, crushed and mixed with water, mixed with the enzyme tablets. They were combining this mixture with one crushed tablet and placing drops into a spot plate. They added iodine as an indicator at 20 second intervals to see if the carbohydrate was broken down into sugar. They took digital pictures of the spot plate with their cell phones. They repeated the procedure with two and then three tablets and could visually compare the series of spot plate results. Their procedures were detailed, systematic, and well justified when I asked them to describe them.

This group’s next step was to test the breakdown of protein using 5 grams of Greek yogurt. They used the same procedure and a different indicator. Their enthusiasm with the results of this test was clear: “we got real results! You don’t need to squint” said one student. “Beautiful” responded the other. They appreciated the clarity and confidence of this set of results.
They continued with a third set of trial to examine the tablet’s effect on breaking down lipids, using melted butter as the substrate. As in the previous trials, they used one, two, three tablets and they ran each trial on a separate spot plate. They used the same procedure and a different indicator. They took photographs to document their results. They used their Macbook computers as both a timer and their cell phone as a camera.

**Team 2.** Meanwhile the team working with skin care products had developed an effective testwork procedure. One student was preparing labeled samples of the correct dilutions. The other was focused on operating the colorimeter. It seemed to be an effective delegation of tasks.

**Time Management of the Session.** At 4:25 the teacher announced the time and asked the students how they were doing. The enzyme group responded “great” and the skincare group was not sure if they would be done on time. A few minutes later the teacher asked one of the skincare team who she was texting. She had observed the student’s attention was on her phone and her movements indicated that she was texting. It was the only time that a teacher reprimanded a student for inappropriate use of technology during my observations at this school. The student responded that she was just waiting for the colorimeter to finish its analysis. The teacher suggested she had other work she could be doing.

By 5:30, the yeast team was on their last carbon dioxide trial. The enzyme team was cleaning up. The skincare team was satisfied with their data; they had cut down the scope of their experiment to only include analysis of nitrate ions, conductivity, and pH.
The yeast team had also cut down the scope of their experiment. They realized that the colorimeter was going to be occupied for the entire time and they were satisfied with a qualitative evaluation of comparing the intensity of the indicator color in their alcohol production trials.

In the last few minutes of the session, no students were working on this project. Two students were observed to be working on a biology lab with an imminent deadline. The teacher was checking the cleanliness of equipment that had been rinsed but still exhibited residue of cosmetics or food.

**Third Classroom Observation**

My third observation session was the student presentations of their work. I was interested in how they would use their technical skills to display their lab experiences. All three of the school’s science teachers were present for this event. Before the presentations began I noticed a student who was rehearsing part of her presentation and timing herself using the stopwatch feature on her cell phone.

The first group to present was the enzyme team. Their PowerPoint was clear, organized, and corresponded well to their oral presentation. It included pictures of the enzyme tablet bottle and the list of ingredients. The methodology of their experiment was done in a narrative story format using photographs from the lab to document it. The chemical background of the reactions was provided, including the equations and pictures. Their results section included the pictures of the three trials (using one, two and three tablets). They had cropped and merged the pictures of individual spot plates to provide a single image that summarized each substrate. The use of images in their presentation was
polished and effective. The presentation also included an explanation of how the indicators work. Their error analysis was quite thorough. They had realized that they had not duplicated digestive conditions and factors such as pH and temperature would have an effect. Contamination of equipment was also a source of error. The teachers in the audience complimented them on the thoroughness of their error analysis. The presentation was professional and smooth, although slightly long. The students answered questions from the teachers confidently.

The second group presentation was by the yeast team. Their PowerPoint included video and music components that highlighted their technical abilities, but it did not always complement the presentation. They had complied with the biology teacher’s instructions to link their experiment topic to both biology and chemistry. Their introduction included a description of the cellular components of yeast, which was relevant, and a biological description of yeast infections which was less relevant. Their PowerPoint slides of their research questions and hypothesis were embellished with background music that made it difficult to hear the students speaking. They clearly described their procedure in words and text. The results section was presented in pictures to show the colour changes of the indicators and the reading of the manometer, but once again they had included loud background music in the PowerPoint which made it very difficult to hear their explanations. The pair of students finished with a description of the chemistry of respiration and fermentation. It was complex and they were clearly reading directly from their notes. The questions from the teachers afterwards involved how they had calculated the gas pressure from the manometer reading – the students had difficulty
explaining this calculation. Another teacher commented that the music was distracting and should be omitted in future presentations.

The third presentation was by the group studying skincare products. The students presented their research question and procedure clearly and competently. Their data included the pH, the conductivity, and the concentration of nitrate ions for each of the skincare products. Their data was presented in bar graphs comparing the results of the two products. Overall their PowerPoint was simple, but effective. It was mostly text, with a few photos of the skincare products and the test devices they used. In the questions afterward, they described how they scaled back the scope of their original plan and they competently answered questions about their procedure, calculations, and the applications of their findings.

After the presentations, I had the opportunity to talk informally with the students. They said they mostly used their computers for data collection and analysis, or word processing. FirstClass is the school-wide system that includes email, assignment dropboxes, and coursework folders. They use Garageband and Photobooth programs for their slideshow presentations.

Observation Summary

The first two groups had significant questions about their experimental protocols. They modified their plans to meet their deadlines and worked out their issues on time. The laptops went largely unused during my observations, and sat at a distance on the conference tables while the students worked on the lab benches. Their lack of use for data collection was highlighted when pieces of paper with data were misplaced and cell phone
photos were deleted before they could safely filed. Technology was integrated as a tool when students needed to document their results by taking pictures with a cell phone or webcam; when they needed to verify the assignment specifications; or research something on the internet. However, the Group 4 projects emphasized low-tech laboratory activities. The presentation of the students’ work was an oral presentation with PowerPoint slides. This presentation provided an opportunity for students to integrate photos of their results as well as other images; it also showcased their ability to present their findings seamlessly and confidently. Overall, the observations of lab work and presentations showed effective student collaborations, but they did not incorporate much communication technology to do so.

**Teacher Interview**

On March 25, I interviewed the teacher. I began by asking about his teaching experience. Mr. Martin is a very experienced teacher, with 30 years of teaching experience in several countries, representing the public and private sectors, and including the elementary, secondary & post-secondary levels. He has been at Atlantic View Academy for 10 years. Our conversation highlighted six main themes, including his interpretation of scientific literacy; teaching resources and technologies; authentic contexts; learning technology skills; the IB curriculum; and extracurricular science opportunities. The following sections describe this conversation.

Mr. Martin has extensive teaching experience. He is quite traditional in his teaching methods; he described it as using “simple, old-fashioned teaching” (Martin, AT1, line 16), that he would augment with technologies such as internet videos and hands-
on activities such as labs or demonstrations. During my observations, I saw the end of his regular lessons: they were generally teacher-led discussions at the blackboard or SmartBoard. This is partly due to the perceived requirements of the IB curriculum. “I think the IB material and the IB work should be individual, rather than group work. Other than the group 4 project, everything they do is individual because they are going to be assessed later on individually” (Martin, A T1, line 98). He is interested in both the historical and contemporary aspects of science and recounts being inspired by reading a biography of Albert Einstein:

When I came here, I was so inspired by Einstein, because I had read his biography…and how he grew up and became a Nobel Prize winner. It was a great spectrum of his life. I was inspired by him, so I used some of my painting skills and did that [portrait]. Later on, I was thinking that since I am teaching in a girls’ school, who can be a role model for girls? I found that Marie Curie is the best and probably only one in this regard. So I spent last summer…and put that portrait together. [Scientists] can be male or female …I even tease them, ‘who’s going to be the third painting from this class?’ (Martin, A T1, line 37)

**Mr. Martin’s Definition of Scientific Literacy.** Mr. Martin’s interpretation of scientific literacy focused on the application of scientific concepts. “If students can apply what they have learned in daily life applications, I would call them knowledgeable. They know their subject. But, if they cannot apply what they have learned, they have not fully learned that subject yet.” (Martin, A T1, line 23). I saw clear evidence of this in the
choice of topics for the group 4 project because all of the projects applied scientific concepts to daily life applications.

**Resources and Technology.** Mr. Martin’s choice of classroom teaching resources was vast and varied. He stated that, “we used anything that is available…we use the internet, the SmartBoard, and hands-on experiments. I do demos; I do many labs. We integrate all of the possible technology, such as watching movies on the internet” (Martin, A T1, line 16). I also had the opportunity to observe Mr. Martin in a traditional classroom setting, usually before our afterschool conversations. I saw him use a variety of resources in his classroom. He integrated a blend of teaching formats, including a lecture format with PowerPoint slides and internet images on the SmartBoard, and manipulatives such as molecular model kits. This supported his statement of using anything that is available, both high-tech and low-tech options. He described the use of technology as a tool, giving examples of a reference source to be able to quickly and easily look up formulae and functional groups.

For example if I am talking about caffeine, I don’t remember its formula, so I go to the internet and find the molecule and it gives it to me…or DDT…you don’t memorize those things, but you know how those are built up, what are the functional groups, so more often we go to the internet and investigate those things. (Martin, A T1, line 55)
When specifically asked about the students’ use of their laptops in class, he described applications that were mostly individualized and data-oriented.

Mostly for writing the lab reports, the word processing, the data processing. They collect the data… and they have to put the data into appropriate figures, graphs or tables…Because they use software, it is fast for them to prepare their lab report and hand it in. (Martin, A T1, line 59)

Computers contributed to the efficiency and accuracy of student lab reports. He perceived that software allowed his students to go beyond the prescribed curriculum in the area of data analysis.

Even for data processing, they want to find out what is the trend, between these variables – dependant and independent variable, then they use those graphing method as well. For example, they might find out R², or regression analysis, or error bars (even though for chemistry it is not necessary to do it, but for biology, for example, they do error bars as well). They want to do those things. (Martin, A T1, line 65)

He also described the students’ use of technology in the school-wide FirstClass program. This allowed him to post all of the PowerPoint lessons for student access on the school website. He appreciated the opportunities that it could provide. “I would like to remove any ambiguity… If we did not have enough time to elaborate, they have access to
those materials so they can re-visit those materials and try to clarify any ambiguity” (Martin, A T1, line 104).

Mr. Martin did recognize the convenience of email as a method for students to contact him with questions. “Sometimes they email me. I’m not bad at responding to their email because I wake up early and the first thing I check is my email” (Martin, A T1, line 106). He recognized that the students used various technologies to communicate, but was unclear on the details. “I think they mostly use the email system, they can easily communicate with one another. Facebook, Twitter, they know all those ways” (Martin, A T1, line 153). I believe that they talk through the technology, instead of directly talking. It’s the way they do it. They prefer to talk with their phones rather than talking directly” (Martin, A T1, line 159).

**Authentic Contexts.** Mr. Martin recognized the importance of connecting the science concepts to real life contexts. One of the key examples of linking the science curriculum to real life contexts was through the use of a Hach colorimeter. This device allowed the analysis of ion concentrations in solutions based on their color. Mr. Martin described having used the same device in his post-secondary teaching experience. He appreciated how it could link the work his high-school students were doing with the authentic contexts such as water or soil analysis in environmental investigations and with future contexts as students prepared for post-secondary education using the equipment they will experience again in university laboratories.
They use the colorimetric method to measure the concentration. That’s going to be one of the things that there are going to be using in university… I see a good connection… they get familiar with these kinds of colorimetric methods and when they go to university it is going to be easier for them to use more sophisticated and more precise devices. (Martin, A T1, line 125)

He described using the Hach colorimeter to do soil and water analyses with the students. “If we have water-logged soil it’s going to be different than aerated soil, and they measure the two types of soil in terms of the content of iron (Fe$^{3+}$ or Fe$^{2+}$) and they relate that to the hydromorphic features of the soil in the site as well” (Martin, A T1, line 138). “Or we took samples of water and analyzed them for different ions, for example, total dissolved salt, sodium, magnesium, for common ions in water” (Martin, A T1, line 147).

He also advocated the integration of experiential field trips. These events allowed students to observe high-tech facilities in operation and to connect science concepts to real life operations. The field trips often took place due to parental involvement and connections.

For example, here in the city we have a site where they are trying to recycle waste material using very, very high technology. So we include in the class what they are doing with plasma, incineration, or different methods of waste treatment. The students enhance their understanding and we might even go see the site on a field trip. (Martin, A T1, line 230)
Learning technology skills. When asked about where the students are taught their technology skills, Mr. Martin acknowledged that the content of other courses integrated well. “Most of the time, they learn those things in Technology, so we are fortunate to see that” (Martin, A T1, line 72). If the student needed instruction in a new technology, he included that into his teaching. “If I know of software that will help them, then I teach that to them” (Martin, A T1, line 73). He also acknowledged that the students were more knowledgeable with a multitude of communication technologies than he was. “They can easily communicate with each other…like Facebook or Twitter…they know all those ways…they have to teach us!” (Martin, A T1, line 153).

IB curriculum. In my conversations with Mr. Martin, he was a strong advocate of the IB curriculum and its individual approach, and although he favored including a variety of hands-on activities, these were carried out in a group setting and evaluated on an individual basis. The intention of individual assessments in class was to remain consistent with the IB Final Assessments. “IB, when they assess, it is an individual assessment. I wish we had some kind of group assessment. Other that the group 4 project, we do not have any” (Martin, A T1, line 222). The IB philosophy also emphasized the application of scientific concepts. “The way that IB is set up, they learn how to apply the material in real life. For example, copper plating of something is one of the applications of electrochemistry” (Martin, A T1, line 218). This concurred with Mr. Martin’s interpretation of scientific literacy.
Science Club. I asked about the activities of the school science club, because I had seen bulletin board displays with work attributed to this student group. Mr. Martin described the school science club as another opportunity for students to explore topics of interest to them. The science club met once per week, under the shared direction of the chemistry or physics teacher. “The main idea was to give them more enrichment about the science, but the outcome of that science club is that …we prepare our students for the [regional] science fair as well.” (Martin, A T1, line 242) “During the year,…once a week, we meet with them and we let them design, use the technology, and do the experiments here, take pictures, gather the data, then process the data, and prepare them for that science fair competition” (Martin, A T1, line 251). However, much of this work still seemed to be carried out on an individual basis. It was not seen as an opportunity for student collaboration or peer review. An additional side benefit of the science club was that it prepared students for the design lab elements required in the IB program.

Summary of Teacher Interview. The teacher interview contrasted with what I had expected to find at this school. It did not seem to match the website description of integrated technology. However, the interview was consistent with my classroom observations.

Student Surveys

The student surveys were intended to obtain information from all participating members of the class. They were designed to gather information about the students’ use of communication technology in both academic and non-academic settings. This data
would develop a profile of technology usage without needing to ask such questions in the focus group. At Atlantic View Academy, because of the very small class size, all of the students completed the survey also participated in the focus group. At the other schools, the survey data represented a larger sample size.

The student survey questions asked about the type of communication technology programs used by the students; the frequency of their communication technology usage for both academic and social reasons; and the benefits perceived by students when they used technology for their schoolwork. The question focused on the specific programs used by the students provided a list of ten suggestions (e.g., email, Facebook, Twitter, wikis, etc.) and gave a blank space for the participant to add in any additional program that they used occasionally or frequently. The two-part frequency question involved a five point Likert-type scale, that asked how frequently they used communication technology for school work and secondly for personal reasons. These results were averaged to give a statistical mean. The frequency questions provided an overview of how pervasive the use of communication technology was in their academic and social lives. The final questions were open ended and asked the students about how the technology contributed to their learning experiences. The surveys were not coded, but rather, the frequency question was averaged to give an overall indication of the prevalence of communication technology usage (closed questions and frequency questions did not fit the structure of the coding). The responses to the open ended questions indicated commonalities in the group. Overall, the survey responses provided a general profile of the students in the class.
Survey data was obtained from 5 students at Atlantic View Academy. The surveys were distributed to this group on the day of the focus group and one student was absent. A sample size was small, but consistent. This portrayed a profile of students who use technology frequently for both school and personal reasons. The average of their schoolwork usage was 4.8 out of 5 and their personal usage average was 4.8 out of 5. The small sample size detracts from having statistically significant data, but the trend is clear: four out of five students indicated that they use communication technology frequently (five or more times per day) for schoolwork (the fifth student indicated that she used it several times per day (2-4 times) for schoolwork. The same results were obtained when the students were asked about the frequency of their use of communication technology for personal reasons. Overall, this portion of the survey presented profiles who are avid users of technology. The frequent use was consistent among all the participants.

The more insightful data came from their responses to the open ended questions. When asked why they use communication technology for schoolwork, 4 out of 5 responses (i.e., A2, A3, A4, and A5) referred to collaborating with peers, even though that was clearly not the teacher’s pedagogic intent. “Sending an assignment to my group members” (A2); completing work along with classmates” (A3). The other survey (A1) mentioned asking questions although it did not explicitly describe collaboration. Clearly collaboration via communication technology was happening covertly with these students, even if the teacher and the curriculum did not encourage it.

When asked how communication technology improves their school work, two ideas consistently emerged: accuracy and efficiency. Students appreciated being able to clarify assignments or access answers to questions to ensure accuracy, and this was stated
by all 5 students (i.e., A1, A2, A3, A4, and A5). They used technology, “when asking a question to a teacher or to a student” (A2); and “you can clarify assignments and ask questions to your peers” (A1).

The general idea of efficiency involved being able to access information quickly and conveniently. This was a benefit mentioned by four student surveys (i.e., A2, A3, A4, and A5). “It saves time, rather than waiting till tomorrow to ask an urgent question” (A2); “when cross referencing with other sources, it allows quick access to very specific sources” (A3).

When asked to describe their technical abilities, most of the students considered themselves quite proficient (the average was 4 out of 5). However, their justification for this self-ranking described a comfort level with using common software applications (e.g., MS Word, Excel, Inspiration, and Photoshop).

**Student Focus Group**

The student focus group was held after school on March 28 in the biology classroom at Atlantic View Academy. Five students were present; the sixth student had been absent that day. The students began by describing some of the ways that they use communication technology to facilitate their school work. They began with describing FirstClass, the school email and course management website. They highlighted the organizational features of such software: they could organize course materials (e.g., PowerPoint slideshows, notes, and reference materials) in a single location. Catching up after an absence was easier and retrieving a lost document was straightforward. They appreciated the ability to go online from anywhere and access all of their school material.
without having to carry multiple binders of notes. They could contact the instructor through the email program of this systems system to ask questions and clarify assignments. The topics of the focus group conversation included the student Facebook group; using collaboration for peer support; technology differentiation; technology for organization; and how the students acquire their technology skills. The details of these conversations will be described in the following subsections.

**Facebook.** The students used communication technology to collaborate online. They had created Facebook groups that allowed them to communicate online on a regular basis. One Facebook group included the Atlantic View Academy IB students and it allowed the students to ask each other questions about assignments or course content, work together collaboratively, and establish a supportive community. “If you don’t want to ask your teacher, or if your teacher is not online, you just post it on Facebook, and then all of a sudden everyone in your class has written a comment” (Ellen, A FG, line 26). “We can talk about the IB work that we have, ask questions, and stuff” (Kay, A FG, line 29).

**Collaboration for Peer Support.** Collaboration was pervasive in the student work, according to the students’ comments during the focus group. This was the type of interaction I expected to see at this school, based on the description of technology integration and the school philosophy on their website. Although collaboration was not a priority of the teacher and had not been optimally exhibited during the observation sessions, it was clearly an integral part of the academic experience of these students, as
expressed in our conversation. Ironically, the students attributed their collaboration to the intensity of the IB curriculum: “I think it really does promote that you work together and collaborate” (Kay, A FG, line 311). The students described using the online connection on a daily basis. The Facebook group was a safe, supportive environment where they were not afraid to ask questions. “If I wasn’t able to ask my friends, I wouldn’t get my answers. Sometimes I don’t want to ask my teacher because I think it’s a stupid question. So I’d be a lot more comfortable just asking my friends” (Kay, A FG, line 121).

The students raised issues of empathy and emotional support. “It’s an emotional support, too. You can rant; you can talk about things that are bothering you about a subject…and people will understand and give you support. It’s nice (Gillian, A FG, line 141). “You’re talking to people who are in the same boat as you; they all have the same issues. You can see everyone’s point of view” (Ellen, A FG, line 134).

**Technology Differentiation.** The Atlantic View Academy students also recognized the limitations of Facebook. Certain subjects were difficult to communicate via Facebook because the text medium was not convenient for visual display. The students talked about selecting the best program for the task, a choice I called technology differentiation. “For some subjects…it’s really hard to post it on Facebook. So you can use a videochat like Skype and you can just hold stuff up to the camera on your computer and then you can communicate with people more easily” (Brittany, A FG, line 38). “A lot of times, in math, instead of a video, we just take pictures and post them on Facebook, if we have questions…to help each other understand the problems” (Kay, A FG, line 43).
The students recognized the strengths and weaknesses of various platforms and selected the resource that best suited the task.

Students also recognized the drawbacks of Facebook. “It can be distracting. Personally I don’t use Facebook to ask a question; I just call my friend on the phone” (Gretchen, A FG, line 328). Although Facebook could be a useful tool, they also acknowledged that they needed to establish boundaries and practice self-discipline. “Facebook doesn’t distinguish between what is your school-Facebook group and what is your other-Facebook group. You are automatically absorbed in this social network. It’s hard to separate yourself. You have to be diligent” (Gillian, A FG, line 341).

**Organization.** The students appreciated the organizational benefits afforded by the course website. The website provided a filing system for units within each course. The students could access their notes at any time, from any location. “It helps you keep track of things more easily, the way FirstClass is organized. Instead of having one binder for everything the teacher has given you, you can organize and choose where you want it to go” (Gillian, A FG, line 15).

FirstClass, the school mailing system is great. Teachers post all of the assignments, things like word documents, PowerPoints, links to websites, etc….so if you lose a copy or you miss a class [you can get it]…It’s great because from any computer you can go and access all your school work. (Ellen, A FG, line 9)
Learning Technology Skills. The students explained that their technology skills were learned in several ways. The school has a Technology course that the students took when they arrived at Atlantic View Academy. “Gretchen is taking Technology now, and when I first came to Atlantic View Academy I took Technology in Grade 8” (Ellen, A FG, line 248). The students also had workshops with facilitators from Apple Computers when they began the MacBook program in Grade 10. “When we first got the MacBook, we had a little workshop in the gym. A guy from Apple taught us the very, very basics” (Ellen, A FG, line 256). However, they found peer support and informal peer tutoring to be helpful on an ongoing basis. “Let’s say I needed help for Photoshop, I’d ask a friend who would teach me and the next person who needs help with Photoshop, I’d say ‘this is how you do it.’ It is kind of a chain.” (Ellen, A FG, line 258). Students were seeking a deep understanding of technical skills so that they would be capable of helping their peers, not just a sufficient understanding to solve a current obstacle.

Summary of Focus Group. The conversation with the students revealed a collaborative, congenial, community of learners. An online communication system was active and supportive, although it was unsanctioned by the teacher and operating outside of the classroom context. Students appreciated the organizational features of the online FirstClass system. They acquired new technical skills in a variety of ways (e.g., school courses, special workshops, peer tutoring). The students had organized the Facebook group, and they were aware of the strengths and weaknesses of the technology. They used other software if a visual component was needed. They were cautious and aware of its potential for distraction.
Summary of Data Collection

This section has described the data collection with Mr. Martin’s class at Atlantic View Academy. The analyses of the data are described in the next section of this chapter. The data from the student survey provides a profile of technology usage by these students. The topics of the interview, focus group, and survey data were analyzed first. Then the data from the teacher interview and the student focus group were analyzed using Nvivo. The classroom observations provide a description of the context which these students and teacher were experiencing.

Data Analysis

This section will describe the analysis of the data obtained from Mr. Martin’s class at Atlantic View Academy. Each of the data chapters will examine the case data individually in a similar manner. The documents pertaining to this case included:

- Notes from informal conversation with the teacher, Mr. Martin, September 23, 2011 (2 pages)
- Transcript of Interview with the teacher, Mr. Martin, March 26, 2012 (9 pages)
- Transcript of Focus Group Interview with five students March 28, 2012 (12 pages)
- Field notes (29 pages) of Classroom Observations: November 22, November 29, and December 6, 2011
- Student surveys (n=5)
Two trials of data analysis were completed. The first considered the data in response to the first research question (i.e., How is scientific literacy experienced in classrooms where teachers integrate communication technology) and the second data analysis explored the second research question, (i.e., How does communication technology contribute to scientific literacy in classrooms where teachers use these technologies?) Each analysis is presented first from the perspective of the teacher and then from the perspective of the students using the data obtained from these participants. Each of these analyses explored the data qualitatively, first considering the topics of the conversation as a whole and also by deconstructing the data using Nvivo software. The software was used to code, categorize, and tabulate the data.

**Deconstruction Analysis using Nvivo**

The transcripts were coded with Nvivo software. The first step with Nvivo was to deconstruct the data and identify all of the details within. This resulted in 74 codes for this case. These were then merged and consolidated into seven appropriate bigger categories and two overall themes which were used consistently for all four sites. Five of the categories aligned with the emic theme of scientific literacy. The other categories addressed teaching issues, student issues, and technology issues. These comments, codes, and categories were important to understanding the experiences in these classrooms, but they were not clearly related to this study with a purpose of examining how communication technology can contribute to scientific literacy. Therefore these categories and codes are not included in this analysis.
The overall theme was scientific literacy and the categories were the five elements in this framework: (i.e., Communication, Critical thinking, Collaboration, Connection, and Content). The transcripts were then re-coded according to these five categories, using the sub-codes described in the previous chapter, and assigning a single category to a given reference. Subcodes within each category were also assigned to each reference as warranted. These subcodes provided insight into the nature of the relationship of the reference to the category and allowed for further analysis (e.g., the category of communication included the subcodes of student-teacher communication, student-student communication, and class discussion. This breakdown allowed the examination of the relationships and the relative frequency of each subcode within the category.

Analysis for the First Research Question

The teacher’s perspective was analyzed through the interview transcript. The students’ perspective was analyzed using the focus group transcript and the survey data. The classroom observations provided context for these data.

The Teacher’s Perspective. Examining the substance of Mr. Martin’s interview highlighted six main topics, as presented earlier in this chapter. These included his interpretation of scientific literacy; teaching resources and technologies; connecting scientific concepts to authentic contexts; learning new technology skills; the IB curriculum; and extracurricular science opportunities. The analysis of these topics, and the details they entail, indicated a strong emphasis on scientific content and connections. For example, his interpretation of scientific literacy described his emphasis on connecting
classroom concepts to real-life applications. The portraits of inspiring scientists that he painted for his classroom demonstrated the importance of emphasizing the personal histories behind famous scientists so that students could relate to them, connect, and more fully appreciate their contributions to the field of science. His description of teaching resources and technologies described the pedagogy and methods of his teaching philosophy in which he prioritized the inclusion of authentic contexts to situate scientific concepts. The analysis of the topic of how the students acquire new technology skills showed elements of communication and collaboration, in that he described how he presented some technology skills to the students, they learned some skills in their Technology class, and the students assisted one another in acquiring such skills. The analysis of the discussion of the extracurricular science club closely matched the connections category, as students could investigate a topic of personal interest that would become their science fair project. The examination of his emphasis on the IB curriculum and how he emphasized certain topics aligned with the scientific literacy category of content.

This analysis of the summary of the topics in the teacher interview showed a focus on the theme of connections and content. The two categories were often interwoven. “The way that IB is set up, they learn how to apply material in real life. For example, copper-plating of something is an application of electrochemistry” (Martin, AT1, line 218). However, it was unclear whether the students viewed such an application as relevant to their own lives or just more content to assimilate.

In the classroom, the technology was used on a very individualized basis. Mr. Martin’s comments indicated he was not a strong proponent of collaborating with
technology, but rather saw it as a tool, usually for data collection, data processing, word processing, or online research. This seemed to take a very narrow interpretation of the school’s philosophy regarding technology; their website described students in the 21st century, who learn most comfortably and enthusiastically when they are able to access, analyze, and synthesize information using digital tools.

**Analysis Using NVIVO Software of the Teacher’s Perspective.** The analysis of the transcripts of the teacher’s interview using the Nvivo software showed a slight emphasis on content. There were nine references to content, seven references to critical thinking, seven references to communication, two to connections and one to collaboration (as shown in Figure 4). These results appeared aligned with the teacher’s priorities as noted in the initial conversation, the interview, and the classroom observations.

![Figure 4. Scientific Literacy Coding References in the Interview with Mr. Martin](chart)

**Figure 4. Scientific Literacy Coding References in the Interview with Mr. Martin**
The Student’s Perspective. Direct data from the students came from two sources: the student focus group and the student surveys. These two data collection strategies complemented each other. The face-to-face conversation allowed them to interact as a group; they could elaborate on previous learning experiences and express their personal opinions. The anonymous student surveys provided a more discreet forum. They also provided a convenient method to collect close-ended data from all students and compiled a profile of in-school and extracurricular technology use and expertise. The two data collection methods contributed to the triangulation of the research design. Similar ideas such as online communication with their peers, collaboration via Facebook, and the organizational convenience and time management features of communication technology were mentioned in both sources.

Student Focus Group. The focus group conversation included the topics of a student Facebook group; using collaboration for peer support; technology differentiation; technology for organization; and how the students acquire their technology skills. The description of the Facebook group aligned with scientific literacy category of communication (student-student communication), collaboration (peer support), and critical thinking. When the students described how they use technology to collaborate and support one another it was an obvious example of collaboration and the subcode of peer support. Technology differentiation, which involved selecting a specific format of technology that was most appropriate for a given task, aligned with the critical thinking subcodes of metacognition and evaluation. When the students described how they
appreciated the organizational features of communications technology, it was a match for the critical thinking subcode of evaluation; this mirrored their similar comments in the student survey data. The final major topic of the student focus group was how they learn their technology skills. The students described their practice of peer tutoring of technology skills that corresponded to the category of collaboration and the subcode of peer support.

**Analysis of Student Focus Group Data with Nvivo Software.** The analysis of the scientific literacy categories in the student focus group (as shown in Figure 5) revealed their issues of importance. A slight shift in priorities between the teacher and the students was revealed. The students also emphasized the importance of communication and critical thinking. They did not mention course content at all, but rather, collaboration had the third most frequent coding. The overlap in communication and critical thinking by both the teacher and the student interviews shows a shared emphasis and importance on these areas. The divergence in content and collaboration can be partially predicted: the teacher was more concerned with the curricular content than the students were and only the students were actively engaged in the online collaboration that took place outside of the classroom.
Closer examination of the communication data from the student focus group showed an interesting pattern. The majority of the communication was occurring between the students themselves (i.e., 13 out of 18 communication references were to student-student communication). This data is shown in Table 7. This concurred with the description of the focus group data, in which the main topics included using Facebook for communication; using collaboration for peer support or to acquire technology skills; and reflecting on the benefits of technology for organization or student interaction.
Table 7

Analysis of the Types of Communication described by Students at Atlantic View Academy

<table>
<thead>
<tr>
<th>Type of Communication (indicated by subcode)</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student-Student Communication</td>
<td>14</td>
</tr>
<tr>
<td>Student-Teacher Communication</td>
<td>4</td>
</tr>
<tr>
<td>Class Discussion</td>
<td>0</td>
</tr>
<tr>
<td>Other (i.e., using Google Science Fair to communicate their science projects to the public)</td>
<td>1</td>
</tr>
</tbody>
</table>

**Student Surveys.** The surveys were not coded, but rather the data were aggregated and summarized statistically using Excel. The close-ended Likert-styles survey questions and the questions about frequency of technology use were not conducive to the same coding approach that the interview transcripts used. However, analysis by general topics was a convenient and appropriate method to aggregate the data. The students’ responses to the open-ended survey questions were brief and they were easy to visually scan and find commonalities and associated categories.

As previously indicated in the data collection section of this chapter, the student responses to the open-ended questions in the surveys revealed two main ideas about the benefits of communication technology. These were accuracy and efficiency. These ideas aligned with the categories of content and critical thinking. Under the topic of accuracy, the students were clarifying the details of assignments and explaining misconceptions of scientific concepts. Efficiency was linked to the category of critical thinking and the subcode of evaluation as the students identified the features of their technology that made
it easier to organize, access and store information and facilitating time management challenges.

**Section Summary: Analysis for the First Research Question**

This research question prompted the examination of the data with respect to the Scientific Literacy Framework. It included all of the comments made by the teacher and students, which referred to their science learning experiences as a whole. Some of these learning activities took place within the classroom; others were facilitated by technology outside of the classroom; some occurred within the classroom but were enhanced by the use of technology.

Examining the topics in the transcripts of the interview and focus group documents provides an early indication of some of the priorities at this site. The analysis of the teacher’s interview suggested that content and connections were important. The analysis of the students’ conversation, in contrast, highlighted communication, collaboration, and critical thinking during their focus group. The student surveys focused on practical issues, emphasizing that communication technology is used to support students with understanding content and that they apply elements of critical thinking to learning and to select a convenient and effective medium for student interaction.

This difference in focus as shown in the analysis (i.e., the teacher’s priority on connecting the content to real-life applications and the students’ focus on communication and collaboration) is accommodated in part by the communication technology. The breakdown of student communication subcodes indicates that while communication is very important to them, it is the student to student interchanges that comprise most of
these references (as shown in Table 7). The students used the online Facebook group to facilitate this communication and the teacher was not included.

Both the teacher and the students shared a common focus on critical thinking. The students emphasized the evaluation subcode of critical thinking (5 out of 8 critical thinking references involved the evaluation of experimental design protocols, website information, and scientific arguments). Mr. Martin’s references that were coded to critical thinking were weighted towards metacognition/learning styles (i.e., 6 out of 7 critical thinking references had this subcode). His comments focused on the pedagogical elements of learning styles and choosing classroom activities that appealed to hands-on, sensory, constructivist activities. Clearly, even when there was overlap it the prioritized scientific literacy category, there were significant differences in what was intended from these two groups.

The analysis of the teacher’s interview showed that the major topics corresponded to the categories of content, connections, and critical thinking. The student focus group data highlighted communication, collaboration, and critical thinking in both the topics and the Nvivo analysis approaches concur and contribute to the triangulation of the data described in the research design. The disparity in the categories emphasized by each participant reinforces the differences in priorities and perspectives.

**Analysis for Second Research Question**

The second research question prompted the examination of the data with respect to the use of communication technology in conjunction with the Scientific Literacy Framework. A second analysis with Nvivo was completed with this research question in mind. It included all of the comments made by the teacher and students that specifically
referred to the use of communication technology. This reduced the quantity of data, but it clearly directed the focus of such data in response to the mandate of the second research question. At Atlantic View Academy, most of these activities that were facilitated by technology occurred outside of the classroom; and most were initiated by the students.

Analysis of the data with respect to the second research question (i.e., with an emphasis on the direct use of communication technology) presented some interesting observations. These included the relative frequency of the comments and the quality of the activities that they represented.

**Frequency.** In the teacher’s interview, Mr. Martin had portrayed his teaching to include a variety of teaching resources, but not a strong emphasis on collaborative interaction or the inclusion of communication technologies. Therefore, the results of this analysis were not surprising. The interview data included some references to the use of email to ask questions of their teacher “They email me. I’m not that bad at responding to their email because I wake up early, the first thing that I check is my email. If there is anything from my students, I go directly to my email and try to answer them” (Martin, A T1, line 107). He recognized that the students use a variety of technologies to communicate amongst themselves: “They can easily communicate with each other…with other ways of technology, like Facebook, like Twitter, definitely they use them...They know all of those ways” (Martin, A T1, line 153). He also recognized the frequency and ease with which his students communicated using technology: “The students, they talk through the technology, rather than directly talking. I think it is the way that they do it. Even at home, they prefer to talk with their phone, rather than direct talking” (Martin, A
T1, line 159). These comments indicated that his involvement with the communication technology was limited, but he was aware of some of the online activity of his students. The analysis of the interview transcript supported this. There were very few coded references to his use of communication technology to support scientific literacy (as shown in Table 8).

Table 8
Coded References to the Scientific Literacy Framework from Mr. Martin’s Perspective

<table>
<thead>
<tr>
<th>Scientific Literacy Category</th>
<th>Research Question #1 (Scientific Literacy Framework in all comments)</th>
<th>Research Question #2 (Scientific Literacy Framework that uses Communication Technology)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Critical thinking</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Collaboration</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Connections</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Content</td>
<td>9</td>
<td>2</td>
</tr>
</tbody>
</table>

(n=number of references)

Analysis of the student data with respect to the second question provided a very different profile. References to the scientific literacy categories that also made use of communication technology (i.e., the second research question) provided similar results to the analysis for the first research question (as shown in Table 9). This supported the overall impression that the students integrate communication technology into many of their academic and social interactions. Evidence of the scientific literacy categories in
situations that used communication technology (i.e., research question #2) mirrored the list of coded references of the scientific literacy framework in their general comments (i.e., research question #1). This indicated that many of the students’ scientific literacy experiences occurred within a technology-enhanced environment.

Table 9
Coded References to the Scientific Literacy Framework from the Atlantic View Academy Students’ Perspective

<table>
<thead>
<tr>
<th>Scientific Literacy Category</th>
<th>Research Question #1</th>
<th>Research Question #2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Scientific Literacy Framework in all comments)</td>
<td>(Scientific Literacy Framework that uses Communication Technology)</td>
</tr>
<tr>
<td>Communication</td>
<td>19</td>
<td>14</td>
</tr>
<tr>
<td>Critical thinking</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td>Collaboration</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Connections</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Content</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

(n=number of references)

**Quality of Scientific Literacy Experiences within a Technology Environment.**

The practices of the students and their teacher clearly differed with respect to the frequency of the inclusion of communication technology. A sharp contrast was also noted in the quality of such applications as well. Mr. Martin’s references to the usage of communication technology were quite basic and did not make use of the opportunities available in the technology. They involved using email to ask and answer questions and
the First Class school website to distribute class notes to the students. The students, in contrast, were using a wide variety of communication technologies and they were selecting technologies in a manner that showcased both their creativity and their selection of technology that best matched the given task. For example, the students described the Facebook group that they had created: it allowed them to ask one another questions of content and logistics and it also afforded them a community of emotional support in the pressure of high achieving academics. However, they recognized that a text-based platform like Facebook was not conducive to discussing equations or graphs and they often chose a video-based platform like Skype in such circumstances. The students were observed using Macbook computers and cell phone cameras; they also described using text messaging and iPads. They were aware of time management features of their technologies and used them to be efficient and successful.

**Summary of Data Analysis**

The description of the school on their website suggested that this would be a location where evidence of student interaction through communication technology would be abundant and productive. The teacher interview and the classroom observations did not demonstrate this as I expected. However, the conversation with the students clearly showed the interaction was present and effective, although it was covert.

The conversations with the teachers and student indicated that the collaborative use of communication technology was not an intentional part of Mr. Martin’s pedagogy and not integrated into his lesson planning. In fact, he was not even included in the online student interactions. This exclusion may have limited the pedagogical potential of the
online communication. However, as the students indicated, it resulted in a private online environment of peers who understood one another’s confusion, misconceptions, and workload. The collaborative support and empathy described in this parallel online community made it a distinctly different environment of interaction than their classroom.

Analysis of the conversations with the teacher and students yielded very traditional roles and relationships. The teacher emphasized content (and connection was occasionally an element of content at this site) and the students emphasized communication and collaboration, i.e., working together as a social community of peers. The inclusion of technology was a student initiative, attributed in part to the ubiquitous nature of technology (they all have MacBook computers and cellphones), the technological skills of the students (they all report to use technology frequently for social and academic purposes), and the convenience afforded by technology to accomplish their goals effectively and efficiently.
Chapter 5

Data Collection & Analysis – Berryfield High School

This chapter describes the teaching and learning activities in the classroom of Ms. Dalton at Berryfield High School. The first section will describe the school setting and the data collection, including the two interviews with the teacher at this school, the four classroom observations, student surveys, and a student focus group. The second section of this chapter will highlight the analysis of this specific case in relation to the theme of scientific literacy. The category codes and subcodes were previously described and defined in chapter three.

Data Collection

This section will describe the data collection at Berryfield High School. All of the names, including the institution and the individuals are pseudonyms throughout this case study.

Location

Berryfield is a small Ontario city. It was previously a manufacturing hub, but as these industries have declined, the student population has also declined. The school board also serves a large rural population which is also experiencing a declining student enrollment. In response to this circumstance, the school board has positioned itself as a leader in making small schools successful. Initiatives include joint pedagogical conferences, split classes, e-learning and arts-initiatives that combine students from two schools.
Two high schools are located in the city: one is recognized for being larger and providing opportunities of scale; Berryfield High School is smaller and has established an emphasis on academic excellence, including the International Baccalaureate (IB) program. The first time I met with the principal of this school, I was asked if I was familiar with Berryfield High School. She clarified that Berryfield High School is a very academic school and the students were very academically-driven.

The class of interest is a combined Grade 11 Biology class, with some students taking the IB program and others taking an academic curriculum. The teacher, Ms. Dalton, is quite early in her career, having taught for five years. She is interested in technology and willing to innovate. She has recently won a national teaching award for her engaging and effective teaching practice. A key element in her teaching practice is the use of Edmodo, an educationally-focused social networking platform. I was eager to see how this reflected in the classroom activities. Arrangements to observe this teacher’s classroom were made quickly near the end of the semester, because she did yet not have a contract for the following term. Observations were scheduled to avoid the end of the semester review activities and were also impacted by school cancellations due to weather.

First Classroom Observation

I had corresponded with the teacher by email to gain a basic understanding of how she was using Edmodo software. I arranged to visit the grade 11 biology class. The combined IB - 3U (university level) class was held during first period every day. On my first visit to the classroom, Ms. Dalton introduced me and my project to the students. I added a brief explanation of the research study and distributed the letters of information
and consent forms. I restricted my observations that day to the physical environment of the classroom and the teacher from whom I had already received informed consent.

**Physical Space.** The classroom is a traditional biology room, with two main zones. The desks are arranged in rows on the left hand side of the room. A blackboard is at the front of this side of the room, behind a teacher’s lab bench. A screen is mounted near the ceiling at the front left corner of the room, above the main door to the room. The right side of the room has parallel student lab benches, which are not used during my observation sessions. The back of the room has a small teacher prep office but is mainly large windows, resulting in a bright and natural light. The size of the room and the height of the ceiling contribute to an airy environment. The left side wall is a cabinet with locked glass doors, containing a class set of microscopes; the older technology which contrasted with the modern, accessible, communication technology.

The visuals in the room demonstrated a contrast. Posters at the back of the room were traditional commercial representations of the dissection of an earthworm, perch, and a DNA/RNA molecule. These were quite predictable pictures for a biology classroom. Beside them (above the microscope cabinet) are physical models of DNA and starch amylopectin, both constructed from Styrofoam balls, to represent the molecules in a more constructive format. At the front of the classroom, are three vocabulary posters of verbs that are commonly used in academic questions (e.g., label, list, annotate, distinguish, design, predict). At first I thought they were there simply to clarify the meaning of these terms so that questions would not be misinterpreted. However, on further discussion with the teacher, she identified that these were central to the IB program – the curriculum
objectives are categorized according to three levels of complexity, comparable to Bloom’s taxonomy. Level 1 would include simple tasks such as define or list; level 2 would extend the level of difficulty to questions that required the students to apply, calculate, estimate, or outline; and level 3 questions would involve situations where the student had to design, predict, solve, or evaluate. By making these definitions a central focus in the classroom, the variety of learning tasks was emphasized. Clarity of curricular goals and clarity of learning outcomes were shared with the students.

Ms. Dalton conducted her lesson from her laptop which was attached to the LCD projector and located in the middle of the student seating area. Ms. Dalton did not use the blackboard during this observation class (or any other). Her location in the middle of the room gave her greater proximity to her students. This seemed to assist with any classroom management issues that might arise in a discussion-oriented, decentralized classroom.

**Classroom Routines.** The content of the lesson was the introduction to the last chapter before the end of the semester, taxonomy. The slides were well organized, easy to read, and made effective use of pictures to illustrate the ideas. The teacher had posted the PowerPoint to the Edmodo website the night before the class, the timing intentional to allow students the flexibility to manage their notes in their preferred format. The students were able to download the lesson to a laptop or iPad and take notes digitally; others printed the PowerPoint as a handout that they annotated. The teacher’s questioning strategy reflected the resources of the students. Her questions were not based on simple facts that could be gleaned by looking ahead in the notes, but rather they required the
students to apply critical thinking to the content to answer questions that emphasized why and how.

**First Teacher Interview**

My second classroom observation was scheduled for the following day, but inclement weather resulted in slippery roads and a school cancellation. Therefore, the teacher interview was completed during this time. The interview highlighted the use of the communication technology in her teaching: our conversation focused on the use of Edmodo with her students, including the features of the software and the benefits for her and her students.

**Edmodo as an Educational Social Media Site.** Our conversation focused on Ms. Dalton’s teaching experience and her integration of a communication technology called Edmodo. It is a social networking platform with an educational focus. It closely resembles Facebook in appearance and features, but with some major differences. The Ontario College of Teachers (OCT) has issued a professional advisory on social media, urging teachers to “maintain professional boundaries in all forms of communication, technology-related or not” (OCT, 2011). Edmodo is closed and private, avoiding professionalism problems by isolating the school context from one’s online friends.

Edmodo is an educational social media site. It’s private, so students have to register with a password that I give them to sign up for the course. The thing I like about Edmodo is that it is appealing to students because it looks a lot like Facebook, in terms of the setup (Dalton, B T1, line 105).
The Edmodo class site is administered by the teacher. Its context is entirely educationally-oriented, with curricular content and a professional teaching relationship.

Our conversation started with the features of Edmodo. Ms. Dalton utilizes the site to post the notes for students, organize materials, and distribute messages. She posts the PowerPoint file online that she will use in class so the students can access it before, during, and after the lesson. The students use the site to access the materials, ask questions of the teacher and their peers, respond to the questions of others, and share resources. The program embraces mobile technology and has an app for use on smartphones.

They can download the app on the smartphone for Edmodo, so it’s just one click. With the app, it comes up in the corner if I have new notifications, so I just click on the app and I can respond to student questions wherever I am. (Dalton, B T1, line 131)

There is a mark book so that the students can view their marks online. “There is also, with every student, a parent code so the parent can go on Edmodo as well and see conversations and marks of their son or daughter” (Dalton, B T1, line 118).

**Edmodo Benefits.** The teacher spoke of some of the benefits that she has observed with Edmodo. One benefit of posting the PowerPoint files online is the improved emphasis on learning and interaction, rather than transcribing notes. “It increases the amount that I can cover. It allows time to have discussions. In terms of
pacing lessons, it’s a lot better” (Dalton, B T1, line 346). The discussions were rich and engaging. “I’ve seen an increase in student participation…they get into the discussion, and often the discussion is really, really good. …They’re engaged, they’re thinking and they’re interested – I just want to keep that going” (Dalton, B T1, line 332). The use of technology facilitated the de-emphasis of note-taking in class, which encouraged the students to interact with the content and with each other.

Another benefit identified by the teacher is the convenience of helping students stay up-to-date when they have missed classes. “If a student is away, they can just go on Edmodo themselves and get the homework. I hardly ever get requests for homework anymore because the students can just go on the site themselves” (Dalton, B T1, line 193).

Ms. Dalton had previous success integrating communication technology in her teaching practice. Before using Edmodo, she had implemented a parent email list to maintain regular communication with parents. Although the parents had access to Edmodo, Ms. Dalton maintained her email list for the purpose of parent communication. “I run an emailing list with parents, so I was in communication with [grade 10] parents on a weekly basis” (Dalton, B T1, line 59).

This year, with them being in grade 11 I wasn’t as frequent in the emails I sent out, because in grade 11 you want them to take some responsibility. I will let the parents know when the unit tests are marked, I will let them know if their son or daughter hasn’t handed something in. I obviously send them the exam date and time (Dalton, B T1, line 147).
The parent email list highlighted Ms. Dalton’s goals for integrating communication technology in her teaching repertoire: improved parent communication.

Goal number one: improved communication between myself and parents.
Especially at the grade 10 level, that’s kind of a critical time, how is the student going to proceed? …If you have that communication between yourself and the parent, a lot of the pressure is taken off you, in terms of ensuring student performance. (Dalton, B T1, line 177).

The open communication between the teacher and the parent encouraged improved communication and support in the parent-student relationship.

Two pedagogical decisions were described during this interview. One dealt with timing, the other on technology, but they would eventually interact with one another. One was the teacher’s intentional decision to make the PowerPoint material available before the lesson. Students were able to preview the material, reflect on the ideas and come to class prepared with questions. Some students printed out the PowerPoint, others did not. The second pedagogical decision was the bring-your-own-technology policy. There was no official laptop policy and technology was not provided to the students in classroom. Some students used iPads, others used their own laptops, others used Smartphones, and some used paper printouts. “With academic students you tend to see more laptops, iPads, and smartphones. Not many students in this school do not have a phone” (Dalton, T1, line 170). She was not concerned about the students’ access to technology; students had a
variety of their own resources and all students had a daily study period where they could access computers and the internet at school. Both pedagogic decisions emphasized flexibility, choice, and attentiveness to individual student learning styles. It encouraged many students to reflect and act on how they learned most effectively.

**Scientific Literacy.** Ms. Dalton’s description of her interpretation of scientific literacy emphasized communication and aligned with her implementation of communication technology such as Edmodo.

My interpretation of scientific literacy for my students is teaching them the information and tools that they need to be able to be effective communicators. I strive for them to be able to understand scientific ideas and clearly voice their opinions or interpretations. I try to incorporate literacy skills into weekly activities. (Dalton, B T2, line 4).

Ms. Dalton described her pedagogical choices as intentional emphasis on providing a forum for her students to practice and improve their communication skills using the scientific content in the course. Discussion provided an opportunity for this to occur within the classroom; Edmodo provided a tool for the conversation to continue outside of the class.
Second Classroom Observation

On the day of my second classroom observation, weather conditions continued to be poor, but the school was open. When the first period class began seventeen students were present, there were a number of students who were late or absent due to the road conditions. As the class began, a trickle of late-arriving students joined the class. Fifteen minutes into the period, there were 23 students present. Ms. Dalton had forgotten to post the PowerPoint in time for students to download it before they came to class, so she had printed the handouts for both the lesson and a review package for a previous chapter. There was a noticeable buzz of chatter in the classroom—the students were less settled than they were during the previous observation—although it was difficult to discern whether this was due to the deviation from their regular routine of accessing the lesson online, the previous snow day, exam anxiety, or the ongoing arrival of late students.

The topic of the lesson was taxonomy. The lesson introduced the structure of classifications and focused on the kingdoms. The discussion included a review of cellular biology and the PowerPoint included high quality photos of organisms. The role of the microscopes that had been observed in the cabinet on my initial observation had been replaced by the PowerPoint technology. It was interesting to observe how a potentially dry and administrative topic could be made interesting. Of particular note was the teacher’s interconnection of this new material to the past, present, and future contexts. When discussing the kingdom of viruses she connected it to a previous unit on HIV, drew the students’ attention to the academic objectives for the current unit, and alluded to their next biology course that would examine mutations of viruses. The discussion had participation from a large number of the class. The topics that emerged from this lesson
ranged from popular culture such as myth busters to health and social issues such as vegetarianism and linked to academic topics (e.g., trophic levels) from the previous year’s science course. The discussion was not directed solely by the teacher; students were asking questions, contributing ideas, and suggesting connections to the material. The initial buzz of chatter in the classroom seemed refocused and productive.

The second part of this class was devoted to understanding how to use and create a dichotomous key. The class went through one example together and then Ms. Dalton explained the assignment for this unit was to create their own key for identifying a group of fictitious creatures that she provided. The assignment would be done in pairs and then evaluated by their peers. The rubric for assessment was shared with the students at this time. The students were encouraged to be creative – they had to name the creatures on the handout first. They could produce their key in paper or digital format; it could be done as a hyperlinked PowerPoint, as chart in the example, as a booklet, or any other presentation chosen by the students. It was to be neatly typed and the students were encouraged to add colour to the images provided to assist in classification.

**Third Classroom Observation**

During my third observation class, I observed what seemed to be a more typical class. There was no distraction due to weather issues and the PowerPoint was loaded onto Edmodo prior to the class. The lesson topic examined Protista (fungi). In the discussion during the lesson the teacher asked the students for examples of pseudopods, cilia, and sporazoa. The students could effectively link the concepts of classification presented in
this unit to their prior learning. The teacher facilitated this by integrating familiar images that they may have seen during prior lessons.

Students were observed to be following the lesson on a variety of devices. Some used paper printouts, other used laptops, some used iPads. Flexibility and choice were explicit in the range of devices used. This is not a laptop school, and students have a variety of technologies- laptops, smartphones, iPads, paper printouts, or school computers accessed during a study period. The teacher caught one student texting on a cellphone during this class and admonished her to stop. Although I had seen a variety of unused cell phones on desks this was the first inappropriate use of cell phones that I observed. The teacher was aware that when a student was texting she was no longer following along with the class discussion.

A consistent pedagogical pattern emerged. The teacher often used the first half of the class for new lesson material and the second half of the period for a different activity. Posting the PowerPoint allowed her to cover more material, but she seemed conscious of not overloading the student with too much content. The second half of this class was spent returning the test from the previous unit and going over the corrections. The topic of the unit test was biological systems, including digestion and circulation. The teacher had a very traditional approach with this activity, identifying each correct answer for the multiple choice and true/false questions. In the short explanation questions she addressed common misinterpretations of the questions that tended to cause errors for students. She said that the long answer section was well done so there was no need to go over it together. The rest of the period was available to work on homework (the dichotomous key project) or to discuss the test with her individually. This allowed her to address
individual concerns while the rest of the class was productive. During this time I distributed the student survey forms to the students who had returned their signed consent forms. I circulated to answer questions about the questionnaire (e.g., to explain what a podcast or RSS feed was, etc.). While working on the homework, three pairs of students were observed to be using laptops. Most students used this time to complete the survey or to review their test.

Fourth Classroom Observation

When I arrived in class on the fourth morning there was a diagram on the chalkboard depicting the ATP cycle from a previous grade 12 class. It was not meant for the grade 11 class, but it did prompt some questions from the students about next year’s work. The contrast between remnants of board work and the impermanent nature of a PowerPoint display was evident. These questions would not have been raised if this diagram was only presented to the other class in a digital format and then closed.

The schedule for this class was to have new lesson material for the first half of the period and then the students would present their dichotomous key assignment to another pair. At the beginning of the class only 14 of 27 students were present. The teacher spent a few minutes distributing handouts until more students arrived and then she began the PowerPoint. The topic of the lesson was the kingdoms of plants and animals. The students were quiet and focused. The lesson was interrupted at 8:20 when the phone rang. The message was related to accounting for two students who were in the resource room trying to print out their assignment to bring to class.
A second interruption occurred in class when the teacher asked a student using an iPad what he was looking at and if it was relevant (it was obviously not the current PowerPoint). It turned out to be an online biology textbook that had just been released for the iPad device.

Another peculiarity in this class period was the presence of another visitor. The girl was a previous student of Ms. Dalton and a current member of her volleyball team and liked to spend her spare periods in the biology room, sitting at the front lab bench. Since Ms. Dalton taught from the middle of the room beside her laptop, the front lab bench was not otherwise used. The class was not disrupted by the visitor’s presence; it appeared routine.

The PowerPoint lesson included lots of pictures. There was quite a lot of complicated vocabulary (e.g., cnidaria, annelida, and nemocysts). One student asked if they would need to be able to spell these terms on a test and the teacher answered that it would be a matching exercise. The discussion again linked to prior learning and popular culture as the topics of discussion included references to previous discussions on tapeworms and a worm dissection lab.

The second part of the period was spent with each pair of students exchanging their dichotomous keys with another pair and trying to use it to identify each of the fictitious creatures. When students had completed the activity, they assessed it using the rubric provided. One student had worked independently and had done a hyperlinked PowerPoint. He had some delays making it work on the classroom laptop. It was unclear whether these technical difficulties were due to a lack of compatibility of software or that the assignment was not quite completed. However, after some last minute adjustments,
the program worked fine. One of the students asked him where he found all the pictures of the creatures to include in his PowerPoint. The teacher answered that he found them in the same place she did – on the internet. (She got the assignment handout from the internet). It seemed ironic that the most technically advanced assignment was from a student who chose to work independently. Another excellent project was submitted by a pair of students who created a book. Each page presented a dichotomous choice, and the response then directed the user to the appropriate page. The solution sheet had the possible names on Velcro so that they could be attached in the correct place.

As the students finished completing the activity and assessing their peers’ work there were a few students who were off task. Some were checking their cell phones; others were on their iPads. There was a small group of students clustered around the iPad with the digital biology textbook, exploring the features of this new resource.

**Student Survey Data**

Survey data was obtained from 26 students. The survey questions asked about the frequency of communication technology usage for both academic and social reasons, the type of programs used and the benefits enjoyed by students when they used technology for their schoolwork. The usage survey involved a five point Likert-type scale. The results were averaged to give a statistical mean. This portrayed a profile of students who use technology frequently for both school and personal reasons, but who use it more often outside of school. The average of their schoolwork usage was 3.23 out of 5 and their personal usage average was 4.46 out of 5. Edmodo was frequently identified as an example of the technology they use in a schoolwork context. They frequently commented
that they use communication technology to catch up on work if they were absent (e.g., B3, B5, B7, B8, B15, B21, and B27). They specified that the electronic versions of notes were easier to organize and that having the notes provided let them concentrate more on the learning than on the transcribing. The students described their use of communication technology for personal reasons were centered on socializing and talking with friends.

Student Focus Group

The student focus group was scheduled for two weeks after my last observation. This was to accommodate study time prior to exams, the exam days, and the professional development days between the terms. The exams were interrupted by more freezing rain, which delayed the start of the second semester, and thus the date of the focus group.

Logistics. I had received focus group consent from more students than the focus group could accommodate. I wanted 6-8 participants, so I selected a group of 10 from those who had returned the consent forms. It was divided equally with male and female students. I distributed invitations with details about the time and date of the after-school session and requested RSVPs from the students. The day before the session I had only had response from one student, but when I spoke to the teacher she knew that more (both male and female) who were planning to attend. When I arrived at the school before the after-school session, the teacher had many of the students in her last period class. She knew of several students who intended to participate but who were not present so she checked with a couple of students who had completed the consent forms and who were
available that afternoon as substitutes. Thus five students participated in the focus group. They were all female, but this was due to the absence of the males.

The focus group session was held in the classroom. It dealt with the students’ experiences with communication technology: what they used (both formally and informally), how they used it, and how their learning experiences benefited from the use of communication technology.

The students talked about the various types of communication technology they use. Email is a basic tool to reach most teachers. They use Facebook, Skype, and text messages to connect with one another. They spoke of the Edmodo program and its features that facilitate effective learning. The main topics of the conversation included the use of communication technology to develop an online student community; the use of communication technology to assist student accountability when absent; the benefits of including visuals; and technology differentiation, the selection of tools appropriate for a specific task. The following sections will describe the focus group conversation in more detail.

**Student Community.** The students in the focus group commented on how communication technology helps them connect as a supportive academic community. They used it to ask and answer questions and to create study groups.

When I’m studying and I have had a question, I just typed the question in Edmodo and I got back six replies from everybody and not from Ms. Dalton on that night. She answered the next day, but I already had my answer from everybody else in the class (Kate, B FG, line 113).
“Also on Edmodo, I know somebody in the class, they’ll come across a website and they’ll post the link on the wall and it is there for everybody else, too” (Kate, B FG, line 125). “I’ve used Skype for group chats and group video chats to study for exams and tests” (Mary, B FG, line 123).

Sharing questions and answer among the class helped develop a sense of community as they supported their peers. It also created a sense of empathy as the students took comfort in the fact that their peers have questions and misconceptions too: “It’s kind of relieving when you see that your friend doesn’t understand…it’s comforting…that everybody kind of feels the same way” (Sandy, B FG, line 119).

**Student Accountability.** Many students spoke of the benefits of using Edmodo to stay caught up when they were absent due to illness or involvement in extracurricular activities. They recognized that absences was not only impacted the material missed, but also affected how well the students could understand the next lesson that built upon the previous.

With Edmodo, if you miss a day of class, the lessons are posted on there and so you can go and print off the slide show that we did and catch up really easy. You don’t come into class the next day completely lost” (Alicia, B FG, line 61).

“I’m absent a lot. In the class, the teacher wants to teach and not tell you what you missed, so you get behind because you don’t have the previous knowledge” (Mary, B FG, line 69). This emphasis on accountability was unexpected, but could be attributed to the
keen academic nature of the students in this class and their busy extracurricular schedule. “For example, I wasn’t in class yesterday – I was at the volleyball tournament – so I missed the lesson. But I have the slide show on Edmodo at my disposal. I could look at it and go at my own pace” (Alicia, B FG, line 165).

**Visuals.** Students commented on the effectiveness of images and videos to assist their learning. “Biology is a lot of terms! When we get to see videos and look at pictures, it helps me understand things and make connections” (Sandy, B FG, line 321). They appreciated that videos could demonstrate the dynamic nature of biological processes. “When you use pictures, it’s not a process, but when you have a video, it’s a series of images that are connected together…you can understand what’s going on” (Daniella, B FG, line 573). Videos also helped with motivation. “I find that videos catch my attention and make me want to understand it” (Mary, B FG, line 593).

The students talked about the challenges and benefits of various pedagogical approaches. It was clear that teachers use technology in different ways in the classroom and that not all implementations had the planned impact. Previous teachers had used Blackboard, another learning management system, with varying results – some teachers just posted a summary of the pages covered and the homework assigned, another teacher was inconsistent with posting updates on the website. A student described one teacher who used Twitter for his class. “I had a math teacher who loved to post every single thing we did – homework and everything would be on that Twitter page. I’d go on it and I’d be up to date” (Sandy, B FG, line 372). 

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Technology Differentiation. The description of Twitter prompted a discussion of the compartmentalization that some students do with technologies. The students tended to assign certain roles to particular applications. The purpose of using Edmodo was for schoolwork. Twitter was a program that was generally considered a social media link for the students, not an academic one.

Edmodo is strictly kind of ‘in your class’ whereas in Twitter it is more of a social aspect and what they do for entertainment. It wouldn’t interest me to use Twitter for a school aspect. It would ruin the fun of Twitter (Alicia, B FG, line 382).

The students thought that the entertainment features of Twitter would override any academic content. They seemed to consider it a source of superficial information.

When I’m on Twitter, even if I were to have a teacher post something, I would see it and keep scrolling down …I follow Patrick Dempsey and if I see there a new Grey’s Anatomy episode tonight I would completely forget about that biology homework (Kate, B FG, line 387).

The discussion of the various communication formats prompted a conversation about the variety of methods used by teachers (e.g., Edmodo, other course websites, Blackboard, Twitter). Students suggested that a single platform used by all teachers would be more convenient and consistent.
If there could be one main website that every teacher could go on and make their own account and then you can connect. With Edmodo you can do this. …all of your courses in the same place….It would be easier cause it’s all in the same place (Mary, B FG, line 423).

There are so many ways that teachers can communicate with you. If they all use one think it would be a lot easier for students. …Rather than having to open five different tabs on my computer and find out different information for every single course….That would be more convenient for students (Alicia, B FG, line 432).

**Focus Group Summary.** The key ideas from the focus group discussion involved student communication to support student learning. In addition to the Edmodo software, the students were using Skype, Facebook and email to maintain an academic community. The students in the focus group had clear opinions on the benefits of communication technology, the differentiation of different technologies for different purposes, and the need for academic coursework to be consistent and organized (they viewed technology as a means to achieve this). They also demonstrated a clear sense of accountability for their absences and technology also served as a means to stay up to date.

**Data Analysis**

This section will describe the analysis of the data obtained from Berryfield High School. The documents pertaining to this case included:

- Transcript of Interview with the teacher, Ms. Dalton, January 17, 2012 (13 pages)
As in the previous chapter, two data analysis trials were completed. The first considered the data with respect to the Scientific Literacy Framework (i.e., to respond to Research Question #1). It provided a broad understanding of the experiences of each participant (e.g., teacher and students) in the case by considering the data within its context and in its entirety. The second data analysis trial considered scientific literacy as it was specifically connected to communication technology. It represented a smaller subsection of the data. The analysis with respect to Research Question #1 will be presented first and Research Question #2 will follow.

**Analysis Using Nvivo Software**

The transcripts were coded and analyzed with Nvivo software. The first analysis was to deconstruct the data and identify the details within. This resulted in 67 codes at this site. These were then merged and consolidated into appropriate bigger categories.

The interview and focus group transcripts were coded and analyzed according to the categories that corresponded to the scientific literacy framework. The coding definitions were previously defined in chapter three.
The overall theme was scientific literacy and the categories were the five elements in this framework: (Communication, Critical thinking, Collaboration, Connections, and Scientific Content). The transcripts were then re-coded according to these five categories, using the categories and subcodes described in chapter three, and assigning a single category to a given reference. These categories and subcodes were used for the main analysis in response to Research Question #1 and the categories were used in response to Research Question #2.

**Data Analysis of Experiences in the Scientific Literacy Framework**

The teacher’s perspective and the students’ perspectives were analyzed by topic and coded with Nvivo to determine which category and subcodes they best represented.

**Teacher’s Perspective.** Examining the transcript of the Ms. Dalton’s interview highlighted Edmodo as the main topic of the conversation. The predominant subtopics in the analysis were the features of the technology, efficient use of classroom time (i.e., discussion not transcription of notes), student accountability for their absenteeism, teacher communication with parents, and student communication were highlighted, as presented earlier in this chapter.

In this first examination of the general topics of conversation, they were related back to the coding categories. The analysis of the use of Edmodo clearly aligned with the scientific literacy framework element of communication (including all three subcodes of student-student communication, student-teacher communication, and class discussion). The secondary benefit associated with the Edmodo interaction indicated the importance
of collaboration (specifically the peer support of answering one another’s questions). The issue of students’ accountability suggested elements of critical thinking as the students exercised elements of metacognition.

**Nvivo analysis of the Scientific Literacy Framework.** The analysis of scientific literacy (i.e., for Research Question #1) coded the comments from the teacher’ interview according to the five categories of the scientific literacy framework: communication, critical thinking, collaboration, connections, and content. Definition of these coding categories was described in chapter three and builds upon the scientific literacy framework developed in chapter two. Subcodes identified common ideas within each of these main categories. The data analysis from the teacher’s interview showed a strong emphasis on communication (as shown in Figure 6). This was not surprising due to her stated focus of her teaching being effective communication with students and parents. This result was anticipated. The deconstruction with Nvivo corresponded to the same coding categories identified in the topical analysis.

**Students’ Perspectives.** In the focus group and surveys the student participants recounted the variety of ways that they use communication technology and the benefits that they perceive as a result.
Student Focus Group. In the analysis of the main topics in the student focus group, the students’ use of online communication was prevalent; the students emphasized the purpose behind why they were communicating in this way. The analysis showed the key topics were the establishment of a learning community and student accountability. In the analysis, the idea of a learning community aligned with both the scientific literacy element of communication and collaboration (students were providing peer support). It also suggested elements of the category of critical thinking, as the students reflected on how they learn most effectively, how they recognized the need to stay up to date with their course work when absent and how they choose the most appropriate technology for a given situation. The references coded as student accountability suggested the category of critical thinking. The comments on student accountability mirrored similar comments...
in the student surveys and the teacher interview, contributing to the triangulation described in the research design.

The analysis using Nvivo software of the student focus group transcript had similar findings to the analysis of their teacher’s interview: the data emphasized the importance of communication to both the teacher and the students. Communication was clearly a goal that was shared by both the teacher and the students and the Edmodo technology supported this objective. The analysis of the student data also showed that critical thinking was also important, usually with respect to issues of metacognition and accountability. The Nvivo results from the student focus group are shown in Figure 7. Overall, the Nvivo analyses of the data from both the teacher and the students clearly concurred on their emphases on communication.

![Student Focus Group](image)

Figure 7. Scientific Literacy Coding References in Focus Group at Berryfield High School
Student Survey Data. As previously indicated in the data collection section of this chapter, the student responses to the open-ended questions in the surveys revealed two main ideas about the benefits of communication technology. These were student accountability after being absent and the organization of materials in a digital format. These corresponded to the critical thinking category of metacognition as the students were taking responsibility for filling in the gaps of their understanding and they were reflecting on the best way to organize and understand their material.

Section Summary: Analysis for the First Research Question

Examining the data from Berryfield High School provides an indication of some of the priorities in this classroom. The analysis of the teacher’s interview suggested that communication is the leading category, with emphasis on all three subcodes within this category (i.e., student-student communication, student-teacher communication, and class discussion). The Nvivo analyses of the teacher and student data also confirmed that communication was the dominant category. The category was examined further in Nvivo to determine if there was agreement with the teacher and students in the distribution of the subcodes. The majority of the teacher’s references to communication involved student-teacher communication (10 of 17 references). The majority of the students’ references coded as communication also involved student-teacher communication (20 of 37 references). The results of this analysis are shown in Figure 8. This indicates that both the face-to-face and online communications often included teacher. (This contrasted with the previous case where the student Facebook group excluded teacher participation). The
analysis of the focus group discussion indicated topics of communication, critical thinking, and collaboration (i.e., with respect to peer support).

![Subcode Analysis of Communication](image)

**Figure 8.** Subcodes of the Communication Category from the Teacher’s Interview and the Student Focus Group

The inclusion of class discussion by both parties included comments referring to class discussions that I had observed during my classroom visits. The students and the teacher described situations that I had seen and I had linked indirectly as a benefit of the Edmodo platform. Ms. Dalton associated the efficiency of distributing electronic notes as contributing to the class time that could be redirected to discussion.

The students have said to me, that they find it so much easier to not have worry about scrambling to copy down notes and to actually be able to listen. I’ve seen an
increase in student participation. If you noticed on Monday, it wasn’t the same students raising their hand, I got quite a bit of interaction and they do, they get more into the discussion, and often their discussion will be really, really good. I’ve started a lesson and gotten three slides in, and I don’t get any more done because I don’t want to stop them from thinking. …They’re engaged, and they’re thinking, and they’re interested – I just want to keep that going. (Dalton, B T1, line 337)

This encouraged more student engagement, more participation, and an opportunity to clarify misconceptions and respond to students’ interests. The students remarked on class discussions that elaborated on the topics of the course but were eventually included on tests.

Somebody always has a comment about the video.....and then it leads to a huge discussion. Like, one day we got into we were watching a video and it came up, something about ancient practices of medicine and we had a 45 minute discussion on tapeworms! It was on the test too. …It wasn’t even planned in the lesson. (Kate, B FG, line 182)

This conversation indicated the interconnected nature of the scientific literacy framework (i.e., the communication subcodes of class discussion and linked to critical thinking in the first example and influenced the course content in the second one). This relationship also reinforced the importance of the two research questions in this study.
The second research question only considers the elements of scientific literacy that are directly linked to communication technology. However, it is clear that there are multiple ways to experience scientific literacy and the interconnectedness will influence learning directly and indirectly.

The student surveys indicated that in addition to communication technology, the critical thinking category of metacognition is also important. This issue was also prevalent in the teacher interview and the student focus group as it related to the responsibility to remain up to date on course material in spite of absences due to illness of extracurricular activities. The benefits of Edmodo for this purpose were described by and appreciated by both the teacher and the students. Overall, the two groups of participants (i.e., teacher and students) showed consistency and coherence with respect to their priorities and learning expectations. The students described the metacognition aspects of their accountability; they recognized that having a solid understanding of prior concepts enhanced their ability to learn the ideas that built upon the prior knowledge. They also recognized that frequent absences interrupted the consolidation of understandings. Although they could not avoid occurrences of absenteeism, they were proactive to mitigate the effects.

**Analysis for the Second Research Question**

The second research question considered the Scientific Literacy Framework as it was connected to the usage of communication technology. A separate second Nvivo analysis was conducted, considering only the data that was specifically related to communication technology.
**Frequency.** Comparing the number of references to the Scientific Literacy Framework in general (i.e., Research Question #1) and those that directly used communication technology (i.e., Research Question #2) indicated that most of the references to the Scientific Literacy Framework were, in fact, using technology. This is shown for the teacher’s data in Table 10 and for the students’ data in Table 11. Although this was a traditional face to face class, the teacher and students relied heavily on communication technology to distribute course material, complete administrative tasks, communicate with one another, and assist one another with questions. The strength of the Edmodo program was its ability to facilitate communication and this was evident in the analysis for both research questions.

Table 10

Coded References to the Scientific Literacy Framework from Ms. Dalton’s Perspective

<table>
<thead>
<tr>
<th>Scientific Literacy Category</th>
<th>Research Question #1 (Scientific Literacy Framework in all comments)</th>
<th>Research Question #2 (Scientific Literacy Framework that uses Communication Technology)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Critical thinking</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Collaboration</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Connections</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Content</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

(n=number of references)
Table 11

Coded References to the Scientific Literacy Framework from the Berryfield High School Students’ Perspective

<table>
<thead>
<tr>
<th>Scientific Literacy Category</th>
<th>Research Question #1 (Scientific Literacy Framework in all comments)</th>
<th>Research Question #2 (Scientific Literacy Framework that uses Communication Technology)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication</td>
<td>37</td>
<td>22</td>
</tr>
<tr>
<td>Critical thinking</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>Collaboration</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Connections</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Content</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

(n=number of references)

**Quality.** Communication technology was used frequently in this classroom and it was also used to improve the quality of learning activities. In chapter two, examples of technology integration were noted that did not add substantial quality to the learning activity (e.g., word processing, retrieval of facts, or email submission of students’ work). In this classroom the chosen technology corresponded to the students’ prior use of smartphones and social media: it was an authentic and useful tool. The scientific literacy references in the analyses for both research questions indicated the strong emphasis on technology-enhanced communication. Both the teacher and the students shared this common priority. This section considers the impact of the technology on the students’ scientific literacy experiences.
Communication was evident within this classroom; it was seen during classroom observations, and well-described occurring outside of the classroom’s temporal and physical boundaries. It was observed this class exemplified all of the communication subcodes: student-teacher communication, student-student communication, and class discussion. The teacher described the importance of class discussion as promoting regular student participation, student engagement, and higher level thinking. Communication technology and the use of electronic notes facilitated the opportunities for class discussion in this classroom. The class discussion, in turn, facilitated opportunities for critical thinking. The emphasis on communication within the classroom naturally extended to the online conversation where collaboration took the format of peer support and shared resources. Perhaps the Nvivo data also highlighted one weakness of Edmodo: there was very little mention of connecting the course material to real life applications that were relevant to the students. Ms. Dalton and the students did mention examples of the classroom discussion extending beyond where it was originally intended (e.g., when discussing Mythbusters episodes or tapeworms). However, overall, the conversation remained quite contained within the boundaries of the course. The technology that enabled the student interactions seemed restricted by the very curriculum it was enhancing. Was this a result of the teacher or the students’ emphases on academic achievement; was it influenced by the content requirements of the IB program; or were the topics of their online conversation influenced by the knowledge that the teacher could view off-topic conversations on the Edmodo platform? The richness and authenticity of the technology contrasted with this rigidity to remain within the course outline.
Section Summary: Analysis for the Second Research Question

The consistency in the analyses of the data for the two research questions indicates the high level of integration of communication technology in this class. Most of the references to the Scientific Literacy Framework included communication technology (i.e., most of the coding in response to the first research question overlapped with the coding for the second research question). The Edmodo platform was seamlessly integrated through many aspects of teaching and learning and consequently, communication among participants was promoted and prioritized. Much of this communication occurred either directly with technology or was indirectly enhanced by technology.

Summary of Data Analysis

Overall, the data from this site showed strong consistency. My impression from the classroom observations and from the conversations with the teacher and students was that student participation, interaction, and responsibility were key elements of this decentralized learning community. This was achieved using the Edmodo platform. The data from the student focus group and the teacher interview corroborate this impression: communication within this learning community was the focus of the teacher and students. However, this focus came at the expense of other learning opportunities. The scientific literacy profile shown in Figure 7 indicates that while the emphasis is on communication, there is much less emphasis given to critical thinking, collaboration, and connections. When specifically asked about connecting topics from outside of the course to their biology class, one student responded, “if we did want to learn more, it’s easy to talk to
Ms. Dalton, or find the news article and attach it to the [Edmodo] website…it would be easy to do, although I haven’t done it” (Sandy, B FG, line 408). Some evidence of the Scientific Literacy categories was observed outside of the coded data: the vocabulary posters on the wall that distinguished between the three levels of IB questions suggested increasing levels of critical thinking. During observation of the class discussion, the students and teacher frequently made connections to prior learning, popular culture and current events. However, they did not necessarily recognize it as outside connections. Although the students were collaborating informally as they assisted one another using Edmodo, the teacher did not emphasize this collaboration. The shift toward communication was partially due to the success of Edmodo. The lack of the other scientific literacy elements could also be explained by the very academic nature of this class (and this school) with a focus on content. The IB program involved individualized assessments which diminished the opportunities for collaborative final assessments.

In summary, the Edmodo software aligned with the teacher’s three priorities to emphasize communication; convenient access of course materials, and student accountability. This classroom also de-emphasized connections, collaboration (as teamwork), and critical thinking. Whether the emphasis of one category caused the de-emphasis of the other, or whether they were unrelated characteristics (or a combination of the two) remains unknown.
Chapter 6
Data Collection & Analysis – City High School

This chapter describes the teaching and learning activities in the classroom of Mr. Saunders at City High School. It reports on the data collection activities and summarizes the data obtained. These will include two interviews with the teacher, two classroom observations, student surveys, and a student focus group. The second section of this chapter highlights some analysis of this specific case. It examines the coding of transcripts in relation to the theme of scientific literacy. The categories and subcodes were previously described and defined in chapter three.

Data Collection

This section will describe the data collection at City High School. All of the names, including the institution and the individuals are pseudonyms throughout this case study.

Location

City High School is located in a large urban center. It is a large inner-city school with 1400 culturally diverse students. The academic students are taking grade 11 University-level chemistry.

The school building is a sprawling, 5-story campus, across the street from a mall and a city library. It borders a park, ravine, and community center. The administrators of the school are supportive of technology initiatives and want to be seen as a hub of innovation. The school’s vice principal was effusive in her appreciation of the teacher’s
technology projects. The school is positioning itself as a leader in technology innovation, sharing their expertise by providing workshops for other teachers in the board on the logistics of netbooks and wikis. The science department had also created a how-to video demonstrating some of their technology initiatives.

First Teacher Interview

I met the teacher, Mr. Saunders, at the first interview. Prior to this meeting we had corresponded by email regarding his teaching activities and scheduling. He sent me the links to some of the online activities in which his class was participating. A major project of this class involved the Global Teenager Project. This international collaboration used a wikispaces wiki platform. It is an ongoing project that brings together students from schools around the world to ask each other questions and share locally-relevant information of interest to their peers. Accessing this site allowed me to become familiar with the students and their work before I met them in person. I did not interact with the students online, but I was able to read their publicly available postings. This included their online introductions; the photos that were posted so that the participating students could get to know one another; and the questions they had prepared for the other students.

On the day of the interview, I arrived early and was guided from the office to the classroom by a student. A grade nine science class was wrapping up, and the students were taking turns using a tablet and pen attached to the laptop and projector to answer review questions. This technological twist to a traditional blackboard activity allowed the teacher to post the digital file on the course website. The novelty of the device
encouraged student participation as they seemed eager to try out the new technology. Our interview began in the science classroom when the class was finished.

Mr. Saunders is a young teacher. This is his third year of teaching experience, but already he is a leader in integrating pedagogical technologies. He enjoys technology and finds ideas and inspiration in a variety of sources (e.g., formal professional development activities, trade magazines, and conversations with colleagues and students). During our conversation, he described a variety of innovative activities including class-based and international wiki projects; media projects, integrating websites of interactive simulation, environmental explorations, and frequent video and multimedia presentations. The technological hardware that he implements include a class set of netbooks (shared among the department), the SmartBoard (located in the library), and the tablet and pen (his own) to use with his MacBook computer and the classroom’s LCD projector. He has taken a leadership role in implementing technology in the school and facilitating professional development opportunities for others in the board. He said that he enjoys technology and actively searches for opportunities to integrate it into his teaching repertoire. He models life-long learning to his students as he works toward a Master’s degree and displays interest and enthusiasm for learning, exploring, and extending new ideas.

**Mr. Saunders’ Interpretation of Scientific Literacy.** The topics of the conversation began with Mr. Saunders’ interpretation of scientific literacy and then explored some examples of the projects that integrate technology in his classroom, the logistical goals, outcomes challenges and successes that have been experienced. His interpretation of scientific literacy emphasized applications and relevance:
For high school students, I think the main thing, is having a basic understanding of science itself. People confuse scientific literacy as spelling and knowing words. But I think it’s more of an understanding of science in itself. If you’re going to get a medical diagnosis or something later on in life or you know you’re hearing about a family member that has something, it’s important to have that basic knowledge of scientific understanding. ... I think it’s important when we hear about the increase in weather or when people start talking about climate change they have that foundation of scientific literacy to understand it and also to make sure it incorporates into their daily life, so to understand that it is important and it’s important to me...or it’s important to my community. I think it kind of stretches beyond just simple terms. (Saunders, C T1, line 62)

The range of technology projects was vast and it indicated the integration of technology with many of the aspects of the course. The teacher described using technology to integrate video clips and documentaries that demonstrated environmental issues and global social responsibilities. The ideas and images in the video clips were followed by rich discussion in the classroom.

We talked about purchasing cellphones – yesterday we watched *The Story of Stuff*, (an electronic version) and we’re saying, all these, they’re ending up in a landfill, and that’s going into the water and we’re drinking it, so there’s your connection to that. Then it’s who wants a new iPad 3, they got talking about it and it is consumerism and that type of thing. So I try to show them that they have the
responsibility to change what’s happening and as well, they are affected by it.

(Saunders, C T1, line 72)

Pedagogy. Mr. Saunders used a variety of pedagogies to complement the variety of technologies. Students worked individually, in small groups, or as a whole class, depending on his plan. He had the students use netbooks in class on an individual basis to access online simulations; they were also using the netbooks to work on the wiki project as a small group. The wiki project provided a forum for students from many countries to come together under a guiding theme and develop questions for their peers and then research and respond to the questions asked by others. The students had the responsibility to research and respond to the questions based on their local context. The theme of sustainability afforded various possibilities to connect to the curriculum and to the interests and concerns of students. The teacher emphasized that the wiki project provided the opportunity for students to both create content and be creative.

The wikis are more of a true 2.0 web technology where you are contributing to some sort of research; you’re not just taking that information and being an audience member. And a lot of the time I try to get the students to take a perspective or be more the ones creating that technology or that material or content. (Saunders C T1, line 137)

The wiki project provided an opportunity for the students to practice their technological skills in an authentic context. Using the communication technology to deliver information
to a specific audience would be more meaningful than using it to merely complete a school assignment.

I encourage them to use different types of media, so produce something on a PowerPoint or a Prezi or something like that, that’s interesting, something they can share, they’ve been really good at getting new things as well, so they’ve been using a Voki where you talk and it’s a little character that talks with your voice. (Saunders, C T1, line 157)

**Motivation.** Mr. Saunders identified the benefits of using communication technology began with motivation (for both the students and himself). Integrating new technology encouraged him to seek new ideas and implement new activities.

So I think that having the technology makes me really interested and it also keeps me, pushes me to do different things as well, and I think it’s more fun. I enjoy technology so I think that it helps me really enjoy my job – I think it’s awesome! I love what I do. (Saunders, C T1, line 236)

Innovative technology enhanced student motivation because it connected the course material to an authentic context, using authentic tools. “I think the goal is just more engagement in teaching the topic” (Saunders, C T1, line 222). “I think the technology keeps them [the students] interested and excited” (Saunders, C T1, line 246).

The benefits of using communication technology extended beyond the immediate engagement of students in his classroom. It also included improved cultural
understanding and investigating issues of relevance to student lives in authentic contexts that prompted meaningful reflection and action. “The reason I like it [the wiki project] is the collaboration and it’s nice that it’s giving them another cultural understanding, especially for science, that it’s not the same around the world” (Saunders, C T1, line 161). “There’s so much cultural knowledge that they [students in other countries] have in how they do things and we don’t know anything about so I think it’s a very good two-way exchange” (Saunders, C T1, line 210). Working on the wiki project supported the development of critical thinking skills because the information produced by the students needed to be clear, complete, and justified. Presenting it to the audience of their global peers who had posed the questions gave the incentive for thorough work.

[Critical thinking is improved when] they’re publishing their information or collaborating or learning. I think it has to be something where they are providing data or providing an opinion, and then kind of sharing that widely. And I think the issues, getting something that is close to home is important too, so it gives more buy-in with it. I think that’s the thing. (Saunders, C T1, line 365)

Mr. Saunders spoke of using video to present scientific and social issues to the students. He felt it was important for them to take a personal interest in the topic by relating the content to the students themselves and their community. “I try to kind of spark some sort of debate, or some sort of question. Like I’ll show a YouTube video or show something that gets them thinking of how does that relate to me?” (Saunders, C T1, line 67).
**Challenges.** Mr. Saunders addressed some of the challenges of integrating communication technology in the classroom. The school has a high proportion of English Language Learners. There is a variety of proficiency with technology use among the students in the class. He described some students as digital natives but also acknowledged that others have no internet access at home or no email address. He was intentional to ensure access to the technology when he included it in his teaching repertoire.

I always ask if there’s anyone who has a problem accessing any of this stuff, let me know – at lunch you can use the computer in the room, you can use the laptop, I can sign the netbooks out for extra time for you, for after school, you can stay a couple hours and here’s a netbook. So I think it’s important to offer that equal playing field. (Saunders, C T1, line 256)

Mr. Saunders described professional concerns that included teaching methods and resources. He described a number of specific projects, mentioned pedagogic resources, and described professional development opportunities to share ideas with colleagues. Our conversation lasted longer than the room we began in was available so we relocated to the science office. The science workroom/office was a narrow crowded room lined with desks on both sides where teachers in the science department had their individual workspaces and a shared computer and printer.

**First Classroom Observation**

On my day of my first classroom visit, I arrived at the classroom before the students arrived. The chemistry classroom was very traditional in its physical layout. It is
a rectangular shaped space with high windows along one long side and a teacher’s lab bench at the front. The teacher’s lab bench had a blackboard behind it and a door to a chemical store room on the left side. Mr. Saunders’ laptop was positioned on the student desk at the very front and the screen was located above the blackboard. The room was divided into a teaching space with desks at one end and a lab space at the far end with two parallel black-topped lab benches. Counter space and glass cabinets of lab equipment surrounded the lab end of the room. The cart for the netbooks was at the front of the room, on the right hand side, close to the entrance door for the classroom which created some congestion as the students arrived and obtained a netbook. When the students arrived at the classroom, the space seemed crowded, with densely packed desks in the teaching area resulting in narrow aisles that extended all the way from the from lab bench to the one at the back. Once the students were seated, with all of their book bags, it was difficult to move around the room. Only 22 of the potential 29 students were in the class. A national math contest was happening concurrently and some of the chemistry students were participating in that event. If the class had higher attendance, it would have been even more crowded.

During this observation session, a number of different technology applications were seen. The students collected their netbooks as they entered the room and took them to their seats. The student survey was also distributed at this point. I introduced myself, gave a brief overview of the research project, and explanation for the survey (Mr. Saunders had also explained the purpose of the survey when he distributed the letters of information in a previous class). The students filled out the survey while they were waiting for their netbooks to boot up and log on. They seemed used to this pattern of
multitasking while waiting for the technology to begin. The students went to their class website and the hyperlinks to the simulation site were provided there. Mr. Saunders led this process from his laptop, displayed on the LCD projector. The size of the display was very small. If the teacher had been using this as a demonstration technique alone, many students would not have been able to see the screen. However, with this as an instructional guide, students were easily able to navigate to the site, understand the instructions and the goal of the activity, and begin working.

Each student had a netbook and they were working individually. It was observed that several students who had difficulty with the login just asked a nearby peer for assistance. A couple of the computers did not have the required Shockwave program on them and would not run the simulation program. Instead of booting up a new computer and going through the login delay again, students with these machines just turned and worked with the student beside them. The class had previously completed the lesson on balancing chemical equations. The simulation activity allowed them to explore these concepts in a visual manner and allowed a choice of preferred formats (e.g., histograms, circle graphs, molecular models). The students spent some time exploring the simulation and then worked through several of the questions on a problems sheet. Most students seemed to appreciate the visual nature of the simulation to reinforce their prior knowledge, although one student (who was proficient with the concept) commented, “You don’t really need all this - just do it in your head!” A couple of students were working together to proofread each other’s work. Most students were observed to be using the histogram format which the teacher had used for the sample problem, but those students who were using a different format were often asked questions by their peers.
Thus, although the students were mostly working individually, collaboration did occur. The emphasis for this activity was the process, not the product; the teacher was reviewing the concept, not evaluating it, and the students were given a tool that they could use for review or future reference. The answers to the problem sheet were provided on the class website. The teacher was circulating through the class, monitoring student progress. The simulation activity concluded with some humour and the teacher suggested that the students could share this activity with their friends.

The class transitioned to the Global Teenager wiki project. I had seen parts of this international wiki project online before visiting the class. A timeline for the project was provided by the project coordinators and nine schools from six countries were participating. The class was divided into groups of approximately five students per group. The students had already introduced themselves and described their schools and communities, presented questions for the other groups to research and answer, and had developed answers to the questions posed by their peers. Their current task was to prepare a summary of the responses from the other schools to the question that they asked. The students had ten minutes of class time to work on this with the netbooks, however, since some of the other schools had not yet submitted their responses, the summaries could not be completed and many groups used this time to plan, organize, and delegate the tasks.

The final technology activity involved a YouTube video that Mr. Saunders showed to the class. It involved two perspectives on the oil sands production, one from the perspective of the company, the other from the local residents whose health was adversely affected by pollution. It clearly demonstrated the concept of bias in media on
an issue that was the topic of ongoing conversation in this class. The positive video from the company was a current advertisement that Mr. Saunders had seen at the local cinema; it was an effective connection to popular culture. The dual perspective was used to remind the students of an upcoming documentary that would be shown at the school for Earth Day. At the end of the class, Mr. Saunders reminded the students of a lab report due the following day. The students logged off the computers and returned them to the cart in an orderly manner on their way out of the classroom. Such procedures were obviously well-used routines.

Second Classroom Observation

The schedule for the second observation was rearranged around a professional development workshop that Mr. Saunders was presenting to other teachers in his school board. A group of teachers came to watch his grade nine class using technology and then participated in a professional conversation concerning pedagogy and logistics.

During the second observation, the class was held in the library seminar room. Mr. Saunders was using an activity with the SmartBoard because the netbooks were unavailable. Unfortunately, many classrooms (including the chemistry lab) were not yet equipped with a SmartBoard, but the seminar room could be booked for class usage. The room was located off the library and had a glass wall looking into the library. The library facility was very modern – bright and spacious. A display of student art was prominently featured in the main library area. A cursory check of the books on the shelves found them to be older editions, but in a conversation with the librarian she mentioned unloading and cataloguing new material. The seminar room had two long parallel tables and
comfortable chairs that created the atmosphere of a conference room. The front of the room (beside the SmartBoard) showed evidence of the adhesive which had once held the blackboard in place. Some of the students asked about the brown, irregularly-shaped blobs that were conspicuous on the white wall, beside the focal point of the room.

Attendance was low during this class due to two different field trips that were conflicting with class times. Seventeen students were present when the class began (a few others were late to this first period class). This was the first visit to the seminar room for many of the students, and for some it was their first experience with the SmartBoard.

The class began with a brief PowerPoint review of stoichiometry (i.e., how to convert between moles and mass). The students were eager to volunteer to write on the SmartBoard, and took their time to ensure that the handwriting was legible. The teacher used this review time to go over the preferred format for the students to show their work on these problems and emphasized the importance of units. Mr. Saunders used the multiple colours available to show where the units were cancelled out. Allowing the students to do the writing on the SmartBoard facilitated this discussion because they could see and critique their peers’ work and styles. The teacher encouraged the students who were writing on the board to explain to the rest of the class what they were doing. When two students tried to write simultaneously on the board (and the board would only recognize one pen) it prompted a tangential discussion about the limitations of the whiteboard. The teacher said that “cooler new SmartBoards can do two at a time.” One of the students responded that it is “still pretty cool.” The students were clearly enjoying the introduction to the new technology and being productive in their review. A late-arriving student commented that “this is so cool!”
After a couple of sample problems to review the concept and the structure, the teacher changed activities. The class was divided into groups of four and each student was assigned a role in their group (i.e., the writer, the calculator, the periodic table, and the coordinator). A buzz of organization ensued as the students organized themselves. The teacher did a cursory check that the roles were assigned (e.g., he asked the students in charge of calculations to raise their calculators which ensured they had the required materials for their role) but he left the delegation of roles to the students. The students demonstrated their prior experience with group work and delegation of tasks.

The students were very competitive and highly engaged. The first group to complete the questions would win the opportunity to write it on the board. The teacher was surprised by their level of intensity. He urged the students to “relax, it’s not the Hunger Games,” making reference to the popular movie that had recently been released. As the student groups continued to work, their conversation was on task. Even in their small groups, they were talking their way through the problem, making sure that all members participated and contributed. After a couple of problems, one student exclaimed, “I think I know how to do this now!”

The class ended with a brief lesson on empirical formulae. They had begun the topic on the previous day. The teacher started by connecting the topic to two real-life examples: the off-gasses released from vinyl shower curtains and the scanners at airports that can detect such molecules. The PowerPoint that followed covered the theory and provided a couple of problems. Many students were observed taking their notes on the scrap paper they used for the previous cooperative group work.
Towards the end of the class, one student was observed to be using technology in a creative way. He was using his iPhone camera/video feature as a mirror to check his contact lenses. Overall, even though this observation class did not take place in the regular classroom, it showed both how the interaction of the students as they worked together and how they were motivated and engaged by the inclusion of technology. Although most of them had not used a SmartBoard before this class, they were eager to explore it.

**Student Focus Group**

The focus group with seven of these students was held in the library seminar room where the second classroom observation was held. It took place during the lunch period to accommodate the busy extracurricular schedules of the students. One male and six female students participated and the focus group lasted 40 minutes.

The students talked about the various ways that they use communication technology to assist their studies. They mentioned using email to contact teachers or peers, Facebook and texting to communicate with peers, using Facebook as a convenient medium to conduct an online survey in their Anthropology class, and online sites such as Khan Academy to review concepts.

**Authentic Learning Experiences.** The students highlighted the Global Teenager wiki project they had participated in as a learning experience that extended beyond the boundaries of science curriculum. They had learned about policy and social structures in other countries, they had developed an appreciation for their resources (e.g., internet,
wifi, libraries, transportation, etc.), that they had previously taken for granted. “The students from other parts of the world, they gave the status of their environment, you really get to understand how different it is. How the level of...how the social structure works in areas, for example” (Mattias, C FG, line 109). The students raised the idea that they had taken for granted the amount of technology and resources that they could easily access. They global comparison made them realize the privileges that they enjoy.

I find we’re privileged, because we have internet access everywhere. And the Kenyans don’t have internet access as much as we do. Because they actually they have their own modems that they have to use while we can just use wifi or we can just go home and use our internet. So I find that we kind of are taking advantage of the fact that we have so much here. (Gina, C FG, line 144)

The students took ownership of their wiki project, and were given control over group selection, organization, delegation, content, and creative presentation. “We got to choose our own groups, so some groups went out of their comfort zone and picked people that they didn’t usually work with before, so it was more fun” (Gina, C FG, line 172).

The only regulation that Mr. Saunders put on the wiki project was telling us when things are due, everything else was our duty. We had to collaborate amongst ourselves and finish something by the due date, otherwise, the only thing Mr. Saunders would do was take marks off. Everything else was up to us. (Mattias, C FG, line 147)
**Learning Technology Skills.** In general, the students portrayed a high degree of confidence in their technical ability. They partly attributed this to the duration of exposure, rather than specific accomplishments. “We’ve been exposed to technology at such a young age, that it’s like second nature to us, even if you don’t know how to use something, if you’ve never used it before, just figure out how to do it.” (Philamena, C FG, line 316).

I started off with the computers since I was in grade 4, and it’s just been my life ever since. So I cannot live without it. So I think because of the years of research and years of assignments that I’ve had to do with computers and researching...when I research I use the computers, not books. (Tonya, C FG, line 309)

The students’ technical self-confidence was later mirrored in the analysis of the student survey data. The focus group concluded when the bell rang to signal the end of the lunch period. The focus group had participation from all the students present although two students in the group were clearly the leaders as shown in the quality, relevance, and spontaneity of their responses.

**Student Survey Data**

Student surveys were completed by 27 students. Student survey data indicated that students use communication technology more often for social purposes than for academic purposes (4.22 out of 5 for social purposes versus 2.5 out of 5 for academic reasons). Email and Facebook were the most common formats for communication in both...
venues. The respondents described their academic purposes for using communication technology usually involved “communicating with group members” (e.g., survey C18, C19, C25, and C27). This was consistent with the wiki activity that the teacher had described.

The larger group demonstrated the technical self-confidence shown by the focus group, ranking themselves as 3.8 out of 5 on a scale of technical ability. The survey asked them to justify this ranking, and their explanations ranged from the superficial (e.g., “I grew up learning about technology & stuff” (survey C18), or “Because I think I am pretty good at computers and phones” (survey C13)), while others were more specific on skills and achievements (e.g., “I know how to restore a computer after it crashed and I can use any of the Microsoft docs without any difficulty” (survey C15), “I’m a YouTuber. I make YouTube videos and make money off it” (survey C21), or “I build/repair PC’s and am currently learning how to code web pages” (survey C2)).

Overall, the survey data corroborated the teacher’s description that the class demonstrated a wide range of technical abilities. It was also consistent with his description of his students as digital natives – they recognized the prevalence of technology to which they had access.

Second Teacher Interview

The second teacher interview was conducted by email to accommodate his busy teaching schedule at the end of the semester. It began with follow-up of the wiki activity, which had evolved to include two Skype sessions to allow synchronous video interaction between these students and a class in Africa. The first session had been
more focused on social interaction between the students. The teacher reported that the two teachers provided additional structure for the second session to keep the students more on task.

The second session was great. We actually sent in questions before to each other so we could spend a bit of time researching and then assigning particular students to answer as many were too shy to be put on the spot to answer them. The second session was very much on topic in terms of sustainability and the environment. I think we need to do it twice as the students were more on task with the content as they never did a session like that before. (Saunders, C T2, line 23)

The teacher commented on the widespread use of the netbooks (they are booked for almost every class period per day). “The netbooks are pretty much used every period. On average they would be sitting maybe 1-3 periods a week” (Saunders, C T2, line 11).

He reflected on the match of the wiki project to the grade 11 chemistry curriculum. He expects that he will participate in such a project again, and he will know what to expect, although it might be a better fit for a different class.

I would probably do this project with grade nines as it could be more related to ecology or grade 10 with climate change. I think it took a little longer than a regular project would as it was my first time but next time we do it I think it
will go a lot smoother and take less prep time for myself. (Saunders, C T2, line 33)

Overall, he appreciated the benefits of integrating technology in his classroom. He sees it as a tool to engage the students and connect them to authentic contexts in their lives. The connected learning is the emphasis, not the technology.

I believe the students were engaged. Many things are becoming more common so now the novelty wears off with technology. Many students play around with apps like Facetime, Skype, wikis, Facebook, MSN, etc. for fun. They can easily make a transition to their learning. I want the experience and content to be memorable. For example with our Skype session with Kenya I really hope the students don’t get excited over my MacBook with built in camera, wifi, and a projector and the software like Skype. I believe they were more interested in the learning experience and connection they have built with a country around the world. (Saunders, C T2, line 56)

**Data Analysis**

This section will describe the analysis of the data obtained from Mr. Saunders class at City High School. The documents pertaining to this case included:

- Transcript of Interview with the teacher, Mr. Saunders, March 20, 2012 (14 pages)
- Transcript of Focus Group Interview with seven students May 1, 2012 (12 pages)
- Field notes (14 pages) of Classroom Observations March 20, April 12, April 26, 2012
As in the previous cases, two trials of data analysis were completed. The first considered the topics in the transcript data as they related to the first research question (i.e., it provided a broad understanding of how the participants experienced elements of the scientific literacy framework). It considered the main topics and it also deconstructed the transcripts to consider the individual components, by assigning codes and using Nvivo software. A second analysis was done to respond to the second research question (i.e., to determine the role that communication technology contributed to the experiences of the scientific literacy framework).

**Analysis using Nvivo Software**

The transcripts were coded with Nvivo software. The first step was to deconstruct the data and identify the details within. This resulted in 67 codes. These were then merged and consolidated into appropriate bigger categories and the overall emic theme of scientific literacy. The categories represented the five elements in this framework: (Communication, Critical thinking, Collaboration, Connections, and Content.) The transcripts were then re-coded according to these five categories, using the subcodes described in the previous chapter, and assigning a single category to a given reference.
Data Analysis of Experiences in the Scientific Literacy Framework

The teacher’s perspectives and the students’ perspectives were analyzed to topic and by Nvivo to determine which category that they best represented.

Teacher’s Perspective. Examining the topics of Mr. Saunders’ interview focused on four key topics: his interpretation of scientific literacy; innovative pedagogy; his motivation to include technology in his classroom; and the challenges he had encountered during such projects. His interpretation of scientific literacy emphasized relevance to student experiences and connection to authentic contexts. This mirrored his teaching emphasis on the big ideas of green chemistry and sustainability. It highlighted the scientific literacy category of connections, and as a teaching issue, it revealed his teaching philosophy. When we discussed his innovative pedagogy, he described the logistics and the goals of using the netbooks, the wiki project, and others. He said integrating technology provides a forum for the students to explore and showcase their technological skills in an authentic context. His students were using PowerPoint, voki, Prezi, wiki, video, and website design to document and share their learning. This highlighted the scientific literacy category of communication as students were using these tools to communicate electronically. In chapter three, communication was defined as the exchange of verbal and non-verbal information and ideas. It could include verbal, written, and multimedia formats with text, symbols, images, and video. These students at City High embodied all aspects of this definition of communication. His comments on motivation were aligned with the category of connection: he wanted to integrate authentic tools as his students answer relevant questions. His comments on the challenges of
implementing technology innovations centered on administrative logistics, rather than on scientific literacy. Therefore, the topics of the conversation indicated communication and connections as key categories.

**Nvivo Analysis.** The Nvivo analysis provided a slightly different perspective of the data. This analysis delved deeply, considering the implications and associations of each comment within the transcripts. Analysis of Mr. Saunders’ first interview showed it was quite evenly balanced between communication and critical thinking and representative of all four of the process-oriented categories (Figure 9). There were 14 specific references to Communication, and 13 references to Critical Thinking, seven to Connections, and six to Collaboration. There was only one reference to the scientific Content of the curriculum. This showed the balance that was evident in this classroom: the emphasis on the big idea of green chemistry and relevant authentic contexts resulted in a broad coverage of most categories of the Scientific Literacy Framework.
The second teacher interview was also coded, but due to its email format, the questions were fewer and the responses were longer so the number of references to each category was not as statically significant as in the other transcripts. There were two references to Connections and one reference each to Critical Thinking, Communication, and Content.

**Students’ Perspective.** The students’ experiences were highlighted in the focus group conversation and in the student surveys. The focus group was analyzed by topic and with Nvivo software. The student surveys were aggregated and summarized in Excel.

**Student Focus Group Data.** The main topics in the student focus group included authentic learning experiences and learning technology skills. The main ideas addressed...
by the students when they talked about authentic learning experiences involved the wiki project and how it dealt with real life problems. They compared policy and procedures in other countries, they expressed their appreciation of the technical resources at their disposal, and they discussed the logistics and responsibilities of group work. These topics clearly suggested the scientific literacy category of connections, as the students themselves were discovering relevant and important connections within the larger issues.

One side effect of using real life issues was that the students felt compelled to act upon their knowledge – it mattered to them. “Personally, knowing all the information of what’s going on in the world, makes me paranoid...so I’m more cautious of what I do with my waste, and stuff, and how I use it” (Cheryl, C FG, line 214).

The topic of learning technology skills, where the students explained how they learn to use new technology showed elements of the category of critical thinking and the subcode of metacognition. The attitude of some students was that exposure to ubiquitous technology in their daily lives equated with comfort, confidence and skill. The students were confident with using technology and the wiki project made them aware of how much technology they can access. This concurred with the survey data that aligned with the same category and showed student confidence and capabilities with technology.

The focus group data was coded in Nvivo and the results were compared to these preliminary results. The Nvivo analysis of the student focus group data (shown in Figure 10) demonstrated a significant emphasis on critical thinking, with 37 references in this category, 9 references to Communication, and 6 references to Collaboration. There was one reference to the Science Content and no references that were best categorized as Connections. This was surprising because the topics in the focus group had strongly
emphasized connections including real life issues, authentic experiences, and big ideas. However, when the coding was re-examined, it was clear that some of the student comments that included these topics were coded as critical thinking because they included elements of reflection, comparison, and personal application of the big idea.

Figure 10. Scientific Literacy Coding References from Student Focus Group at City High School

**Student Survey Data.** The main topics from the student surveys included using communication technology to communicate with peers, either for group work on the wiki or informal peer support to clarify assignments. This suggested the scientific literacy category of collaboration. They surveys also demonstrated student confidence with technology. They rated their technical ability quite highly (3.8 out of a scale of 5). When asked to justify this ranking, and their explanations ranged from the superficial (e.g., “I
grew up learning about technology & stuff” (survey C18), or “because I think I am pretty good at computers and phones” (survey C13), to those that described specific skills and achievements (e.g., “I'm a YouTuber. I make YouTube videos and make money off it” (survey C21), or “I build/repair PC's and am currently learning how to code web pages” (survey C2)). These comments highlighted the category of critical thinking. The students were demonstrating metacognition as they described how they learn new technology skills and their confidence with using technology. This also corresponded to the teacher’s comments in the first interview that the students represented a wide range of technical abilities.

**Comparison of the Subcodes of Communication and Critical Thinking.** Due to the fact that the categories of Communication and Critical thinking were both highly prioritized by both the teacher and the students, these data were more closely examined to compare whether the two groups treated it differently. First the subcodes of communication were analyzed. As shown in Figure 11, communication references in student focus group tended to involve student-student communication (seven of the nine references), while communication references in the teacher interview tended to be more balanced, although half of the references (7 of 14) dealing with student-teacher communication. The participants tended to talk about the experiences that they took part in—this was expected. Analysis of the critical thinking data (as shown in Figure 12) demonstrated that both groups were more balanced across this category. This was partly due to the larger number of subcodes in this category, but also many of the subcodes were reflected in each transcript. For example, the teacher’s references that were coded as
critical thinking were distributed among metacognition/learning styles; applications; evaluation/comparison; and reflection. The students’ references that were coded as critical thinking were distributed among metacognition/learning styles; reflection; resources; application; and others. The pattern of similarities included the wide range of distribution (both data sets were well-diversified) and a common importance attributed to metacognition and learning styles.

Figure 11. Subcodes of Communication in the Analysis of the Teacher Interview & Focus Group at City High School
Figure 12. Subcodes of Critical Thinking in the Analysis of the Teacher Interview and Student Focus Group at City High School

Section Summary: Analysis for the First Research Question

Examining the topics in the documents provides an indication of some of the priorities at this site. The documents for this site highlighted many diverse examples of the scientific literacy framework. In the teacher interview data, his inclusion of big ideas in his teaching repertoire pointed to the scientific literacy category of connections. The technology activities he integrated in his classroom provided opportunities for communication across a variety of media. Connections were also highlighted in the teacher’s interview, particularly in the conversation of teaching philosophy and teacher motivation. The student surveys highlighted the scientific literacy categories of collaborations and critical thinking. The focus group data suggested the scientific literacy categories of connections and critical thinking.
Significance of Scientific Literacy Analysis. The activities in this class were designed to be contextual, with an emphasis on real life activities. The wiki project focused on global issues and sought answers to student-generated questions. Beginning with the big ideas and letting technology be a tool and not a topic, allowed for rich learning experiences. Critical thinking became a clear outcome (observed in data from teachers and students) although it was not the main goal. Analysis showed that authentic contexts facilitated critical thinking, collaboration, and connections, while the communication technology allowed for communication and collaboration. In Mr. Saunders’ classroom, where the pedagogical emphasis was placed on the big ideas instead of the course content or the technological tools, it encouraged a richer, broader, deeper exploration of topics of interest to the students. As a result, it appeared that more elements of the scientific literacy framework were emphasized by choosing to focus on the big idea.

Overall, the results of the two perspectives (i.e., from the teacher and the students) were quite consistent. In the scientific literacy theme, it was noteworthy that these data demonstrated a linkage to many of the scientific literacy framework categories. In the teacher interview analysis showed that communication, critical thinking, and connection were evident. The focus group data analysis highlighted connections and critical thinking.

Analysis for the Second Research Question

The data were re-analyzed with respect to the second research question, i.e., how does communication technology contribute to the scientific literacy learning experiences? Only the comments with direct references to communication technology were coded
according to the five Scientific Literacy Framework categories. This case was unique in this study due to the variety of communication technologies used and the diminished emphasis on the technology (i.e., it was a tool to achieve a goal, but technology usage was not the main objective in this classroom). Once again, the data analysis for the second research question provided insight regarding frequency and quality of usage.

**Frequency of Communication Technology Usage and Connection to Support Scientific Literacy.** In the first analysis of the data for both the teacher and the students, a diverse range of categories within the scientific literacy framework were noted. This was due in part, to Mr. Saunders’ emphasis on a big idea of green chemistry (i.e., establishing connections to authentic contexts) and encouraging his students to consider the personal relevance and responsibility within their learning (i.e., the analysis linked these ideas with critical thinking). Technology per se was not a key topic, so it was not a surprise that the frequency of codes in this second analysis was less than the first trial, as shown in Table 1 for Mr. Saunders’ transcript and Table 13 for the student focus group. Technology usage accounted for all or most of the teacher’s and students’ references that were coded as Communication and Collaboration and for the teachers references to Connections. Technology (e.g., the wiki project) served as a key tool for projects that encouraged student collaboration and student communication. It was interesting to note that although the teacher’s pedagogy had a strong emphasis on Connections, the students had no codes in this category. Upon second look at this apparent anomaly, it was due to the fact that in the students’ comments that involved connections to real-life issues, the students were taking the issues to a deeper level; often when the students mentioned
authentic issues they were describing how they were applying elements of critical thinking to these contexts. Perhaps one flaw in the method that coded the transcripts according to a single category did not demonstrate the interplay of multiple layers in a given comment. However, the categorization of the main topics in the conversations addressed this concern by considering the data in its entirety.

Table 12
Coded References to the Scientific Literacy Framework from Mr. Saunders’ Perspective

<table>
<thead>
<tr>
<th>Scientific Literacy Category</th>
<th>Research Question #1 (Scientific Literacy Framework in all comments)</th>
<th>Research Question #2 (Scientific Literacy Framework that uses Communication Technology)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td>Critical thinking</td>
<td>13</td>
<td>7</td>
</tr>
<tr>
<td>Collaboration</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Connections</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Content</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

(n = number of references)
Table 13

Coded References to the Scientific Literacy Framework from the City High School Students’ Perspective

<table>
<thead>
<tr>
<th>Scientific Literacy Category</th>
<th>Research Question #1 (Scientific Literacy Framework in all comments)</th>
<th>Research Question #2 (Scientific Literacy Framework that uses Communication Technology)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Critical thinking</td>
<td>37</td>
<td>10</td>
</tr>
<tr>
<td>Collaboration</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Connections</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Content</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

(n = number of references)

**Quality of Communication Technology Integration in the Scientific Literacy Framework.** When the second analysis considered how the use of communication technology contributed to the experiences within the Scientific Literacy Framework, it also noted some patterns in how it was used. Clearly, in this case, the emphasis on wiki projects resulted in Communication and Collaboration being evident in the students’ activities. However, the discussions with Mr. Saunders and the students yielded more than just these two categories. The authentic context and the big idea provided diverse opportunities for students to investigate issues of personal relevance and importance. The previous discussion noted that critical thinking was the most frequent category identified in the student data. The wiki project prompted the students to compare global differences in technological resources, information management, environmental policies,
and they were reflecting on the personal implications that these implied. The students at City High School were communicating with one another, but also with a cohort of global peers: the technology was a tool, but the conversation and interaction were their focus.

**Summary of Data Analysis**

This data analysis in this case corroborated the classroom observations: this was a classroom where the students were engaged with the material, relating it back to their own lives and acting upon their newfound scientific knowledge. Elements of the scientific literacy framework were evident in both the discussion topics and the analysis using Nvivo. However, no single category of the scientific literacy framework was strongly emphasized to the exclusion of others by either the teacher or the students. Figure 10 showed a high number of critical thinking references coded from the student focus group discussion. However, as previously mentioned, many of those critical thinking references were reflections or comparisons of real-life issues or big ideas that also hinted at connections and collaboration. The emphasis on a big idea encompassed many aspects of scientific literacy.

The integration of technology in this classroom raised several surprises. It was not a resource-rich location; the netbooks were functional but not top-of-the-line technology. The class set of netbooks were shared throughout the department and were almost always in use. Equity and accessibility were issues that Mr. Saunders had to consider because not all of the students had access to computers or internet at home. However, the classroom technology was used as a tool and not as the focus of the lesson. This allowed the focus to extend much wider.
Elements of the scientific literacy are clearly evident and engaging in this classroom. These scientific literacy outcomes were supported by communication technology and facilitated by focusing on an authentic connection via the big idea. This case provides insight into activities and technologies that support scientific literacy in a classroom context.
Chapter 7

Data Collection & Analysis – Deepwater Academy

Introduction

This chapter describes the teaching and learning activities in the classroom of Mr. Rutherford at Deepwater Academy. The first section will describe the data collection, including the two interviews with the teacher at this school, the three classroom observations, student surveys, and a student focus group. The second section of this chapter will highlight the analysis of this specific case in relation to the theme of scientific literacy. The categories and subcodes were defined in chapter three.

Data Collection

This section will describe the data collection at Deepwater Academy. All of the names, including the institution and the individuals are pseudonyms throughout this case study.

Location

Deepwater Academy is a private girls’ school located in a residential area of a large urban centre. The student population is a combination of day students and residential students and represent diverse cultural backgrounds. The leadership of the school seeks to implement best practices from around the world (such as initiatives from Singapore and Finland). The school headmaster is supportive of new innovative ideas that support student learning.
First School Visit

When I contacted the school, the headmaster was very receptive to the idea of participating in educational research. The school had benefited from research done elsewhere and he was eager to participate in educational research projects to promote goals of academic excellence. On my first visit to the school he encouraged me to think of the school as a “learning laboratory.”

During my first visit to the school, I had a tour of the facilities with the guidance counsellor. I was introduced to the teaching staff, including the three teachers in the science department and the teacher of communications technology. I also met the headmaster of the school. The teachers and the support staff were welcoming and encouraging. During a discussion with the science teachers where I outlined my research project, it was determined that Mr. Russell Rutherford would be the best fit for this project. It was recommended by the teacher that due to the very small size of the classes (e.g., grade 12 only had 7 students) that I include both the grade 11 and grade 12 students in my data collection (surveys and observations).

Technology Resources. Technologically, the school is a laptop school, with senior students given the option of Macbooks, Lenovo tablets, or netbooks. This option provided both opportunities and challenges that were later identified by both the teacher and the students. Wireless internet is available throughout the school. Ethernet connections and blue cables are still evident in the lab and speak of the technology that predated wifi.
Physical Environment. The private school is located in a residential mansion that has been extensively renovated for its current purpose. Many of the features of a home remain, however, creating a unique sense of community among the faculty and students. The non-traditional setting is emphasized the common room (a formal double parlour with a grand piano, chandeliers, elaborate ceiling moulding, and ornate paintings) and by a lack of hallway lockers. There is a communal dining hall that bears no resemblance to a typical school cafeteria. Physically the dining room is surrounded on two long sides by large windows which provide ample natural light; staff, students, and visitors eat together, seated at round tables in groups of 10, which facilitates comfortable conversation; logistically the food and utensils are delivered to each round table; the meal begins with grace by the headmaster; and administratively, the end of the meal provides an opportunity for announcements to the student body.

Teacher Interview

On April 11, I met with Mr. Rutherford to discuss his teaching initiatives and integration of communication technologies. He began by showing me some of his teaching materials. He uses Flash animations that he creates himself. He prefers this method over finding material on the internet, because he can tailor it to his own lessons. He uses PowerPoint slideshows for his lessons. The school has Moodle as a learning management system, so he can post slideshows and assignments to the course website.

Our conversation began with background of his teaching experiences. Mr. Rutherford has experience in public and private schools, internationally and in several Ontario locations. He currently teaches grade 11 and 12 chemistry, grade 11 physics,
grade 9 science and grade 10 math. His current initiatives include creating an assortment of Flash animations to demonstrate dynamic scientific processes. His professional development opportunities centre on collaborations with colleagues and local science education conferences.

**Mr. Rutherford’s Interpretation of Scientific Literacy.** His pedagogical emphasis was to have students “think like a scientist,” a goal of providing in-class opportunities to encourage critical thinking in his students via discussion, data analysis, and argument justification. “Think like a scientist” was his interpretation of scientific literacy. He linked this initiative to real life activities where students could assess the justification of arguments to determine if they were valid. “Realizing if this situation is a controlled situation when they read things in the paper or hear about it on the news” (Rutherford, D T1, line 30).

The students use their computers in class “mainly to take notes...when we want to do research they get online on their computers. I give them PowerPoint lessons and Flash animations that they use as their notes” (Rutherford, D T1 line 36). “I have them use Excel to learn how to plot information and how to analyze information.” (Rutherford D T1, line 40). Thus, the technology that he included in his class is mostly used on an individual basis, but it often prompted class discussion.

**Technology Policy.** Mr. Rutherford commented on the school technology policy that allows a choice of computers. A prior policy that mandated one computer model did not mean uniform resources. “It used to be that you had to have a school computer, but
then you had the ones that didn’t have the right software on it” (Rutherford, D T1, line 63). The current policy created challenges in the variations presented by the different formats. However, this provided a context for problem solving, as the teacher often directed students to their own help files because of the nuances in different software versions.

I find there is a discrepancy between the PC and the Mac…It’s a bit challenging. It’s also good because it enhances when I direct them to their help file because I’ll have different students in the same class have a similar problem but the menus don’t work out the same (Rutherford, DT1, line 65).

He described the options provided in the current computer policy as trying to improve accessibility for students. “I think we have some families that are working hard to afford to send their student here, so for them to change or have different computers at home, it can be a challenge. We try to accommodate that” (Rutherford, D T1, line 86).

**Pedagogic Choices.** Mr. Rutherford spoke of the benefits of posting PowerPoint notes or flash animations. He said that time is better spent on clarifying student understanding and encouraging student interest than on transcription. “We can have a broader discussion. It gives them more freedom to ask questions about curiosities because they don’t sit there writing notes” (Rutherford, D T1, line 110).

Mr. Rutherford identified that YouTube videos and news videos provided a conduit for connecting course material to real life situations. “For example, water pollution – I found a good one about lawn fertilizer being the main culprit in some areas.
Mr. Rutherford’s expressed his goal of integrating communication technology was to encourage more critical thinking, more discussion, and more engagement from the students. “More thinking…you actually have more time to do a lot of thinking and discussion…that’s my goal” (Rutherford, D T1, line 133). In this way his technology goals, aligned closely with his “Think like a Scientist” activities, creating a cohesive pedagogy. He was concerned that students tended to view a main benefit of technology to be expediency “they like to take shortcuts, but I think they would do that whether they had technology or not” (Rutherford, D T1, line 145).

Mr. Rutherford described current student usage of communication technology in group work. “They share things. They work on a project together and they send each other the websites they’ve found. They can divvy up the work. They can share, pool [resources], and come up with the final project” (Rutherford, D T1, line 183). He expressed an interest in using more group work, but said that equitable assessment was occasionally a challenge if the work was not shared evenly. He spoke of a desire to integrate more communication technologies in class, but had not solved all the logistical concerns.

Critical thinking, as framed by the “Think like a Scientist” activities, was a theme throughout our conversation. Mr. Rutherford reported that he regularly asked his students...
to read selected articles and identify any bias, “everything has some bias in it” (Rutherford, D T1, line 226). In earlier grades they were coached in developing a preparing an effective lab report. “We teach them what a testable question is…we’re trying to work on developing experimental skills and analytical skills” (Rutherford, D T1, line 251).

Overall, I left this interview with several new questions. The flash animations were useful teaching tools, but I wanted to see how the students responded to them. I hoped that the classroom observations would demonstrate the integration of technology and the engaging student activities that would embody thinking like a scientist.

First Classroom Observation

On April 24, I observed a grade 12 chemistry class. The planned activity was to use Pasco probes to explore an acid-base titration. The room was a traditional school lab: a teacher’s lab bench was at the front of the room; lab benches for student use were arranged along the far side and one towards the back of the room, parallel to the teacher’s bench. The empty space in the middle contained four groups of four desks each. The class I was observing had only seven students who were spread among three of these table groups. The fourth table group was used for the experiment as the teacher’s bench was completely covered with stacks of papers.

The class began with a discussion that reviewed strong acids and strong bases. The students were familiar with the concepts. They also discussed a prior experiment that involved the titration of a strong acid with a strong base and they had observed a titration curve. Pasco probes had been used in the previous experiment and were used in this
lesson also. The first titration used vinegar, as an example of a weak acid. At the end of the review discussion, the teacher erased the sketches from the board, to the audible dismay of some students. The teacher reminded them that already had that material in their PowerPoint notes. However one student replied that she “can’t remember it from the PowerPoint.”

They were ready to begin the experiment. It proved to be more of a class demonstration, than an individual exploration or experiment. Mr. Rutherford stated to the class that he had ordered magnetic stirrers, but they had not arrived yet. The activity began with the calibration of the probes. Mr. Rutherford asked for a volunteer, who came up to the equipment and poured some buffer with a pH of 12 into a beaker. Mr. Rutherford pulled out the box of safety goggles and the student tried on three pairs before settling on one. Then she rinsed off the probe and commented that she had volunteered for this task in the previous experiment. As the teacher connected the probes and booted up the software, he asked for a second volunteer. No student responded, so the first student offered to continue. She proceeded to calibrate with a buffer of pH 2. The technical part of the activity was quite teacher-directed. He was doing all of the computer work with the probes and the software. The majority of the students were spectators and the one volunteer was calibrating probes.

As the titration began, so did the technical difficulties. On the first trial, as the base was added to the acid, the pH remained constant at 2. There was no change. The teacher got a different pH probe and data logger, making sure it was the same equipment that was used successfully last time. The new probe needed to be calibrated. This task was done by a second student volunteer. The titration still did not work. A third Pasco
data logger was brought out; it was still unsuccessful. Finally, the teacher got a third probe and also rebooted the software. As the new probe was calibrated and rinsed, a student asked why it was necessary to rinse the probe after each buffer solution. The answer given was that it was “good protocol.” It seemed to be an insightful student question that was prompted by the fact the students had just watched the probe being calibrated three times. It was my first example of the students thinking like a scientist by questioning the given process, and asking for justification. Due to the technical glitches he was focused on, Mr. Rutherford did not elaborate on the details. However, the students were perceptive of such points and this could be revisited to consider the potential errors that would be introduced if it were skipped.

Finally the titration worked as planned and the pH probes, data logger, laptop and projector displayed the titration curve to the watching students. A student volunteer was managing the burette and the teacher was managing the technology. A titration curve was obtained for this weak acid and it was compared to the previous titration curve for a strong acid. Some observations were made about the shape of the graph and where the equivalence point was.

Mr. Rutherford was ready to begin the second titration. He asked his students to look up vitamin C. This titration was to use an everyday substance. One student looked at her Smart phone. Another student’s laptop had a dead battery at this point. She looked at her neighbor’s computer, but the display was in Japanese. The teacher wanted the students to find out that the chemical name for vitamin C is ascorbic acid. He then directed them to their chemical data tables to determine if it was a strong or weak acid. Many students did not have these reference charts with them, so the teacher distributed
some extra copies. The students eventually found the Ka value of ascorbic acid and determined it was a weak acid. The teacher pointed out that two Ka values were listed but did not explain what this would mean, other than it was unique from previous data.

As the vitamin C titration proceeded, a student volunteer crushed one tablet with a mortar and pestle and began the experiment. Technical difficulty interceded again as the previous graph was still present (the teacher wanted to be able to compare the two trials) and the current graph was displayed on top of the previous data, making it difficult to discern either one. A second attempt of this experiment began with the software refreshed and the teacher suggested using four tablets this time. All the students were now eager to volunteer – apparently the mortar and pestle was the favorite lab equipment. The titration progressed and the group looked at the titration curve. Two vertical sections were evident, although not as distinct as the teacher would have liked, but he directed the students’ attention back to the data charts with the two Ka values and they deduced that two Ka values meant that two protons would be release and thus two equivalence points would be seen as two vertical sections on the titration curve. This new concept was developed using class discussion based on discrepant events in the laboratory.

The discussion after the experiment was important to understand the events. The students had not been overly involved in the experiment itself, but participated well in the discussion that followed. The teacher explained that it was not a cookbook recipe lab, but a chance to explore the method and see trends. As such, it was probably better to be doing it as a whole group, especially with the technical difficulties that were involved.

After the experiments section of the lesson, the teacher switched to a PowerPoint of acid-base titration curves. A titration curve diagram displayed the plateaus, transitions,
and equivalence points with flashing labels. It helped draw the students’ attention to these parts of the graph. The lesson had included low-tech research methods using the data charts. It had used high-tech research methods as the students searched online for the formula and chemical name of vitamin C. However, neither of these methods really had students interacting. Their role in the experiment mostly involved assisting (i.e., crushing tablets or calibrating probes) and observing.

**Second Classroom Observation**

On April 25, I observed Mr. Rutherford’s grade 11 chemistry class. The group of students were studying solutions and water quality and it proved to be a better example of technology integration that facilitated student engagement and interaction. The teacher showed a variety of video clips on water quality and bottled water, some as news clips, others as advertisements, and others as scientific explanations.

The first video was a CNN clip about pharmaceuticals in tap water. The news anchor used such terminology as “teeny, teeny, tiny amounts” as she spoke about a report from the Environmental Protection Agency. The students in the class picked up on the vagueness of this description and they asked, “how big is the amount?” That led into the first discussion of the class about quantifying the amount of solute in a solution. In addition to the amounts of impurities in tap water, they also discussed the different types of contaminants. This news clip had highlighted the presence of drugs and hormones in drinking water. The class also discussed the cost of purifying water and how clean pure water should be. The video allowed the students to recognize the importance of using precise amounts when discussing concentrations.
The second media clip was an animation of a sodium chloride dissolving and the ions in the solution. This was followed by an activity in which the students were given a handout where they had to rank 6 concentrations in order from weakest to strongest and explain their reasoning (e.g., 6 solute particles in 200 mL of solution, 3 particles in 75 mL, and 3 particles in 100 mL). The students’ struggles with units were evident in their table discussions of how to proceed. Students at one table debated strategies. One student suggested “use ratios,” and another countered with “no, use science,” as if there was a separate set of rules for a scientific context. As the class went over the answers and the teacher recommended comparing how many particles were in 100 mL, one student asked if that was a formula. The teacher responded that “no, it’s just common sense.” Another student asked if it was acceptable to do mL/particle and the teacher responded that it could work. A third student asked if it mattered if they used mL or L, and the teacher turned the question back to the students.

A second handout followed. (e.g., 5 solute particles in 1 L of solution, 3 particles in 500 mL, 2 particles in 200 mL). The student responses were varied: one student complained “this is so complicated,” while another student exclaimed, “this is so easy!” The one thing they did agree on was their problem solving strategy: when the teacher asked how they intended to solve these problems, the students answered “ratios.”

After the handouts provided some practice with comparing solution concentrations, the teacher provided several more videos that explored solutions in real-life contexts. The first video in this segment presented an infomercial description of an ion cleanse footbath, in which the water turns dark brown as it supposedly removes toxins from a person’s feet. A news clip from Fox news also described this product. The
classroom discussion that followed examined some of the portrayals of science in the media (e.g., does wearing a white lab coat qualify as a credential) and raised questions about some of the obvious errors in the videos. A third video in this series presented an argument buying a particular brand of bottled water, *Beyond H₂O*. The speaker in the video described and measured the total dissolved solids (TDS) in various bottled waters and tap water. This video emphasized the units of parts per million (ppm) which the students in the class agreed was better unit than teeny. The bottled water video showed digital analytical equipment that did the TDS testing and it also used experts in white lab coats. When the electrolysis was performed on all of the water samples, the *Beyond H₂O* sample remained clear, while all of the others turned brown and murky. The implied message was that contaminants were associated with TDS. *Beyond H₂O* was pure (with zero TDS) and all of the other water sources were less pure (with higher values of dissolved solids). The TDS measurements provided quantitative measurements and the electrolysis showed the supposed contaminants. A final video provided a good summary to this series. It began with the scientific principal of electrolysis of water and that water must have ions to be conductive. The students commented that they remembered this concept. The video explained the scam that the discolouration of the water was caused by the electrodes. The TDS merely allowed the water to conduct electricity. The colour in the electrolyzed water samples also came from the electrodes.

The variety of media selections illustrated the range of data was excellent at sparking discussion amongst the students. In this situation, although the activity was not presented with the title, “Think like a Scientist,” it demonstrated the communication
elements of clear use of vocabulary, and the critical thinking elements of evidence-based justifications and using logically-structured arguments.

**Other Classroom Observations**

I also had the opportunity to observe the Grade 11 physics class, which was the same group of students as the Grade 11 chemistry class. They were working on a lesson of wave patterns. I was interested in observing Mr. Rutherford’s general teaching methods. His PowerPoint was displayed using the LCD projector, and he was also drawing diagrams on the chalkboard. When the projector was on, the classroom lights were off and the chalk was extremely difficult for the students to see. When the chalkboard was used and the lights in the classroom were on, his references back to the screen were extremely difficult to see. This was unfortunate, because the integration of chalk diagrams and PowerPoint supported one another well. The blackboard work could address questions from the students. The interference was unfortunate because it diminished how effectively the teacher could use his teaching tools. This was also ironic, because the topic of this lesson was interference. The chalk sketches had displayed visual reminders of the single slit and double slit interference patterns seen in previous lessons.

It was not only the teacher who had difficulty with the classroom tools. Students in this class were observed to have surprising challenges with low-tech devices. While working on their physics assignment, students were having difficulty using a protractor to measure angles. Another student exclaimed “math makes no sense!” as her calculator was giving a negative value for the sine of 60 degrees. She understood that the negative value
was not normal, but did not recognize the reason—that her calculator was not set to degree mode.

Mr. Rutherford invited me to observe his other classes to see the “Think like a Scientist” activities in a broader context. In each of these cases, I was targeting my observations on the teaching and choice of activities, rather than the students. I observed a variety of ways in which technology and critical thinking activities were implemented across the curriculum. In one example, science students were graphing data in Excel and finding a trend line of astronomical data. Although they had used Excel before, they were struggling with creating their graph. It was intended that each student would complete this activity on their own laptop, working individually. The students seemed confident in their use of Excel, but they tended to leave all of the software defaults in place (without sorting the data and selecting what they wanted to be the independent and dependant variables, they got a meaningless scatter). Mr. Rutherford circulated through the class to help individual students. He tended to be answering the same questions with each student. The prevalence of peer mentoring meant that unplanned communication and collaboration occurred as many students assisted their neighbours. Although the activity was not intended to be collaborative it did lead to interactive discussions among peers about the data and analysis.

**Student Survey Data**

Survey data was obtained from 23 students, representing sixteen participants from grade 11 and seven participants from grade 12. The survey questions asked about the frequency of communication technology usage for both academic and social reasons, they
type of programs used and the benefits enjoyed by students when they used technology for their schoolwork. The usage survey was a five point Likert-type scale. The results were averaged to give a statistical aggregation. The data portrayed a profile of students who use technology frequently for both school and personal reasons, but who use it more often outside of school. The Deepwater students’ surveys indicated that their schoolwork usage of communication technology was 3.87 out of 5 and their personal usage was 4.47 out of 5. In the open comments section of the survey, two main ideas were common. One emphasized expediency, e.g., it is “easy to search for information” (D12 2), and “to get information faster” (D11 5). The second common idea was to gain a better depth of understanding or to elaborate on material. Technology “allows me to gain new knowledge that I didn’t have time to learn in class and to go beyond classroom boundaries” (D12 3); “for background and additional information…it helps me get a more in-depth understanding of the course” (D11 4); “different opinions will let me think in a different way” (D11 10).

**Student Focus Group**

This focus group was held at lunch time at the school. The students picked up their lunch at the cafeteria and met in the library. This is a room that currently gets used much less than it did in previous years. It is a large space with high ceilings that used to contain both library books and the school computer lab. However, when the school implemented its laptop policy the school computers were removed. Students currently access many of their resources online. The room now serves mostly as a study room for students during their spare periods.
The conversation began with six students present. A seventh arrived a few minutes after we had started. They represented both grade 11 and 12 students. The key ideas of the focus group had included organizational benefits, difficulties in computer compatibility, the prevalence of using and sharing photo notes, how technology (including video and images) supports their learning, and how students learn technology skills.

**Organizational Benefits.** The students identified that technology is beneficial for them to stay organized and to access information. “On PowerPoint you can have certain information that kind of pops out – I need to remember that! With papers everything is just in the way” (Brianne, D FG, line 27). Ironically, we were located in a library and one student commented, “If you go to a library, you have to look around for all these books. I’m not saying that books are bad. It is much faster to type something on Google and you can get a bunch of sources” (Alison, D FG, line 14).

**Dual Computer Policy.** The students in the focus group were opinionated about the two types of approved computers at their school. They recognized the different features and benefits of the hardware. The students liked the interactive nature of the tablet for working collaboratively. “Mine’s a tablet, so I can write stuff on it, so for explaining something to someone, it’s like writing on pen and paper, it’s a lot easier” (Brianne, D FG, Line 50). They recognized that the software on certain computers were better for certain tasks. “If you have to use Moviemaker, you want to pair up with someone with a Mac because they have I-Movie and it is better software than Windows Moviemaker” (Alison, D FG, line 67).
The conversation indicated that the students recognized the dual computer policy allowed for more exposure to different technology and the relative strengths of each one, there were significant compatibility issues. “Macs don’t have software that PCs have and PCs don’t have the software that Macs have. It would be nice if it all worked the same – it shouldn’t be an issue now” (Carla, D FG, line 392).

We have that problem in calculus class where it’s just me and one other student who have tablets and the rest have Macs. So for Windows Journal they can’t open it, so when we have notes he has to print it out because he can’t send it to them. They can’t open it. (Brianne, D FG, line 398)

The students talked about the various communication technology platforms they use for both academic and social purposes. They were very proficient at selecting the best software for a specific task. For example, they used Facebook, Skype, Moodle, Facetime, and text messaging. They described using Skype during an in-class work period “we’re supposed to be quiet, but we can go on Skype and you can talk [type] about your project and figure it out and you are not being disruptive for the whole class” (Brianne, D FG, line 188). Other students used their cell phones and text messaging options to seek help from their peers because everybody has their phones with them.

**Photo Notes.** One item of surprise was the prevalence of the students’ practice of taking photo notes. This involved taking a picture of the board, with the teacher’s notes on it, rather than transcribing it themselves. This time-saving measure allowed them to
focus on the teacher during class, share photos with one another and it ensured an accurate record of what was written on the board. “I would take a picture of the notes on the board and upload it [to Facebook] and all the classmates can see it” (Shawna, D FG, line 104). Transcribing errors in their notes were attributed to lack of focus, lack of time, or operating in a second language. “Sometimes we don’t focus and we miss some something” (Dianne, D FG, line 131). “There are lots of notes. The teacher is explaining, so you are [listening] I have no time and the class ends and you are like beep and you go” (Dianne, D FG, line 111). “Sometimes when you write it by yourself, you can make some mistakes, so you take a picture and you can get the right information” (Lee, D FG, line 118). The students were opinionated on the best technology to use for photo notes. “Blackberrys are tough to read from” (Carla, D FG, line 127). “If you have an iPhone and you are taking the pictures, they are clear” (Alison, D FG, line 129).

There were a number of international students participating in the focus group. They commented on the usage of similar applications in their home schools and the different languages that could be accessed. “On Facebook you can have groups…in Mexico too…we remind each other of things. We always check Facebook.” (Dianne, D FG, line 221). “I use a Chinese program, it is something like Skype” (Shawna, D FG, line 195).

**Visuals.** The students talked about the benefits of visuals, including images and videos. They appreciated the greater depth of understanding that video could provide. “If you see it on video, you understand more” (Dianne, D FG, line 269). Sometimes a teacher would direct them to watch an online video for homework and then they could
discuss it in class. “Mr. Rutherford, he always uses videos. Sometimes it’s not easy to do that during a class, because it takes time, so we can watch that on our own” (Shawna, D FG, line 143). Other times, the students would seek out video support to answer questions or solve misconceptions.

Sometimes I go on YouTube for calculus. If we have to do something and I don’t understand how, I’ll search YouTube for it and it will go step by step and I can re-watch it until I get it. It’s so much help. (Brianne, D FG, line 148)

Certain subjects, particularly in science, benefited from the inclusion of images in the teaching material. The students described the importance of images whenever spatial relationships were involved. Videos were also helpful for dynamic processes. Text alone did not meet their needs. “In exercise science, I need lots of pictures! When we have to [identify] the bones, I can’t just look at the names, I need pictures” (Brianne, D FG, line 281). “For biology I have to look at a picture, I can’t understand mitosis without one” (Carla, D FG, 294).

**Learning Technology Skills.** The students were quite candid about how they learn to use technology. Some of them described a hands-on approach that differed from that of their parents. Technological problem solving provided the opportunity for exploration and built self-esteem. “I also think that one you figure out something you feel accomplished and you feel so good about yourself” (Alison, D FG, line 357). They recognized that they learned technology differently than older people.
I think it’s our generation. Even when I was little, if I got a game I did not read the instructions, I just figured it out. My mom will come and sit down and read the instructions. I’m like, no, just figure it out. Even when you get a new phone, parents will sit and read the manual. (Brianne, D FG, line 329)

The students did admit that sometimes it helped to have a peer show them some of the basics about new technology applications. However, they thought they remembered certain technology skills better if they had opportunities to explore and discover.

It depends. When I got my laptop, I just figured it out…I guess I had learned about Microsoft Word at my old school…but I had never seen PowerPoint before. And moviemaker was hard to figure out, but once I had a friend show me how to do it, it helped a lot. I got to see all the cool things you could do with it. (Carla, D FG, line 349)

The difficulty with learning technology through self-discovery was the inevitable frustration that accompanied it. “You want to get to that point [where you know how to use it] before you start trying to smash your computer” (Carla, D FG, line 362).

Overall, the students’ self-reporting of their technology skills rated their skills highly. However, they had difficulty justifying this assessment with evidence. They seemed to think that lifelong exposure to technology or secondary school experiences had developed a high level of expertise. They only gave examples of using cell phones, PowerPoint and video production. “I think it’s our generation. We fool around with stuff”
until we figure it out.” (Brianne, D FG, line 335). “I think it comes when you age. You see different websites and you like those websites” (Alison, D FG, line 327).

Some of us have been here since grade 7. From those years, we’ve built up an understanding of technology. When I came to Deepwater, I didn’t know how to use anything, but now I know how to use pretty much every software. (Alison, D FG, line 319)

The closing comments from the students involved issues of accountability and absenteeism. They commented on the convenience of certain communication technologies in staying up to date. Facebook and Twitter could be accessed quickly on their cell phones, while connecting to the internet to access the school website and school email took much longer.

It will take 15 minutes to load, because I live in the country, so trying to check my email is [slow]. If I’m sick, I don’t want to wait 15 minutes. But I can go on Facebook and ask a friend what I missed. It’s just better.” (Brianne, D FG, line 380)

The students clearly took responsibility for catching up on missed work, but the school technology was not as helpful as it could have been.

The focus group ended as the bell rang to signal the end of the lunch period. As they left the library, the students were talking among themselves of setting up a Facebook group for their chemistry class.
Data Analysis

This section will describe the analysis of the data obtained from Mr. Rutherford’s class at Deepwater Academy. The documents pertaining to this case included:

- Transcript of interview with the teacher, Mr. Rutherford, April 11, 2012 (8 pages)
- Transcript of Focus Group Interview with seven students May 3, 2012 (12 pages)
- Field notes of Classroom Observations April 24, April 25, 2012
- Transcript of final email interview with teacher June 20, 2012 (2 pages)
- Student surveys (n=23)

As in the previous cases, two trials of data analysis were completed. The first considered the topics in the transcript data as they related to the first research question (i.e., it provided a broad understanding of how the participants experienced elements of the scientific literacy framework). It considered the main topics and it also deconstructed the transcripts to consider the individual components, by assigning codes and using Nvivo software. A second analysis was done to respond to the second research question (i.e., to determine the role that communication technology played in the scientific literacy framework).

Data Analysis with Nvivo Software

The transcripts were coded with Nvivo software. The first step was to deconstruct the data and identify the details within. This resulted in 74 codes. These were then merged and consolidated into appropriate bigger categories in the overall emic theme of scientific literacy.
The overall theme was scientific literacy and the categories were the five elements in this framework: (Communication, Critical thinking, Collaboration, Connections, and Content). The transcripts were then re-coded according to these five categories, using the sub-codes described in chapter three, and assigning a single category to a given reference.

**Data Analysis of Experiences in the Scientific Literacy Framework**

The teacher’s perspectives and the students’ perspectives were analyzed by topic and with Nvivo software to determine which category that they best represented.

**Teacher’s Perspective.** The main topics of the teacher’s interview included his interpretation of scientific literacy, the school’s policy about technology, and the pedagogical choices in his teaching repertoire. Mr. Rutherford’s interpretation of scientific literacy was centred on a theme of ‘think like a scientist.’ This encouraged students to look for bias in the media, to question scientific claims, and to critically evaluate information. This focus aligned explicitly with the scientific literacy category of critical thinking. Our conversation on the school’s dual computer policy included the strengths and weaknesses of such a policy. It allowed the students to become familiar with the manipulating both types of devices and provided opportunity for problem solving and platform selection. The analysis of the coding of this conversation aligned with the critical thinking subcode of evaluation of resources. His pedagogical choices to include media such as flash animations, YouTube videos and PowerPoint indicated his appreciation of connecting the material to a format that was relevant to the students. It suggested the critical thinking category subcodes of metacognition and learning styles.
Data Analysis with Nvivo Software of Scientific Literacy Experiences. The scientific literacy analysis coded the comments from Mr. Rutherford according to the categories of communication, critical thinking, collaboration, connections, and content. Subcodes identified common ideas within each of these main categories. The data from the teacher interview showed a strong emphasis on communication (as shown in Figure 13). There were nine references to communication and only four references to critical thinking. This was surprising due to the focus of his teaching being effective critical thinking skills through the “Think like a Scientist” initiative. Some of Mr. Rutherford’s references to communication emphasized the teacher-student communication and generally involved coaching students in problems solving on their computers.

What I try to teach them, (and this frustrates them), is to go to the help file. I know that since I started using some of these programs, they have changed the way they do things. So I tell them, ‘I can tell you where it is, but if you learn to use the help file, then that’s going to be more beneficial when things change on you. I’d rather you learn how, rather than memorize steps.’ (Rutherford, D T1, line 51)
Figure 13. Scientific Literacy Coding References in the Interview with Mr. Rutherford

The other main topic of communication was class-based discussion, which often involved issues of critical thinking. He used “quite a bit of YouTube videos and news clips to stimulate discussion” (Rutherford, D T1, line 118). “For example, water pollution ...ends up creating interesting discussions” (Rutherford, D T1, line 121). Therefore, although the scientific literacy analysis indicated an emphasis on communication instead of critical thinking, the anticipated focus on critical thinking was evident.

The Students’ Perspective

The students’ experiences were highlighted in the focus group conversation and in the student surveys. The focus group was analyzed by topic and by Nvivo. The student surveys were aggregated and summarized in Excel.
**Student Focus Group Data.** As previously described in this chapter, the focus group conversation presented five main topics: organizational benefits of technology; the dual computer policy at the school; the use of photo notes; the benefits of visuals; and learning technology skills. The organizational benefits of technology aligned with the critical thinking subcodes of metacognition. The dual computer policy also aligned with the critical thinking category (specifically with the subcode of evaluation). The benefits of visuals and the use of photo notes, where students took pictures of the board rather than transcribe the information, both corresponded with the critical thinking category subcode of metacognition, as students were reflecting and acting on how the presentation of material best fit their learning styles. The discussion of how students learn new technology skills also matched the critical thinking category in the subcodes of reflection and metacognition. Overall, in the student focus group, critical thinking was the dominant category.

Analysis of the student focus group with Nvivo aligned with the critical thinking emphasis (Figure 14). The focus group had twenty references to critical thinking and eleven references to communication.
Student Focus Group

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication</td>
<td>12</td>
</tr>
<tr>
<td>Critical Thinking</td>
<td>20</td>
</tr>
<tr>
<td>Collaboration</td>
<td>11</td>
</tr>
<tr>
<td>Content</td>
<td>0</td>
</tr>
<tr>
<td>Conletion</td>
<td>4</td>
</tr>
</tbody>
</table>

Figure 14. Scientific Literacy Coding References in Focus Group at Deepwater Academy

**Student Survey Data.** Two main ideas that emerged from the survey data were expediency and elaborating. Students appreciated the convenience of using technology to quickly and efficiently connect with classmates and their teacher. They also used communication technology to extend their understanding, answer any outstanding questions, and explore topics from class in greater depth. Later in the focus group they gave examples of looking for a Youtube video to demonstrate and clarify a math problem. The first of these two topics reflected the communication category (both student-student communication and student-teacher communication), and the second topic indicated an interest in understanding scientific content.

**Comparison of the Subcodes of Communication and Critical Thinking.** Both the teacher and the students ranked communication and critical thinking as their top two
categories. Therefore, these were more closely examined to determine if they viewed these categories the same way. The breakdown of the communication references is shown in Figure 15. It shows that while the teacher spoke mostly of class discussions, the students’ references were mainly to student-student communication. The pattern is very distinctive and highlights the differences in priorities that were seen in other data from the teacher and students (i.e., the teacher was emphasizing his facilitation of class discussion, and the students valued their online collaboration). Likewise, the critical thinking subcodes were analyzed in the two transcripts. Here more commonality was observed: both the students’ and the teacher’s references were coded to highlight the evaluation of resources as a key subcode. The students also included references to metacognition and learning styles.

Figure 15. Subcodes of Communication in the Analysis of the Teacher Interview and Focus Group at Deepwater Academy
Section Summary: Analysis for the First Research Question

The analysis of the three documents (i.e., the interview transcript, the focus group transcript, and the spreadsheet compilation of the surveys) that were analyzed for Mr. Rutherford’s class showed a scientific literacy emphasis on critical thinking. He described it when we first met, and it was clearly evident in the teacher interview analysis and the student focus group analysis. Otherwise, the students seemed quite traditional: they focused on student-related issues such as communication with their peers and exploring new technologies.

A comparison of the two perspectives showed some common features. The prevalence of critical thinking as the dominant scientific literacy category was evident for both and the teacher and the students. Although communication had a higher ranking in the Nvivo analysis of the teacher interview (as described earlier in this chapter), several of the references coded as communication in the teacher interview had elements of critical thinking as well.

Analysis for the Second Research Question

The data was re-analyzed with respect to the second research question, i.e., to explore how communication technology impacts the experiences of the scientific literacy framework. Only the comments with direct references to communication technology were coded according to the five Scientific Literacy Framework categories. Once again, the data analysis for the second research question provided insight regarding frequency and quality of usage.
Frequency of Communication Technology Usage to Support Scientific Literacy. The analysis of the frequency of communication technology usage (as shown in Tables 14 and 15) indicated that all of the teacher’s and students’ references to collaboration involved the use of communication technology. When the students did collaborative work, they relied on the benefits of communication technology. These included a variety of formats, including Facebook, Skype, photo notes, Twitter, text messaging, and the Moodle discussion board. A high number of the references to experiences in the Scientific Literacy Framework (i.e. Research Question #1) involved the direct use of communication technology (i.e., as shown in Research Question #2). Therefore, it was evident that communication technology plays a significant role in the scientific literacy experiences of students at Deepwater Academy. Furthermore, the variety of framework categories in which communication technology is prevalent (as shown in Tables 14 and 15) indicates that its use is widespread. Communication technology is not relegated to isolated projects but is involved in daily classroom teaching (e.g., YouTube videos to prompt discussion; Moodle for administrative logistics or the distribution of notes and materials; and student interaction via Skype, Facebook, or cell phones).
Table 14

Coded References to the Scientific Literacy Framework from Mr. Rutherford’s Perspective

<table>
<thead>
<tr>
<th>Scientific Literacy Category</th>
<th>Research Question #1 (Scientific Literacy Framework in all comments)</th>
<th>Research Question #2 (Scientific Literacy Framework that uses Communication Technology)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Critical thinking</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Collaboration</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Connections</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Content</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

(n=number of references)

Table 15

Coded References to the Scientific Literacy Framework from the Deepwater Academy Students’ Perspective

<table>
<thead>
<tr>
<th>Scientific Literacy Category</th>
<th>Research Question #1 (Scientific Literacy Framework in all comments)</th>
<th>Research Question #2 (Scientific Literacy Framework that uses Communication Technology)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Critical thinking</td>
<td>20</td>
<td>6</td>
</tr>
<tr>
<td>Collaboration</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Connections</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Content</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

(n=number of references)
Quality of Communication Technology Integration in the Scientific Literacy Framework. When I considered the use of communication technology at Deepwater Academy and how it contributed to the scientific literacy experiences, some patterns became evident. These included patterns of teacher usage and student usage.

Many of the examples of integrating communication technology that were seen during the classroom observation were initiated by the teacher. His use of communication technology tended to occur within the classroom. His choice was purposeful: he avoided group work outside of the classroom in order to encourage fair distribution of the work and to make the evaluation fair and transparent. This approach missed out on authentic opportunities for students to interact with one another using their technological skills for class-related work.

Many of the examples described by the students were quite social in nature. These students did not exhibit the same degree of self-discipline and awareness of the potential distractions of social media observed with other students (e.g., the students at Atlantic View Academy articulated these concerns and described how they managed them). Mr. Rutherford expressed concerns that his students sometimes used technology as a shortcut rather than to enhance their learning. My observations and conversations with these students highlighted examples where they focused on how technology made their academic tasks quicker and easier.

Section Summary: Analysis for the Second Research Question

Overall, observations and conversations at Deepwater Academy revealed a classroom where a variety of communication technologies were used. The teacher tended
to use such tools within the classroom context, promoting classroom discussion and critical thinking, while the students tended to use communication technology outside of the classroom for a combination of peer support initiatives that also provided elements of social interaction. Analysis of the use of communication technology to support scientific literacy tended to show a high frequency of usage, but a lower quality of usage. That is, although the technology was used in a variety of ways, initiated by a variety of stakeholders; it often missed the potential richness afforded by the technology. These limitations represented a combination of teacher-centered pedagogy and limitations of evaluation and assessment policies.

**Summary of Data Analysis – Deepwater Academy**

Overall, the data analysis from the teacher and the students at this site showed consistency in their most prevalent framework category and common topic of conversation. They both highlighted critical thinking and the dual technology policy. My impressions from the classroom observations and from the conversations with the teacher and students were that this classroom emphasized primarily a teacher-led pedagogy. The activities, the lesson presentations, the hesitancy about group projects, all indicated a centralized level of control. The analysis of Research Question #1 (i.e., the scientific literacy experiences) showed a minor surprise. The teacher talked about emphasizing critical thinking skills, but the analysis of the interview indicated a greater focus on communication. However, further examination of the communication coding revealed that much of it dealt with teacher-student communication about problem solving, or
whole-class discussions on contextual issues, both of which fit into Mr. Rutherford’s goal of encouraging his students to think like a scientist, and to think critically.

The student focus group data, however, did match the expected profile for this school. The scientific literacy analyses of the focus group indicated an emphasis on critical thinking.
Chapter 8

Cross Case Analysis

The previous chapters have presented the description and analysis of data from the four case studies. Each case study has included both the description of context for data collection and the scientific literacy insights obtained through data analysis. This chapter will discuss how these case studies inform the research questions presented in chapter one and the implications of these results for technology-facilitated scientific literacy.

This chapter compares the findings from all four case studies. It begins with the emic findings, those that were anticipated in the data. These include the main themes of scientific literacy that characterized each case. These themes from the scientific literacy framework included communication, collaboration, critical thinking, connections, and scientific content. Evidence of the five categories was apparent in the four cases, but the emphases with respect to the scientific literacy framework were distinct, representing the findings at each of the four sites. Next, the cross case analysis examines the etic findings, those that were not expected, but that emerged from the data.

Throughout this cross case analysis, the term case will refer to the respective classroom, including the teacher and the students and their teaching/learning activities. If only one of the stakeholders (i.e., either the teacher or the students) is referred to, then they will be identified as such.
Emic Findings: Aspects of Scientific Literacy Experienced by the Students in the Four Cases

The emic findings were those that were anticipated before the data analysis began. They corresponded to the categories in the scientific literacy framework. Evidence of the scientific literacy framework was anticipated in the data analysis; it was the main focus of this study and it was actively sought after. Of particular interest were the scientific literacy priorities in each case: different elements of scientific literacy were highlighted by teachers, as shown in their individual teaching philosophies and definitions of scientific literacy. These differences had distinct influences on student experiences. Each case was unique and resources varied. Each teacher displayed their individualized teaching philosophy. The teachers were not intentionally implementing the Scientific Literacy Framework as it was presented in chapter two; they were pursuing their regular routine according to their teaching philosophies and priorities. This Scientific Literacy Framework was imposed in the data analysis phase. However, the data analysis showed that there was some overlap in the priorities emphasized at each case, indicating similar outcomes from very different classrooms.

Scientific literacy is a goal worthy of being in the curriculum but it needs pedagogic resources to support implementation. Each of the case studies informs this investigation, providing insight into how each teacher used communication technology to facilitate students’ scientific literacy. Part 1 of this cross case analysis will consider an overview of how the data from the four case studies aligns with the Scientific Literacy Framework, in response to Research Question #1. Were the categories that were perceived to be emphasized by the teachers successfully translated into the actions and
interactions of the students? This is not intended to evaluate the teacher’s role, rather to determine the robustness of the framework.

The subsequent section, Part 2, addresses the responses to the second research question, considering how technology contributed to the scientific literacy experiences, according to each category of the Scientific Literacy Framework.

Part 1: Research Question #1: Experiencing Scientific Literacy

The first research question asked: **What kind of learning experiences aimed at promoting scientific literacy are evident in classrooms where teachers integrate communication technology?** This shall be examined in terms of each of the categories from the framework.

“There are many ways to be scientifically literate” (DeBoer, 2000, p. 597). The Scientific Literacy Framework, developed in chapter two, simplified the previous descriptions of scientific literacy that were complex and cumbersome. Even so, with five categories in the framework, it was apparent in the data analysis that each case demonstrated a focus that matched the teaching philosophy of the teacher. It is important to note that the teachers did not modify their practice to accommodate this framework; neither was the framework designed to match these case studies (the Scientific Literacy Framework was developed a priori, before the case study sites were selected). The teachers continued with their regular teaching activities and the research mapped their actions onto the framework.
Comparing Intentions and Outcomes. Considering the intended goal at each case, and comparing it to the experiences of the teachers and students (both observed and described) highlighted that the intended curriculum often differed from the students’ and the teachers’ experiences. Some of these observations are summarized in Table 16.

Table 16

Comparison of Scientific Literacy Intentions and Observations in each Case Study

<table>
<thead>
<tr>
<th>Case Study</th>
<th>Teacher’s Intentions</th>
<th>Observations of Students’ Experiences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlantic View Academy</td>
<td>Content &amp; Connection</td>
<td>Covert Collaboration</td>
</tr>
<tr>
<td>Berryfield High School</td>
<td>Communication</td>
<td>Communication / Community</td>
</tr>
<tr>
<td>City High School</td>
<td>Big Idea</td>
<td>All Subcomponents of Scientific Literacy</td>
</tr>
<tr>
<td>Deepwater Academy</td>
<td>Think like a scientist</td>
<td>Think like a technologist</td>
</tr>
</tbody>
</table>

Covert collaboration. At Atlantic View Academy the focus on content was evident in several ways. Mr. Martin’s previous teaching experience prompted his inclusion of advanced analytical equipment, knowing his students would use these skills with similar technology at the post-secondary level. His interpretation of the IB curriculum guided the focus on individualized assessment. Although he stated that he did not use group work in the grade 12 IB chemistry class: (e.g., “I think the IB material and IB work should be individual, rather than group work. Other than the group 4 project, everything they do is individual because they are going to be assessed later on
individually” (Martin, A T1, line 98)), Mr. Martin did acknowledge that it improved the learning and interaction in the grade 10 science class where he did include group projects. Although he did not intentionally include collaborative work in the IB chemistry class, the students created their own online venue for peer support, fielding questions from one another, and sharing support. They recognized that each one had different academic abilities and that together they could share their strengths and resources. They acknowledged that they needed an environment where the IB students could meet to help and support one another. Their classes were composed of IB and non-IB students; they wanted a forum that was distinctly their own – they found it on Facebook. They had recognized that they needed their own space and thus created the online group halfway through the school year to meet an unfilled need.

One interesting aspect of the Facebook group was their decision to keep it private – the members were only students, not the teacher. The exact reason was unknown. It may have been the result of the teacher’s attitude toward collaboration; it may have been the result of the teacher’s lack of proficiency with social media; or it may have been due to the fact that the students and teacher already had a functional way of communicating through email and did not need another mode of communication. One benefit of the exclusivity of this group meant it was a characteristically different than the physical classroom space. The students described this as a more than an academic group; it was space for emotional support, where they could privately vent about frustrations or workload. They respected the confidentiality of their peers. The Facebook group took on the properties of school topics without requiring the students to conform to a student role. This finding concurred with previous empirical studies that indicated that some students
did not want to use Facebook for formal academic interaction (e.g., Madge, Meek, Wellens, & Hooley, 2009). Their study indicated that students wanted to use Facebook as an informal media to interact with their peers concerning school issues but they did not want to use Facebook formally as a virtual classroom. They imposed boundaries and assigned specific roles to certain technologies. Their primary use of Facebook was for collaboration, but it did serve a secondary purpose to improve their understanding of content.

A communication-centered community. At Berryfield High School, the explicit goal of the teacher and the students was communication. Edmodo allowed the teacher to send material to the students; it allowed the students to pose questions to the teacher or to their peers; it allowed members of the class to share resources; and the students could ask questions privately to the teacher or publicly to the entire group. The software provided features where small groups of students could work together in a virtual breakout room. It even included an app that sent out a notification to the students’ cell phones whenever a new event happened on the class Edmodo website.

At Berryfield High School, the goal was communication and it was clearly achieved. Table 16 indicates the concurrence of emphasis and results. The students in the focus group recounted their experiences of posing questions and receiving assistance and support from many individuals. Ms. Dalton spoke of receiving many student queries through Edmodo (especially before a test) and her preference to answer such questions promptly (i.e., not to wait until the next class). Edmodo made these interactions quick and convenient. The transparent nature of Edmodo allowed other students to be aware of the questions asked; to respond if they were inclined; to learn from the answers provided to
other students; and to be reassured that their peers had similar questions and misconceptions.

Of particular significance at Berryfield High School was the intensity of class discussion. This forum for student communication was facilitated in part by the distribution of electronic notes before class. It allowed the students to preview the material, and consider questions, connections, and extensions. It gave them time in class to devote to more engaging activities than transcription of notes. The class discussion provided a forum for authentic conversation. A wide range of students in the class participated in the during the observation classes. This aligned with the importance of participation in scientific conversation to make meaning of vocabulary, concepts, and understandings (Arons, 1983; Driver et al., 1994; Lemke, 1990; Norris & Phillips, 2001).

Pacing contributed to the quality of the class discussion. It was noted in each observation that Ms. Dalton used half of the hour-long class for the lesson and the other half was used for a different activity (e.g., working on an assignment, taking up test answers, and student peer assessment of an assignment). This ensured that the amount of new material was consistent and manageable. Participation was important in the class discussions. The range of participants was observed to be numerous, varied, and with a range of good insights. The teacher encouraged discussion and recognized that the student-initiated topics can deviate slightly from the curriculum topics, but they allow the students to pursue interests and make connections with prior learning.

The observations and comments from the teacher and students at Berryfield High School provide a practical example as they align with Lemke’s (2001) description of a sociocultural perspective on science education. He described the importance of social
interaction in making meaning of scientific concepts, arguing that science was “a very human activity, whose focus were and are a part of and not apart from the cultural and political issues of the day” (p. 298). He recognized that “science and science learning enjoy a rich synthesis of linguistic, mathematical, and visual representations” (p. 298), but that these methods of communications require practice and participation to master, manipulate, and integrate. Aikenhead (2006) advocates for a humanistic approach to school science that also prioritizes active participation. The data analysis shows evidence that the students at Berryfield High School were actively participating in the online and classroom discussions surrounding their course material, establishing an engaged learning community.

**The big idea: Embracing many components of scientific literacy.** City High School was unique because it did not emphasize any particular category of the Scientific Literacy Framework. Neither did it have a singular communication technology focus. Instead, Mr. Saunders emphasized a Big Idea in his teaching. This had the benefit of promoting connections to real life issues, and it also encouraged critical thinking and communication. This paralleled the work of Roth and Lee (2004) who also found that a real-life community situation provided an authentic and engaging context for student learning. Jones (2012) also stated that emphasizing connections to real life contexts helped students to understand and remember the key concepts. The use of a variety of technologies meant they were used authentically (i.e., the most relevant tool was selected for the project). The wiki project encouraged collaboration, communication, and critical thinking through the connection to a real life problem. This concurred with Corole’s (2008) work on technology and pedagogy that found wiki projects provide a context for
situated learning and social constructivism. The result of this focus on Big Ideas at City High School was that this class demonstrated a wide variety of elements of scientific literacy. These were identified through the coding analysis described in chapter six. All of the categories of the framework were evident, without a priority given to any single element. This will be discussed later in the next chapter (i.e., in the future directions for research).

**Think like a scientist.** Deepwater Academy showed consistency in its main category, as the analysis of both the teacher’s interview and the students’ focus group emphasized critical thinking. Mr. Rutherford was highlighting the importance of thinking like a scientist (i.e., using evidence to support their claims and recognizing biased or unsubstantiated arguments). Although the students’ comments reflected critical thinking, they were more often aligned with evaluating resources (e.g., the dual computer policy). The thinking like a scientist attitude was evident in the interpretation of some of the classroom observations, as students asked critical questions about experimental protocol and in class discussions about water contamination. These examples that were interpreted as critical thinking concur with the ideas of Zoller and Nahum (2012) and Shen (2010) on this topic, who defined critical thinking as an umbrella term for questioning, argumentation, justification, logic, bias, metacognition and self-reflection.

The results from Deepwater Academy illustrated an interesting feature of the scientific literacy framework. The categories were developed to be wide enough to include various interpretations of an element (i.e., critical thinking included metacognition, argumentation, justification, and evaluation of resources). In this case the two perspectives on critical thinking displayed some overlap and some divergence.
Therefore sometimes the students and the teacher concurred on their approach to critical thinking, but at other times they were more divergent (e.g., when the teacher was encouraging the students to think like a scientist, his goal was for them to evaluate scientific claims rather than evaluate technology options, but similar elements of critical thinking were involved).

Section Summary: Overview of the Scientific Literacy Experiences

The first research question asked: What kinds of learning experiences aimed at promoting scientific literacy are evident in classrooms where teachers integrate communication technology? The four case studies have demonstrated how the scientific literacy can be experienced in different situations. The framework has also been used to show the scientific literacy emphases at each case. Berryfield High School and Deepwater Academy had alignment between the perceived teacher’s goals and the students’ experiences. City High School had a more generalized approach, where the teacher and students focused on a big idea. The analysis of the data from Atlantic View Academy prorated a more divergent profile. The different priorities and different outcomes, as described in the previous section provide insight into the different approaches. At City High School, where Mr. Saunders emphasized a big idea in his teaching experiences, the students experienced the widest range of scientific literacy experiences. Interacting with the ideas through collaboration, communication, connection, and critical thinking helped the students be engaged and the concepts were individually relevant.
All of the elements of the scientific literacy framework are important for scaffolding students’ scientific literacy. The four different case study perspectives provided different insights with respect to different emphases within the framework. The different emphases reflect the differences in instructor’s teaching philosophy and their values concerning technology. Based on the interpretation of scientific literacy in the Ontario science curriculum document, it was expected that connections could be the most important category. In chapter one, the Ontario science curriculum described the importance of scientific literacy in relation to its real-world applications:

[Science] underpins much of what we now take for granted, from life-saving pharmaceuticals to clean water, the places we live and work in, computers and other information technologies and how we communicate with others. The impact of science on our lives will continue to grow…consequently, scientific literacy for all has become a goal of science education throughout the world. (Ontario, 2008, p. 3)

However, these four case studies suggest that emphasis on a single category may not be the best guide towards scientific literacy. Although no school exhibited an emphasis on connections, it was observed that at City High School Mr. Saunders’ focus on the big idea of green chemistry allowed for the greatest variety of scientific literacy categories, integrated authentically within the learning activities. A singular emphasis on communication or critical thinking, while it did provide these specific experiences, it did not achieve the overarching goal of scientific literacy as effectively as a broad-based
approach which was evident at City High School.

Part 2: Research Question #2: How Communication Technology Facilitates Scientific Literacy

The second research question asked: How does communication technology contribute to scientific literacy in classrooms where teachers use these technologies? The STAO definition of a scientifically literate person described individuals who were initiating conversations on science-related issues. “A scientifically and technologically literate person is one who can…confidently engage in discussions and decision-making activities regarding issues that involve science and technology” (STAO, cited in Ontario, 2008, p. 3). This trait was clearly seen in the students’ activities at all four cases: the communication technology was the medium that the students used for social and academic interactions. Their discussions differed: they were covert at Atlantic View Academy, public (i.e. to the class) at Berryfield High School, they were project-based at City High School, and they were often image-focused at Deepwater Academy. At some classrooms the discussion was initiated by the teacher and at others it was initiated by the students. However, in all four case studies, students were using communication technology to facilitate their interaction.

The following sections examine the benefits from technology that were observed in each category of the framework, i.e., communication, collaboration, critical thinking, connections, and scientific content.
**Communication.** In chapter two, communication was defined as the exchange of verbal and non-verbal information and ideas. These could include text, symbols, images, and video. The coding identified three types of communication which were all observed in the four cases: student-teacher communication; student-student communication; and class discussion. Communication technology contributed to all of these forms of communication in different ways. The next section will describe how the technology was observed to facilitate student communication in each of these ways.

**Student-teacher communication.** Teachers used technology to distribute information (e.g., course outlines, assignment specifications, or test dates) and course materials (e.g. PowerPoint slides, SmartBoard screen captures, or website URLs) to the class through a course website or learning management system. Students posed questions to their teacher using email, which remained private between the teacher and the student. Students could also pose questions to the teacher and the class as a whole via a class website such as Edmodo. Public questions received answers from a wide range of respondents and students expressed appreciation at seeing that the questions other students were asking reflected their own uncertainties too. They were relieved to see that their questions were shared by others.

Communication technology facilitated more opportunities for student-teacher questions because they were not limited to the time and space of the classroom. Students could reflect on the material and pose questions when questions arose. Prompt responses via communication technology supported student learning. The students from all four case studies commented on the benefits of timely responses to questions that were posed via technology such as Edmodo or Facebook.
**Student-student communication.** Communication among students corresponded to a strong level of engagement. Student discussion shows interest in the topic; asking questions to their peers demonstrates confidence in their peers’ responses. Therefore, student-student communication indicates a high level of engagement. This interaction via communication technology might otherwise have gone unnoticed, but this study uncovered the richness and authenticity of this media. Students were asking one another logistical questions, questions of conceptual understanding, sharing expertise, and organizing online study sessions using a variety of communication technologies (Arons, 1983; Driver et al., 1994; Lemke, 1990; Norris & Phillips, 2001). In some case studies, the teacher was involved in some of the online communication (e.g., Berryfield High School), at others the online communication was strictly a forum for student interaction (e.g., Atlantic View Academy). Technology allowed a degree of choice in privacy levels, according to the comfort of the student (i.e., a question could be public to the class and teacher or directed privately to a smaller group).

**Class Discussion.** The surprise in the data with respect to communication data was how communication technology facilitated class discussion. These were face-to-face classrooms and although the technology was not being used as the medium for these discussions, it certainly contributed to its success. In three of the case studies, all or some of the notes were distributed electronically. In each case, by de-emphasizing the transcription of notes, the teacher had de-emphasized the transfer of content. Instead, the focus was student interaction, application, and discussion of the material. The classes were engaging and student participation was high. The time that would otherwise have been spent on transcription was re-directed to participatory actions such as class
discussions. This illustrates the ideas that were cited from Brown and Sprang (2008) and Lemke (1990) in chapter two: when students use scientific language in peer conversation it becomes meaningful and relevant to them. The vocabulary was a tool for the students’ ongoing conversation. The students at Berryfield High School were often leading the direction of the class discussion on topics of interest to them.

**Collaboration.** In chapter two, collaboration was described as the sharing of effort and expertise exhibited through teamwork. It showcases the students’ interpersonal skills of planning, delegation, and negotiation. The scientific literacy framework recognizes that learning is a social activity; collaboration provides a structure (either formal or informal) for student interaction to occur. Communication technology can provide a medium for students to work collaboratively in a virtual environment. The social interaction of collaboration clearly aligns with the humanistic approaches (Aikenhead, 2006) and Lemke’s (2001) sociocultural perspective. The elements of creating a community also allude to Wenger’s (1998) work.

Analysis of student collaboration that was facilitated by communication technology in this study identified two parallel strands of collaboration. These were identified by the two subcodes in the category of collaboration: teamwork and peer support. Communication technology fostered student collaboration in each of these strands in different ways. The ways in which technology was integrated into both strands will be explained in the following section.

**Collaboration as teamwork.** Collaborative teamwork referred to students working together in a team on a project instigated by the teacher. This was observed at City High
School. The wiki project was planned, presented, and administered by the teacher. The students formed their own groups and reached a class consensus on the questions they would ask. The delegation within the groups, accountability for completion, and decisions about what to include or how to present their findings were left to the responsibility of the students. In the focus group, the students recognized that this was both unusual and a valuable learning opportunity. Their teacher left the organization and delegation of tasks within the group’s control. The students appreciated this autonomy and responsibly. The features of the wiki that allowed the teacher to track contributions from group members allowed him to monitor from a distance.

In the wiki activity, communication technology played three major roles: it facilitated interaction amongst the group of students at City High School; it provided a medium for the international cohort to share questions and ideas; and it provided a context for students to explore, share, and display information using new technologies (e.g., prezi, voki, etc.). Communication technology fostered collaboration among the City High School students because it allowed flexibility in when they could contribute to the group wiki. “They didn’t have to take so much class time or say everyone meet at 4:00 after school. Like one could log in when they feel like it, do their piece and the next person could come [at their convenience]” (Saunders, C T1, line 47). The online wiki format allowed all of the international students to participate. Mr. Saunders described the diversity of technologies that the students used: “I encourage them to use different types of media…a PowerPoint or a Prezi or something like that, that’s interesting, and something they can share. They’ve been really good at getting new things” (Saunders, C
In this way, the new media was used by the students to authentically present information to their audience.

**Collaboration as peer support.** Collaboration was also described as peer support, where students would informally assist one another. This was observed in all four cases: students would ask one another questions (either directly or pose it to the group as a whole), share online resources (e.g., websites, articles, or Youtube videos). The technology involved included Facebook, cell phones, text messaging, Skype, and Facetime.

Collaboration as peer support was one of the most consistent findings in this analysis. Students used communication technology as a convenient medium to create an extended learning community in all four cases. Under the umbrella of collaboration, these learning communities also showed elements of critical thinking (i.e., as the student selected the most appropriate technology for each task); scientific content (i.e., the students raised questions about scientific material and logistics of assignments); communication (i.e., the students recognized that explaining a concept clearly and effectively to a peer enhanced their own understanding of the material); and empathy. Peer support led to a sense of community. Wenger (1998) and Lemke (2001) advocated community-building as a culturally authentic way to encourage transformative learning. The students at these four sites demonstrated the benefits a learning community that impacted the way they interacted with one another and the course material.

**Critical thinking.** Critical thinking was a frequently used category in the analysis of these four case studies. This may have occurred for two reasons: definition or
intentionality. With respect to the multi-faceted definition of critical thinking, there were a lot of subcodes in the category of critical thinking (i.e., metacognition, reflection, justification, evaluation, application, etc.). However, critical thinking is a broad field and the number of subcodes could actually have been much larger. The literature in the field of critical thinking supported this range of interpretations. (Shen, 2010; Zoller & Nahum, 2012). The number of subcodes defining this category was not solely responsible for the frequency of its occurrence.

Intentionality refers to the explicit teaching (and subsequent application) of critical thinking skills that were apparent in these schools. Students were aware of the different learning styles, how such approaches impacted learning, and how they fit into the spectrum. They were informed and proactive. They realized that their teachers could not direct all teaching to a particular learning style, but they recognized and appreciated the variety. As such, the students spoke of such issues in the focus groups and these comments were coded frequently as critical thinking. The students also recognized that community technology often accommodated their particular learning styles and afforded greater flexibility.

**Metacognition.** Metacognition referred to individuals expressing their level and depth of understanding. It refers to an individual’s monitoring of their understanding of the subject matter and their strategies to achieve certain learning goals (Hollingworth & McLoughlin, 2001). Metacognition was the most commonly coded reference in the critical thinking category. This usually was used in situations concerning descriptions of students’ learning styles or reflections on their learning experiences. Communication technology was not frequently implicated in a direct manner in these coding references,
but indirectly, students described how the technology allowed them to access images or videos that assisted their understanding. Sometimes these images or videos were suggested by the teacher; often they were found and shared by the students themselves.

**Evaluation.** Evaluation was a subcode that identified when students were making an assessment of an argument, resource, or practice. These examples concurred with the ideas on evaluation as an element of critical thinking by Zoller and Nahum (2012). Technology figured prominently in these coding references: the students at all four schools were frequently comparing hardware or software to best meet their needs. At Deepwater Academy, the dual platform policy meant that for many projects, students were considering whether the Apple or Windows programs would best suit their needs and choosing partners based on their technology systems.

The informal student interaction (i.e., via Facebook, Skype, or Facetime), where students could ask one another questions, provided opportunity for evaluation. Students from all four sites described choosing a technology that best suited their needs: Facebook or Edmodo was a good choice to ask a text based question that would generate many potential responses; equations or graphical questions required a technology that permitted visual display- so Skype or an attached photo was deemed a better choice. The technology was a tool; these students were proficient at choosing the best tool for the task. Evaluating and selecting technology was a regular part of these students’ routine.

**Application.** Applications of critical thinking involved students extending scientific concepts to practical, personal applications. Application was not a commonly used subcode. This was surprising, based on the context of the study and the Ontario curriculum’s mandate to emphasize the scientific literacy skills needed to thrive in a
science based world. However, the application subcode was frequently used by both the teacher and the students at City High School. This was not a coincidence. In this case, Mr. Saunders used a big idea as the foundation of his pedagogy and encouraged his students to consider the impact of science on their communities. They reflected on applications regularly.

Overall, it did seem that issues of critical thinking were an important element of the teaching and learning repertoires in these four classrooms. This indicated a depth of interpretation of the scientific content that went beyond the superficial. Technology supported this emphasis on critical thinking, in an indirect manner.

**Connection.** A big scientific issue may not fit conveniently within the confines of a classroom space or within the imposed structure of a poorly-chosen technology. However, this study showed that for an issue of interest, appropriately-chosen communication technology allows the exploration of wider questions with larger groups of interested students. The wiki project at City High School allowed collaboration between students from around the world on a common project. Each group presented responses that represented their own country. In doing so, they created a profile of student interpretations of scientific issues, provided social commentary of how these issues impacted their own lives and could contrast the global similarities and differences. An international online conversation commenced on an issue of common interest and global concern. They took the global problem and considered it from their local perspectives. Communication technology provided the medium to interact. The City High
School example shows that the international collaboration provided global perspectives that any one school alone could not achieve.

**Environment.** Connecting the scientific content to issues related to the natural environment was the most common pedagogical practice. The teachers and the students were both interested in such issues and there was an obvious relationship between the curricular content and such topics. Indeed, in the literature, environmental issues such as urban gardening or the health of a fish population in a local river were a common theme on which students could enact their science learning (e.g., Fusco, 2001; Roth & Lee, 2004). However, if there was one concern, it might be that the category of connection was too strongly aligned with the natural environment to allow other topics to be considered.

**Economy.** Economic issues were usually raised by teachers and usually involved issues of purchasing and advertising. The students at City High School were readily engaged with discussions of new electronic devices and could relate to the concerns of waste disposal. A minor concern might be the equity issues that would highlight the socioeconomic differences of students for whom this discussion was entirely hypothetical and for other students for whom this discussion was impacting their purchasing patterns. The differences in socioeconomic backgrounds and purchasing priorities was evident at Berryfield High School where some students had iPhones and iPads; other students could see the benefits of such devices but could not access them.

**Social Justice.** Social justice issues included references to understanding conditions, policies and practices from different cultures. These topics were most often raised by students, indicating an awareness, interest, and responsibility for social action.
The topics included the political unrest in the Middle East, KONY 2012, and understanding the impact of natural disasters. The students described getting their news information through Twitter feeds or through iPad apps. The few students who read newspapers said they preferred online formats. The students’ interest and engagement in social justice issues was not anticipated, but it was clearly evident in our conversations, and it was developed in part by the use of communication technologies.

**Scientific content.** This study was not explicitly investigating students’ understanding of scientific content (e.g., there was no final test, consideration of exam marks, test scores, or standardized achievements). However, content was clearly a significant portion of all classroom observations within the scope of activity-based learning. Communication technology was observed to support students’ understanding of scientific content in a variety of ways.

The communication technology allowed the students to ask questions of their teacher and other students. This was a convenient way to clear up misconceptions and uncertainties in a quick and efficient manner. The public nature of these questions (i.e., within the class group) allowed others to learn from the questions and be reassured that other students share similar questions.

The collaboration among students and the establishment of online learning communities on Facebook and Edmodo allowed the students to help one another with questions and resources. These responses improved the level of understanding and engagement of all who participated.

The use of electronic notes facilitated the use of technology-enhanced pedagogy (i.e., as observed at Berryfield High School). This approach allowed for more discussion
of the material and better understanding of the concepts by the students. The organizational features of communication technology were helpful for students to manage, organize, retrieve, and make sense of their learning materials. The digital format removed the barrier of disorganization that can sometimes impede student success.

**Section Summary: Communication technology - Redefining classroom boundaries**

It was observed that communication technology transformed the classroom boundaries. The evidence from the case studies revealed that communication technologies facilitated students’ experiences of scientific literacy in two ways: beyond the traditional classroom boundaries and within the classroom. Communication technology expanded the physical and temporal boundaries of science classrooms. The students could ask questions to their teachers and their peers at any time and from any location. The benefits of communication technology used outside of the classroom were displayed in two ways: some interactions included the teacher, others were for students only. The profiles for these two approaches were quite different. The online group that included the teacher often resembled a virtual classroom or tutorial session. The online group that was for students only was a more private social sphere where school work was the focus through collaboration, questions, and support. The two approaches were very distinct although each had an academic purpose.

Within the classroom, communication technology improved student engagement and effective use of class time. Students and teachers spoke of the benefits of using electronic notes. It provided a medium to deliver material that avoided the routine of transcription. Teachers spoke of the frustration of engaging students who transcribed
notes at different speeds and the students appreciated the accuracy and flexibility of electronic notes. The students could choose to work with the notes in a variety of formats—some chose to write their own summary notes on paper after the class discussion so they could emphasize the most important ideas; other students chose to annotate the PowerPoint slides. The students also described and appreciated the sustainability benefits of paperless electronic notes.

Electronic notes had an additional unexpected benefit: the time in class could be better spent on class discussion, explanation, extensions, and addressing student questions. Pacing was observed to be more consistent; the students’ class time was efficient, on task, and engaging. The electronic notes also appealed to the students’ sense of organization: it was easy to catch up on missed work, it was convenient to access their materials from any computer, and they could organize computer files more easily than pieces of paper.

The communication technology facilitated scientific literacy within and beyond the classroom. It also blurred the boundaries between the two, bringing the classroom material into the conversations and lived experiences of the students while using authentic communication media (i.e., in classroom discussions and online interactions). The students demonstrated greater participation in the face-to-face classroom. This participation was observed at Deepwater Academy and at Berryfield High School (where the teacher commented on the quantity and quality of student participation during our interview).
Etic Findings

Data analysis from the four case studies revealed emergent findings that provided unexpected understandings of these classrooms. The patterns that were not anticipated included the implementation of technology-enhanced pedagogy; resource management and the comparative benefits of resource-rich schools; and the differences in the initiation of innovations (i.e., whether teachers or students initiate new technology integration). The next sections will describe these findings, as evidenced in the data analysis.

Implementation of technology-enhanced pedagogy. The integration of technology innovations in the classroom caused some observable differences from what might be present in more traditional classrooms. The technology included the use of electronic notes, the use of a Learning Management System (LMS), and the online conversation via email, discussion boards or other communication media such as social networking sites. Technology-enhanced pedagogy refers to the authentic use of technology to support learning; it involves changes to traditional classroom routines. In technology-enhanced pedagogy the integration of technologies is a tool to support student learning, it is not an end in itself.

Lankshear and Knobel (2006) use the term Pedagogy 2.0 to refer to the participatory emphasis of internet technologies when it is reflected in classroom activities. Cullen (2011) uses the term open pedagogy to describe a model that integrates Second Life, blogs, and wikis to create an empowered role for student participation. The term flipped classrooms describes the integration of didactic lessons delivered on online video so that the class time can be directed toward higher level thinking activities such as
problem solving or laboratory experiments (Bergmann & Sams, 2012). Rather than choose one of these terms (i.e., open pedagogy, pedagogy 2.0, or flipped classroom), the term technology-enhanced pedagogy can include relevant elements of each. Aspects of flipped classrooms were observed at Berryfield High School where the teacher provided the PowerPoint notes in advance to student to preview prior to class. The integration of these tools into the pedagogy and planning made them authentic and effective. The students commented that they appreciated that the technology accommodated different learning styles; it fostered student interaction (i.e., it allowed them to work collaboratively); it helped them stay organized and access their course material from anywhere and anytime; and it enabled them to be accountable for missed work. The technology was not the focus of the class; rather it was a functional tool to achieve a goal. To attain this synergy of students, science, and software required planning, vision, leadership, and flexibility.

**Electronic Notes.** All of these schools were observed to use electronic notes to some extent. Some teachers used PowerPoint notes exclusively (i.e., Berryfield High School) while other schools used electronic captures of class work them as a tool to support student learning, especially for students who were absent (i.e., City High School). The teachers had very different philosophies about posting their notes online. At Berryfield High School, the notes were almost always posted prior to the class, to allow the students to upload them on the device of their choice and preview them before class. At City High School, the teacher preferred not to post the notes on the website ahead of time. He wanted to encourage his students to be engaged in class. He did not want online notes to be perceived as a replacement for personal teaching and student interaction.
Whether the teacher chose to post the notes in advance or not, it was a very deliberate choice and this decision matched the teaching philosophy and purpose of the teacher.

The other two sites (i.e., Atlantic View Academy and Deepwater Academy) were in between these two extremes. At Atlantic View Academy the PowerPoint slideshows, SmartBoard files, and other resources were posted on the course website, usually after class. The students took class notes in the format of their choice: electronically, a traditional paper format, or a combination.

**Organizational Benefits.** At Deepwater Academy, often the PowerPoint and Flash programs were posted on the class Moodle site ahead of time (often for an entire unit). It was observed that these online resources were supplemented by chalkboard lessons. The students at Deepwater Academy were observed to take notes during these lessons and in the focus group they described their practice of using photo notes as well.

At all four sites, evidence of technology-enhanced approaches to pedagogy were observed. Technology facilitates new ways to access and disseminate information. These teachers were adept using the Learning Management Systems at their disposal to provide access to course materials. The students appreciated the many benefits of receiving notes in an electronic format. These ranged from time management (not spending class time transcribing), to access: (e.g., “from any computer you can go and you can access all you school work” (Ellen, A FG, line 14)); to organizational support: “It’s a lot easier to keep your information intact. I lose all my papers, so it’s nice to just have it all in one spot” (Carla, D FG, line 9). The students for whom English was a second language valued the electronic notes for their accuracy and because it allowed them to focus on participating in class.
Flexibility was a key factor in technology-enhanced pedagogy; communication devices fostered such flexibility. Students and teachers acknowledged that individuals have different personal preferences for note-taking, studying, and organizing their materials. Flexibility allowed each student to accommodate their individual preferences. The teachers and students in these classrooms recognized that the learning preferences of each student need not be the same. Conformity of methods does not produce conformity of achievement.

**Social networking.** At all four sites, the students were making effective use of social networking sites for academic purposes. Using either Facebook or Edmodo, the students at all four sites participated in social networking groups to establish a sense of community in which they enjoyed academic and empathetic support. Sometimes the social networking was used for intense periods of group study before tests and exams. The students were flexible to use different platforms for certain tasks. For example, they would switch from Facebook to Skype if they were working on a study session for math and required video display for equations and formulae that were inconvenient to type in the text-based format of Facebook. Overall, social networking sites provided a forum for students to ask and answer questions, to participate in an authentic, student-generated conversation about their course material that was unencumbered by the classroom limitations of time and space.

**Pedagogy 2.0.** The term Web 2.0 has been used to describe the increasingly participatory nature of internet usage. The internet has evolved beyond being a conduit for the transmission of information, and pedagogy can take inspiration from this too. The abundance of technological opportunities that are available to integrate into classrooms
must be used authentically, to promote student creativity and participation. Including new technology into existing pedagogy may limit the rich learning potential. Pedagogy 2.0 will use Web 2.0 technologies in authentic contexts and it will align with best practices in education (Conole, 2008; Lankshear & Knobel, 2009; Poore, 2013).

**Resource Management.** The data from the four case studies showed notable differences between the schools that required the students to purchase their own laptops and the schools that did not. A spectrum of technology requirements was demonstrated. A range of outcomes and efficiencies was observed at the four sites. These will be described in this section.

**Laptop Schools.** The two private schools had laptop policies, but these guidelines showed sharp contrasts. Atlantic View Academy required students to purchase a laptop and insisted on a single model for all students (Macbook). This meant that students had a common platform, consistent software, and everything in the school was compatible. The other school requiring laptop computers, Deepwater Academy, allowed for flexibility and choice. The technology policy stated that students could purchase one of three different models (Although it was observed that all students had chosen one of two options: either the MacBook or the Lenovo tablet). This allowed for the students to experience the strengths and weaknesses of each system, which were clearly evident. Differences were noted by both the teacher and students that software programs like Excel ran differently on the two platforms. Differences were also noticed in various subjects and situations: students preferred the MacBook’s iMovie program but thought the calculus applications in the Window platform were better.
At Deepwater Academy, where students had a variety of computer options, the students spoke about occasionally planning or managing a project based on what type of computers they had to work with (e.g., video projects worked better with MacBook computers and iMovie software). The teacher was promoting critical thinking activities where the students would think like a scientist; it was clear that these students were also practicing these skills as they selected the optimal equipment and they were frequently thinking like a technologist.

**Non-laptop schools.** The schools that did not required students to purchase a laptop also demonstrated a spectrum of technology options. One school (i.e., City High School) provided a class set of netbooks to ensure that all students were supplied with technology in class equitably. At the same time, the school cell phone policy allowed students to use their own smart phones at the teacher’s discretion. He allowed the students to use their cell phones as long as they could do so without disruption. They often used their own Smartphone technology to access the wiki project in class.

At Berryfield High School, another approach to the non-conforming technology options was observed. This was a technology-rich class, but in a bring-your-own-device (BYOD) environment. Students were observed with a variety of laptops, iPads, or smart phones. Some chose to use paper printouts of the slideshow. Some used their own computers; others accessed the material using school computers during their study period. Students could choose to work with the materials in whatever format matched their resources, learning styles, and preferred study habits.

At Berryfield High School, students could use their own devices. Although this allowed them to coordinate their learning with the technology they were most familiar
with, making it comfortable and authentic, it did lead to some inequity within the classroom. I referred to it as tech-envy. Berryfield students could use whatever device they brought, but they were aware of the differences in technologies and the opportunities each device could offer. “It definitely makes you want to buy the iPad…[I’d see] people doing little jot notes on their iPad and I’d go ‘That’s a great tool. I’d really, really like to use one.’” (Sandy, B FG, line 259).

**Observed usage.** In the laptop schools, the students’ technology was clearly present, as they always carried their laptop with them. However, the use of these computers was intermittent. The students were reassured by the omnipresent technology, because they could begin an assignment at school and continue with it at home or while commuting. In the non-laptop schools, technology seemed to be used more intensely. At City High School, Mr. Saunders stated that the netbooks were shared among the science department. These netbooks were signed out for most periods of the week, putting them in the hands of students for activities that were connected with the curriculum. “They wanted it to be not just a computer lab, …it’s meant to be more curriculum-based connections, like using gizmos, or working on a Moodle, or actually creating something instead of just word-processing” (Saunders, C T1, line 47). When these classes were observed, the students were working on gizmos (online simulations) to reinforce previously learned topics with visual cues and then the students worked in group with the laptops to access their wiki projects. The use of netbooks was maximized during this period due to effective lesson planning and efficient use of student routines to distribute and collect the computers. The website links were all posted on the course webpage to
facilitate student access to the correct sites. Students were clearly familiar with these routines.

**Differences in Initiation of Innovation.** Two of the classrooms (i.e., Berryfield High School and City High School) had communication technology initiatives that were led by the teachers. In the remaining two classes, communication technology initiatives were led by the students. Even when the teacher did not promote such means of interaction, online interactions were occurring. Students were communicating and collaborating through Facebook, Skype, and a variety of technologies. The conversations that began in the classroom continued after classes ended, unfettered by the physical and temporal boundaries of the school building. There were similarities between the two (teacher-led and student-led): both types of innovation had logistical elements, such as asking questions about assignments, and clarification of content.

However, comparing the two types of technology leadership also illustrated the differences between them. Innovations that were led by the teacher were closely connected to the curriculum content. Initiatives that were led by the students, were sometimes more superficial in scope and student-led initiatives tended to be slightly more social in nature. This was not surprising because it was the teacher who often directed the online conversation towards applications and extensions.

Students were concerned about potential distractions on Facebook. Other communication media (i.e., Twitter) was deemed sufficiently distracting that they did not use it for academic purposes at all. On Facebook, students recognized that there was an opportunity to interact with their colleagues, but they had to be diligent to manage their time and technical resources.
Facebook doesn’t really distinguish between what is your school-Facebook-group and what is your other-Facebook-group…You go on and you are automatically absorbed in this social network. It’s hard to separate yourself…You have to be diligent. You have to be able to say “I’m going to log off.” It’s really hard sometimes. (Gillian, A FG, line 341)

When the teachers were present in the online discussion they commented that the conversation stayed appropriate and on task. The online tools (e.g., Edmodo or wiki) allowed them to monitor the postings of their students. “As administrator of the site, I see all conversations and they know this. The maturity level in the class is quite high, so there’s never an issue with appropriateness (and they know that I can see everything.)” (Dalton, B FG, line 114).

One other difference that was observed in the teacher-led and student-led initiatives was the depth of focus. Teacher-led initiatives tended to have closer connections to curriculum and could delve deeper into course-related topics. Sometimes these were guided by the teacher as suggested extensions to class work or a class discussion that was slightly tangential but relevant. Teacher-led initiatives were seen to explicitly include links backs to prior learning.

Student-led initiatives tended to be social and supportive in nature. They appreciated that a student-only environment allowed them to interact in ways that they would not in class. They described the security of asking questions privately and the convenience of asking questions through their technology.
A lot of things I have questions about. And if I wasn’t able to ask my friends, then I just wouldn’t get my answers. Sometimes I just don’t want to ask my teacher because I think it’s a stupid question...so I’d be a lot more comfortable just asking my friends. (Kay, A FG, line 119)

Students also mentioned the quality and quantity of online responses. The shared ideas were relevant and appropriate, often other students had worked through similar confusions. There were usually multiple contributions from classmates and their teacher.

The online interaction also fostered a sense of empathy as students saw the questions and comments from their peers. This would not have been possible in a traditional face-to-face situation where students could individually ask questions of the teacher after school.

It’s almost kind of relieving when you see that your friend doesn’t understand and you think ‘I don’t [understand] either...I’ve been looking for this answer too’...It’s almost comforting that way...you’re on the same page as someone else (Sandy, B FG, line 119).

Communication technology facilitated the implementation of an online learning community. Whether it was initiated by the teacher or the students often determined who was a member of this community. Wenger (1998) defined a community according to three dimensions: a) the participants shared a mutual engagement- they share a common
interest, although not necessarily a equal expertise; b) the participants share in a joint enterprise (i.e., they work together); and c) the participants have a shared repertoire (i.e., organization and delegation of tasks, ideas, and vision for the community) (p. 73).

Technology facilitated the building and bridging of communities. It connected students and gave them a degree of autonomy and responsibility. It allowed them to connect with one another, with their teacher, and with people and resources beyond their classrooms.

The implementation of communication technologies in these four case studies demonstrated the use of communication technologies in authentic contexts. Students used the technology as a tool to achieve a common purpose, rather than as an artificial or contrived assignment. Authentic contexts were facilitated by the use of big ideas and they helped encourage student engagement. Wenger (1998) described the importance of the sense of belonging to a community. Participation in an authentic community context helped students identify their roles as active members of society.

**Summary of Etic Findings**

The cross case analysis of the etic issues focused on the implementation of technology-enhanced pedagogy; resource management; and the differences between teacher-initiated and student-initiated innovation. Once innovation took root in these learning environments, the impact on the students and teachers was evidenced in unexpected ways. These outcomes of the use of communication technology were not planned, but they integrate the strengths of human potential with the technological opportunities.
Cross Case Analysis Summary

The cross case analysis presented in this chapter describes the individual characteristics of these four classrooms. They had unique resources, they were led by teachers with distinctive teaching approaches, and they were made up of students with very different interests, abilities, and technical experiences. The plan for intensity sampling from information–rich sources (as described in chapter three) and site selection that would describe different and distinct types of technology innovation has been achieved.

Despite these differences, the cross case analysis has identified certain similarities. In every site, communication and critical thinking were important to both teachers and students. Collaboration was important, but the two groups of participants (i.e., students and teachers) prioritized collaboration differently: some teachers highlighted formal teamwork projects while students valued informal peer support. This dichotomy suggests that the different perspectives in teaching and learning may be widened when an online format is introduced. The students’ experiences of online interaction in a learning community are vastly different from the teachers’ perspectives. This is partly due to the fact that much of the student interaction takes place without the teacher present or aware of it.

Communication was prevalent and diverse. The data analysis of the four cases with respect to the first research question indicated that the most prevalent component of scientific literacy observed was communication. The analysis of the four cases identified 124 references to communication. This may have been a trait of the participants in these classrooms (i.e., the teachers encouraged discussion and the students were eager to
participate). The three types of communication specified in the subcodes of the analysis were evident at the four sites, but with differing emphases relevant to the teacher’s pedagogy. The prevalence of communication technology also facilitated the interaction beyond the classroom.

Similarities in the references to communication included the students’ proclivity towards online communication. They used communication technology frequently, effectively, and knowledgeably. The students described issues pertaining to technology selection (using the best tool for the task) and technology differentiation (allocating certain technologies for particular tasks – they recognized that some platforms were better suited for entertainment purposes while others were more conducive for academic conferencing).

Other apparent scientific literacy experiences were evident in these cases studies. The data analysis also highlighted that critical thinking was the second most prevalent coded scientific literacy category. This indicated that the students were actively reflecting on meanings and the metacognition of their own learning. The impact of communication technology was apparent, as students described their assessment and selection of various technologies to meet certain needs, and seeking out and sharing online resources to clarify topics of misunderstanding or confusion.

The data analysis showed that the individual teachers had very different approaches towards collaboration. Some teachers encouraged it, believing that student interaction was an important part of their classrooms; other teachers did not prioritize collaboration. This resulted in very different learning experiences within the classroom. However, regardless of the teacher’s emphasis on collaboration within the classroom, all
of the students described experiences of online collaboration outside of their classroom learning.

Communication technology facilitates the opportunity for students to take responsibility for managing some of their own learning. However, to maximize effectiveness, these skills need instruction and modeling. The next chapter will respond to the research questions that prompted this study. It will discuss the implications of these four case studies to consider how this study informs theory, practice, and policy. The Web 2.0 technology (online activities that facilitate participation rather than just the transmission of information) requires a new vision for a corresponding Pedagogy 2.0. Pedagogy 2.0 could facilitate opportunities to use communication technology to enhance the learning opportunities, to promote student engagement, and encourage student interaction with the ideas and with one another. Pedagogy 2.0 describes how the communication technology is actually implemented in student learning; this can facilitate scientific literacy. The following chapter will consider the implications for science education and the potential opportunities for students when various elements of the scientific literacy framework are emphasized.
Chapter 9

Discussion

This chapter will discuss how these case studies inform practice and theory in science education and the implications of these results for technology-facilitated scientific literacy. Scientific literacy is a goal worthy of being in the curriculum but it needs resources for implementation. Each of the case studies informs this investigation, providing insight as to how each one uses communication technology and the scientific literacy opportunities that it facilitates.

In Part 1 of this chapter, I describe the implications for theory and practice in science education. In Part 2, I discuss the issues (both emic and etic) that were identified in chapter eight. In Part 3, I examine the robustness of the Scientific Literacy Framework. It has been the central to this study, and mapping these ideas onto four very different classrooms can illuminate the strengths and weakness of this analytic framework. In Part 4, I discuss the limitations of the study. In Part 5, I acknowledge that education is a dynamic process; I consider future directions for research and conclude this study.

Part 1: Implications for Theory and Practice in Science Education

Data collection and analysis from these four case studies informs theory, policy, and practice in science education. The implications for academia will be discussed first, followed by contributions for educational policy and curriculum development, and finally insights for practicing teachers.
Implications for Academia

Chapter two identified that there is vast literature dealing with the conceptual nature of scientific literacy. However, a significant gap exists in the literature with respect to applying these conceptual ideas in a classroom context in classrooms where communication technology is now so prevalent. The development of the scientific literacy framework is a step toward remedying this gap. It deconstructs the broad field of scientific literacy into a synthesized analytic framework and provides a structure onto which classroom activities can be mapped in order to describe and plan. The scientific literacy framework can serve as a bridge between the islands of theory and practice. For scientific literacy, with real-world applications, the theory needs to connect with authentic experiences. This study also links the objectives of scientific literacy with the tools of communication technologies, a pairing that is lacking in the empirical literature.

Chapter two also identified a dearth in the literature of empirical studies in the field of scientific literacy that recognized or included the importance of the students’ voice. This study has highlighted the students’ perspectives of their experiences. Notably, this study has identified that the teachers’ priorities were not always shared by the students. When the students recognized the potential benefit of an online learning community they established it via social media.

Implications for Policy-Makers

This study has highlighted the issue of an incomplete and ineffective policy in the province of Ontario regarding scientific literacy. It is recommended that those responsible for curriculum development may need to reassess goals, resources, and relevance. The
goal of scientific literacy, although stated in the curriculum, needs to be clarified and specified. The Ontario secondary science curriculum defines scientific literacy as reading and discussing media articles, however, these case studies have shown that it can go beyond that. The case study description from City High School indicated that emphasizing a big idea was beneficial for students. The students could contextualize the material and apply it to their lives. The importance of this teaching strategy needs to be shared with other science teachers.

This study has shown that communication technology can be used to facilitate scientific literacy. Such resources need to be acknowledged and promoted through funding and professional development. As observed at City High School, the resources can be quite modest (a class set of netbooks was shared between two departments). However, City High School also exemplified excellent teacher support: the administration was enthusiastically supportive of the teachers’ initiatives; formal professional development opportunities were encouraged; and teachers from the board met for informal classroom observations and peer-to-peer mentoring to share ideas and strategies. Lindsay (2011) describes a shift in policy paradigm when an Australian school district chose to prioritize science education and scientific literacy. He recognized that scientific literacy could not be implemented with a one-size-fits-all program. “Change in science education towards a scientific literacy approach is not going to be solved by a top-down PD program” (Lindsay, 2011, p. 11). Therefore, the school reforms were locally-developed and teacher-led; the school district provided resources, on-going professional development, and mentoring.
Finally, the Ontario curriculum needs to recognize the importance of subject-specific literacies. Currently, there is an emphasis on the reading and writing of fundamental literacy (as defined by Norris & Phillips, 2003). However, subject-specific literacies provide an application for learning and they may engage students differently based on their interests and aptitudes. Subject-specific literacies should be embraced as a complement to the current emphasis on literacy, not seen as a competitor.

**Implications for Science Teachers**

Practicing science teachers face a daily challenge to facilitate the delivery of curriculum to a diverse student population. Venville, Rennie, & Wallace (2012) describe the four dimensions of curriculum as aims/objectives, content, methods, and assessment. The current Ontario secondary science curriculum documents are explicit in their content, but the objective of scientific literacy is less clear. The opening pages of the curriculum describe the importance of scientific literacy without actually defining what it is or describing how to achieve it. This needs to change. This research has examined what kinds of learning experiences promote scientific literacy and the role of communication technology in these learning experiences. It is intended that this study will clarify the goal of scientific literacy and these case studies will inform teachers of the implementation and impact of science activities in other classrooms.

The scientific literacy framework has been used descriptively to categorize the activities in these case studies. It may be possible that it could be used in the future to inform teachers’ planning and implementation of science curricula. A possible future
study could describe the activities science learning activities in a classroom that is planned in alignment with the scientific literacy framework.

One of the key findings from chapter eight was that communication technology was ubiquitous in the lives of students and it was used both intentionally by some teachers and covertly by some students to facilitate science-related conversations. Recognizing that such interactions do occur, teachers can choose to be proactive by participating in the online learning community, gaining insight into students’ questions and misconceptions, and appreciating the collaborative support and sharing of resources that takes place beyond the classroom walls. Alternatively, if teachers choose to not participate in an online forum with their students they miss rich personalized learning opportunities.

Another key finding that is relevant to teachers was that focusing on solely one aspect of scientific literacy (e.g., communication) tended to achieve that goal, but was less likely to incur the other aspects of scientific literacy. A broad-based approach is more authentic and will appeal to diverse learners as was observed for the teacher and students at City High School case. The wiki project provided the opportunity to experience many elements of the scientific literacy framework in an authentic context.

**Part 2: Discussion of Anticipated and Emergent Issues from the Data Analysis**

The previous chapter highlighted both anticipated (emic) and emergent (etic) issues that were apparent during the data analysis. This section will discuss how these issues inform science education.
Anticipated (Emic) Issues Arising from the Scientific Literacy Framework

The development of the scientific literacy framework allowed the learning activities to be coded, classified and analyzed. This use of this analytic tool on the data from the four case studies revealed some common patterns.

Communication was both explicit and covert. Communication among students will occur. The students who participated in this study were proficient with communication technology. The devices were available to them and the students were adept at selecting the most appropriate technology for a particular task. When a text-based format such as Facebook was not convenient, they chose an image or video format such as Skype. Even when the teacher did not initiate an online classroom forum the students made it happen. Communication technology was utilized for both official online coursework (i.e., organized by the teacher) and for informal learning communities, (i.e., those populated by only students). Communication technology was a convenient, efficient, ubiquitous forum for academic interaction. Where teachers participated in the discussions that occurred in the virtual extension of their classrooms they were aware of their students’ questions, concerns, and level of comprehension. The amount of student interaction in these online discussions indicated interest and engagement.

A communication emphasis may deliver only communication. A strong emphasis on one category, such as communication, can be limiting. At Berryfield High School, the strong emphasis on communication seemed restricted to curricular topics only. The conversation on course-related material was rich and the students and teacher participated in answering questions and sharing resources. However, the topics remained
fixed on the course outline. Whether this structure was intentional or an accidental result of the students staying on task, it resulted in missed opportunities to connect the material to real world issues.

Big ideas connect student learning of science to world issues. At City High School, using a big idea as a foundation for pedagogy provided a structure for the course that facilitated the flexibility to connect to authentic issues and diverse student interests. Connecting to real world issues provided context that emphasized both the global importance and the personal relevance. Scientific concepts were liberated from the pages of the textbook in a personally meaningful way. Technology provided the opportunity for communication and collaboration on a global issue with an international cohort. Mr. Saunders enjoyed the flexibility to customize the course topics based on the interests of the students and current events. The students were clearly engaged in a course that was timely and personally relevant to them.

**Technology can both solve and create problems.** In many ways technology was observed to facilitate interpersonal communication and build learning communities. Technology provided a conduit for the sharing of ideas and resources. However, it was also seen to create obstacles. Students and teachers at Deepwater Academy described the compatibility challenges of a dual platform policy. Students at several schools described the distractions presented by ubiquitous social media. They recognized the need to disconnect themselves from their online networks to focus on assignments; some commented on the excessive duration of time online of some of their peers; and they
described their differentiation of certain technology (e.g., Twitter) for solely entertainment purposes.

**Emergent (Etic) Issues Evident in the Data Analysis**

The emergent (or etic) issues that were described in chapter eight included: 1) the implementation of technology-enhanced pedagogy, 2) effective resource management, and 3) the initiation of technology innovation in the classroom. These will be further addressed in this section.

**1) Implementation of Technology-Enhanced Pedagogy**

The implementation of technology-enhanced pedagogy was clearly evident in these four classrooms, because the teachers and students were enthusiastically using technology in a variety of ways. Examples of this in practice included electronic notes, online discussion fora for students’ questions and answers using either Edmodo or Facebook, and virtual study groups via Skype. The use of such tools was pervasive in these classrooms. The outcome included more efficient use of class time, more engagement and participation by the students in class, and the decentralization of teaching as the students themselves took responsibility for answering their peers’ questions and assisting their peers collaboratively.

Observing these practices in the case studies prompted an exploration of relevant literature for this phenomenon. In addition to using the tools, technology-enhanced pedagogy involved using the network of human resources available and using innovation. The technologies are available to many classrooms, what are key features of
implementing technology-enhanced pedagogy? Reflection on the case studies and exploration of the literature in the field of digital learning identified four factors of technology-enhanced pedagogy: a) using modern technological tools; b) use of human resources; c) use of technological networks; and d) use of innovation.

a) Using modern technological tools. Technological tools facilitated many of the changes that were observed in these classrooms. The technology included communication technologies and the online Web 2.0 tools that encouraged user participation. The tools included the use of electronic notes that allowed the students to be more engaged in learning and discussing the material, rather than merely transcribing it. This resulted in a more efficient use of class time and respected the potential contributions of each student. It was an authentic use of the tools to facilitate learning, rather than using technology as a goal in itself (Poore, 2013).

b) Human resources. The decentralized classrooms where student contributions though discussion were rich with participation, application of ideas, connection to prior learning, and creative elaborations. This reflects the ideas of social literacies presented by Lankshear and Knobel (2006) who describe literacy as a social practice where knowledge is applied in a specific purpose within a given context. Students need to apply their knowledge through discussion, engagement, and action. Student participation was evident in all four case studies.

c) Technological networks. Web 2.0 provides insight into practices of technology-enhanced pedagogy. The internet has evolved from an original web that was a unidirectional commercial platform to a 2.0 version that is participatory and collaborative in nature. “The ethos is to reach out to all of the web for input through limitless
participation, rather than the more traditional belief that expertise is limited and scarce” (Lankshear & Knobel, 2006, p. 13). Many online literacy formats encourage inclusion, collaboration, and participation; this can be emulated and extended in a classroom context as well.

**d) Innovation.** Technology evolves rapidly. New hardware, software, devices, and applications are being developed on an ongoing basis that will be integrated into daily routines and learning activities. The creativity of teachers and students is the only limiting factor in how these new opportunities will be integrated into their classrooms. When teachers choose not to use new technologies, students may incorporate it regardless. Poore (2013) describes the four major social media in educational contexts to be blogs, wikis, social networking, and podcasting (p. 41). Teachers can incorporate these technologies in their classrooms and students can learn new skills or demonstrate prior learning. These social media were not prevalent a decade ago and will be replaced by new innovations in the future.

**2) Effective Resource Management**

The differences in the technology resources from school to school were evident. Some schools required students to purchase laptops, other schools provided class sets of netbooks, and yet other schools had a bring-your-own-device policy. However, the bigger difference was the integration of technology into classroom activities. Availability of rich technology resources did not always correlate to frequency or richness of
implementation. Why not? Exploration of the literature on technology resource usage identified two key themes: access and pedagogy.

There has been much debate about the prevalence of technology in the lives of adolescents (Tapscott, 2009). Several teachers in this study described how they addressed concerns of access and equity. The students in this study had access to technology in various degrees. The term digital native was used by teachers and students in these case studies to describe some students. Some of the critics of Prensky’s (2001) use of this term cited his lack of empirical evidence (Bullen, Morgan, Belfer, & Qayyum, 2009); others criticized the stereotyping of all students under one label (Jones, 2011). Looker and Theissen (2005) examined the Canadian data from three surveys to gain insight into the technological profile of Canadian students. These surveys included the General Social Survey (GSS), the Youth in Transition Survey (YITS), and the Second International Technology in Education Survey (SITES). Their analysis of this data concluded that both males and female students in Canada use computers regularly. Students in rural areas had greater challenges accessing technology that their urban counterparts. This was not an issue in the case studies of this study because they were all urban locations. The students in these case studies who did describe difficulty with dial-up internet connections or other issues with computer access at home had technology resources easily available in their schools and communities (i.e., libraries). Looker and Theissen reported that the respondents indicated that they use computer technology more frequently at home than they do at school. This was an interesting statistic and was consistent with other studies describing trends of student technology usage, specifically that they use technology at home more often than they do at school (Cullen, 2011). Where technology access was a
challenge, teachers were conscientious to promote equity and access (e.g., at City High School and Berryfield High School).

Variations in the pedagogy using technology were clearly observed in the four cases. Some of this variation is explained by Stephenson (2008). He describes four metaphors to describe digital technology and the pedagogy of its implementation. He describes metaphor as a useful way to understand a topic as complex as technology because they “illuminate objects in new ways” (Stephenson, 2008, p. 836). Technology can be viewed as a tool, a tutor, an environment, or a resource. Technology as an environment implies a “new milieu in which a personally constructed niche is adapted to suit an individual’s needs” (Stephenson, 2008, p. 849). The environment metaphor was observed as students used Facebook (e.g., at Atlantic View Academy) to create their own discussion space where they could work collaboratively and provide peer support.

Technology as a tool was observed as teachers promoted the use of computers for data analysis and graphing (e.g., Atlantic View Academy). Technology as a tutor was observed at Deepwater Academy where the Flash animations helped explain concepts and the students described finding YouTube videos to clarify misconceptions.

Stephenson described technology as a resource as adapting digital technology to align with the curriculum. It requires decision by the teacher to make the resource available and it may not always be an authentic use of the technology. Technology as a resource was observed at Berryfield High School: the teacher chose to implement the Edmodo technology as a resource for her students. It clearly aligned with the curriculum and without her decision to include it in her classroom it would not have been used.
3) Initiation of Technology Innovations in the Classroom

Some of the technology initiatives were instigated by the teacher (e.g., at Berryfield High School and City High School) while other projects originated with the students. This was interesting for two reasons. First, the absence of a teacher-initiated communication technology forum did not result in a complete absence of such interaction. If such communication was not directed by the teacher (e.g., at Atlantic View Academy), the students took responsibility to implement it themselves. They recognized the usefulness of an online group for collaboration, for clarification of content, and as a source of community support.

The differences in initiation of technology initiatives illuminate some of the factors involved in the resistance of classroom teachers to embrace technology usage. Groff and Mouze (2008) developed a framework to address challenges to classroom technology use. They identified six categories of challenges to integrating classroom technology: 1) legislative factors, 2) school factors, 3) factors associated with the teacher (whom they termed the Innovator), 4) factors associated with the technology project, 5) factors associated with the students (whom they termed the Operators), and 6) factors or challenges inherent in the technology. This framework fails to even consider that the technology usage might be implemented by someone other than the teacher. However, in two of the four cases, this is exactly what took place.

Part 3: Assessing the Robustness of the Scientific Literacy Framework

It is appropriate at this point to consider the effectiveness of the framework design. How robust was the Scientific Literacy Framework at describing the science
activities of secondary students? Are there changes that should be considered? The Scientific Literacy Framework is an analytic framework; it was used to describe and categorize the activities observed in the four case studies. This revealed some of the strengths and weaknesses of the new framework. These will be discussed in the following subsections.

**Strengths of Scientific Literacy Framework**

The Scientific Literacy Framework was useful in streamlining the descriptors that can be observed during scientific literacy activities. This framework was designed to respond to a need that saw a curricular goal of scientific literacy without a clear path for teachers to help students achieve it. The categories were chosen to be easily matched to the recognizable actions of the students. A strength of this framework that was evident in its implementation was the use of fewer categories (i.e., fewer than the 16 categories of the Canadian Common Framework) made this framework very manageable.

Four of the categories were process-oriented, action-emphasizing approaches to learning science. This promoted the idea of engaging students to participate in activities and be responsible for their own learning. The balance of categories is more weighted toward participatory activities rather than the transmission of content. In this manner, the framework aligns with the ideals of Aikenhead (2006), Hodson (1998), and Roth and Lee (2004).
Weaknesses of Scientific Literacy Framework

Assigning only one category to a particular reference allowed the framework to identify the main intent of each comment. It has already been described how categories were sometimes hidden within the coding. Choosing only one code for each comment did not show the integrated and inter-related nature of the framework elements.

Initially, I attempted to use a checklist to identify elements of the framework during my classroom observations. This proved to be unworkable. The classrooms presented such different experiences that preparing a common checklist ahead of time could not account for all the possibilities. I wanted to record the rich data, descriptions of interactions, conversations, inclusions of technology, and scientific problem solving. The field observations required for a case study were inconsistent with the structure of a checklist.

During the analysis, it was questioned whether the range of categories was sufficient, or if there were data that indicated another category might be useful. The Scientific Literacy Framework was designed to have a workable number of categories: it had been observed that larger frameworks (e.g., Roscoe & Mrazek, 2005) were cumbersome to apply to a classroom context. Two elements that were not included in the Scientific Literacy Framework, but that were considered during analysis were community and creativity.

The sense of community would have overlap with the category of collaboration, but it would extend to a common purpose and a sense of belonging (Wenger, 1998). It was determined that the collaboration effectively described the observable interactions. Many of the other anticipated features of community were internal, emotional, or
reflective elements that corresponded to the category of critical thinking. Therefore, the concept of community was accounted for.

The idea of creativity displays applications of scientific literacy and personal engagement as individuals apply their own interpretation and expression. Creativity was not included in this framework for two reasons. First, it could be difficult to identify. Interpretation of creativity could be subjective and inconsistent. The goal of this framework was to improve such gaps. Second, it could already be included under the category of communication: in the case studies at Berryfield High School and City High School, student creativity was accommodated under the umbrella of communication. (For example, at Berryfield High School, some students presented their dichotomous keys in a book, or in a hyperlinked Powerpoint; at City High School the teacher described students preparing videos, creating websites, or using vokis as narrator avatars).

One of the major challenges of using the Scientific Literacy Framework was the consideration of mainstream science education reform initiatives such as the Nature of Science and Scientific Inquiry. A useful framework would need to either explicitly include these ideas or implicitly co-exist. Ideally, a useful framework would support the implementation of such challenging ideas by making them more transparent and connected to the curriculum. The potential utility of the Scientific Literacy Framework was indicated by how effectively the concepts of the Nature of Science and Scientific Inquiry aligned with the category of Critical Thinking category. Hopefully, when presented in this format, the objectives of Scientific Literacy, the Nature of Science, and Scientific Inquiry can all support one another and the students’ learning in a coherent and integrated approach.
Part 4: Limitations of the Research Design

Any research study is constrained by its design limitations. Recognizing and acknowledging these allows the study to be informative without misleading. At this time, the following limitations are acknowledged.

The data collection involved interviews and focus groups. One potential limitation was the selection of participants. Finding and selecting innovative sites where communication technology is used to facilitate student communication relied on recommendations from those with connections in the schools. The recommendations of teachers with best practices came from a variety of individuals with different interpretations of best practices. A lack of uniform referral criteria allowed this range and resulted in a diverse selection of case studies. A pre-defined criteria (e.g., with technology, the selection could have asked for only teachers using wikis) would have excluded potential sites with rich data. The decision to select a mix of public and private schools was also intentional. This resulted in the selection of diverse sites with differences in administrative policies, resources, and challenges. The deliberate lack of uniformity produced case studies that highlighted different successful approaches to science education.

This study did not involve interviews with every innovative science teacher (locating them would be time consuming and costly and saturation of data would mean that much of the data gathered would be unused). However, with a sample of four good interview subjects, it was expected that different contexts, approaches, and results were be showcased and some common themes were discovered.
The focus groups of students were comprised of volunteers taken from the interviewed teacher’s class. It was anticipated that by recruiting voluntary student participants that those individuals with interesting contributions have taken part and useful data was gathered. Volunteering can skew the results if the quiet, introverted, timid students choose not to take part thereby biasing the data towards extraverted, outgoing, tech-savvy students. This was addressed by including questions about student participation and inclusion during the teacher interview and by considering student responses on the surveys.

The cultural identity of a school is a significant factor in establishing their policies and priorities. Every school community has a unique collective persona, reflective of the current staff, students, administration, and their activities. This study includes both private and public schools, which could have very different cultural identities due to student demographics, student interests, resources, and school initiatives. Large schools and small schools also represent very different contexts. Developing an analysis that both recognizes these characteristics but also looks beyond them, presented challenges to adequately identify and describe qualities which may or may not have been common to my teaching experiences.

The quantity of data gathered may be a limitation. Additional interviews would have supplied more information from the teachers. Follow-up interviews were difficult to schedule around the teachers’ busy schedules (many follow-up questions were answered by email). However, the main interview was comprehensive and tended to saturate the data. Additional classroom observations over an extended period of time would give greater insight into the technological interactions in each classroom. However, these
observations are not meant to be the focus of the data analysis – they are specifically described as anonymous overviews of general interactions within the classroom. These give an overview regarding what the teacher and students are doing (or not doing) with technology, so that the focus group and interview questions can be targeted and relevant. Some non-participating principals expressed concerns regarding the inconvenience and interruptions that classroom research can incur. The time allotted for data collection was planned with an awareness of this potential tension, an intentionality to attempt to be non-intrusive, and a recognition that the priority of both the teacher and students would be on their classroom learning.

The focus groups were unintentionally weighted with more female participants. Some of the schools were all girls’ schools. At the co-ed schools, although a gender balance was included in the invitations, more of the male students were unavailable. Did having more female participants create a bias in the data, and if so, how did it affect the findings?

The challenge exists to interpret the data effectively, recognizing that I do not share a common experience or communication culture with the students in each focus group. However, my teaching experience provides a common background with the interview participants to appreciate the contexts. When the teacher interviews were completed and the tapes were transcribed, these transcripts were member checked with the participants to ensure accuracy and to clarify items where necessary. Additionally, the frequent contact with each site through observation visits or email provided opportunity to clarify questions on an informal basis.
Part 5: Future Research

The posing of research questions, data collection, data analysis, and discussion of findings often uncovers anomalies, reveals unexpected trends, and generates more questions. This study was consistent with such a pattern. Some of the outstanding questions for future research involve the role of using big ideas in science education and the benefits of covert student initiatives (the behind-the-scene activities that may contribute strongly to students’ learning, but that the teacher may be unaware of). How does gender play a role in the use of communication technology for scientific literacy activities, and how does it differ for males and females? Previous work by Kennedy, Wellman, and Klement (2003) indicated that there are empirical gender differences in internet usage. How does their work inform my interests in the use of online technology to support science education, and does it differ for male and female students? Does the culture of the school (or class) impact scientific literacy activities? How does project-based learning, such as a science fair project, contribute to scientific literacy? Do resources or innovation leadership have the greater influence on student learning? How does change knowledge and change management impact the implementation of scientific literacy initiatives and communication technology initiatives (Fullan, 2013; Groff & Mouze, 2008)?

Conclusion

The Scientific Literacy Framework was developed to provide a model to describe, categorize, and understand initiatives that contributed to secondary students’ scientific literacy. The implementation of this model on the data from the four case studies of this
thesis show it to be a useful and manageable framework that can inform theory, practice, and policy in the sometimes vague and murky area of scientific literacy. Following the descriptive application of the framework, it could now be used for planning purposes (i.e., to encourage teachers to include more participatory learning activities in their classes or for tracking or assessment purposes (i.e., to chart which elements of the framework a teacher has used to encourage a balanced, multi-faceted approach).

This study has shown that communication technology is being used to facilitate scientific literacy. Communication technology aligned better with certain aspects of the scientific literacy framework. For example, communication was a clear match for the integration of technology. This study identified two modes of collaboration. Communication technology facilitated each type of collaboration (formal teamwork and informal peer support) in different ways. Critical thinking was evident in these classrooms, but was more difficult to explicitly align with communication technology.

The implementation of communication technology to support student learning was most useful in a non-prescribed format, where the technology is selected to be appropriate to the task. A wide variety of communication technologies were observed (e.g., Edmodo, Facebook, Skype, wiki, text messaging, photo notes, etc.). Students were observed to be very proficient at choosing technology that was convenient, efficient, and task-appropriate.

**Communication Technology is Ubiquitous, but not Uniform**

Communication technology permeated all of these classrooms. However, it was not the same technology and it was not implemented uniformly. Resources vary;
administrative policies vary; and teacher exhibited unique teaching philosophies that reflected their backgrounds, experiences, and interests. All of these teachers displayed some use of communication technology in their classroom environment. The students displayed skill, creativity and willingness to participate and elaborate on classroom concepts in their technological environment. The students established online communities when such networks were considered beneficial to them. One size did not fit all, but none of these classrooms existed in a technological vacuum.

**Authentic Tasks are Important to Nurture Scientific Literacy**

The students observed in this study were involved in activities that were engaging and personally relevant to the students. Authentic issues provided a context for students to explore, converse, and connect with the new ideas. The observations took place during learning activities that emphasized communication technologies; however, the inclusion of scientific content was clear. Reducing the emphasis on scientific content in this framework did not diminish the students’ understanding of scientific content; rather, it encouraged application, extensions, and engagement.

This study showed that one particular category in the scientific literacy framework was not a better support for scientific literacy that the others. For example, is emphasizing communication a better choice than emphasizing critical thinking? No. Teachers’ priorities and teaching philosophies will be the best guide there. However, it was interesting to see the opportunities of using a Big Idea to guide the classroom learning. It aligned effectively with the idea of connections to a scientific issue (although in different language). Exploration of the big idea allowed access for each of the
categories of the Scientific Literacy Framework. This prompted authentic contexts, real-world issues, student-initiated collaboration, and student-driven questions, and interests. In other words, it sowed the seeds of scientific literacy.

Fullan (2013) describes the confluence of technology, pedagogy, and change knowledge as the stratosphere. He advocates that the synergy of these three elements will revolutionize learning. In science classrooms, the scientific literacy framework provides a structure for these three elements to come together. Then secondary science students can truly experience and engage in a stratosphere of higher levels of interest, engagement, and interaction. Lindsay (2011) describes a more contextual approach to scientific literacy. He suggests a more grassroots approach to scientific literacy reform, in which teachers have the time, resources, and support to implement reform and integrate science authentically in all aspects of school life. I suggest a combination of these two perspectives. Science education should be relevant and connected to the issues of interest and importance to students and teachers. Communication technology provides a conduit for their engagement to extend beyond the classroom. Scientific literacy topics should be both grassroots and global in their scope. Student engagement will determine the path.
References


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Appendix 1: Letter of Research Ethics Board Approval

May 16, 2011

Ms. Shireen VanBuskirk
Ph.D. Candidate
Faculty of Education
Duncan McArthur Hall
Queen’s University
511 Union Street
Kingston, ON K7M 5R7

Dear Ms. VanBuskirk:

GREB Ref #: GEDUC-549-11
Title: “Using Communication Technology to Foster Scientific Literacy”

The General Research Ethics Board (GREB), by means of a delegated board review, has cleared your proposal entitled “Using Communication Technology to Foster Scientific Literacy” for ethical compliance with the Tri-Council Guidelines (TCPS) and Queen’s ethics policies. In accordance with the Tri-Council Guidelines (article D.1.6) and Senate Terms of Reference (article G), your project has been cleared for one year. At the end of each year, the GREB will ask if your project has been completed and if not, what changes have occurred or will occur in the next year.

You are reminded of your obligation to advise the GREB, with a copy to your unit REB, if applicable, of any adverse event(s) that occur during this one year period (details available on webpage http://www.queensu.ca/ors/researchethics/Greboweb/forms.html – Adverse Event Report Form). An adverse event includes, but is not limited to, a complaint, a change or unexpected event that alters the level of risk for the researcher or participants or situation that requires a substantial change in approach to a participant(s). You are also advised that all adverse events must be reported to the GREB within 48 hours.

You are also reminded that all changes that might affect human participants must be cleared by the GREB. For example you must report changes in study procedures or implementations of new aspects into the study procedures on the Ethics Change Form that can be found at http://www.queensu.ca/ors/researchethics/Greboweb/forms.html - Research Ethics Change Form. These changes must be sent to the Ethics Coordinator, Gail Irving, at the Office of Research Services or irvingg@queensu.ca prior to implementation. Mrs. Irving will forward your request for protocol changes to the appropriate GREB reviewers and / or the GREB Chair.

On behalf of the General Research Ethics Board, I wish you continued success in your research.

Yours sincerely,

Joan Stevenson, PhD
Professor and Chair
General Research Ethics Board

c.c.: Dr. Peter Chin, Faculty Supervisor
Dr. Lesly Wade-Wousley, Chair, Unit REB
E-REB: c/o Graduate Studies and Bureau of Research, Attn.: Celina Caswell

JS/gi
Appendix 2: Letter of Information for Teachers

“USING COMMUNICATION TECHNOLOGY TO FOSTER SCIENTIFIC LITERACY”

This research is being conducted by Shireen VanBuskirk under the supervision of Dr. Peter Chin, in the Faculty of Education at Queen’s University in Kingston, Ontario. This study was granted clearance by the General Research Ethics Board for compliance with the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans, and Queen’s policies.

What is this study about? The purpose of this research is to explore how communication technology can be used to support student engagement in science education. In particular, it maps student experiences onto a pedagogical framework to explore how innovative communication technology can be used to meet the curricular goal of scientific literacy. The goal of scientific literacy is often described in vague terms; this study explores specific pedagogical initiatives and how they can support student learning in this area. The study will require three individual interviews with you, the classroom teacher; four classroom observation sessions of one period each, to be arranged at a time convenient for you; and a student survey of communication technology uses and interests to be distributed in your class. There will be a focus group discussion for student volunteers. Your interviews will be audio taped and transcribed verbatim. If you wish to review the transcripts of your interviews they will be available to you. The time involvement will be approximately nine hours (the three hour-long interviews, the four classroom observations, fifteen minutes for survey distribution and collection, and 45 minutes of scheduling via email. There are no known physical, psychological, economic, or social risks associated with this study.

Is my participation voluntary? Yes. Although it be would be greatly appreciated if you would answer all material as frankly as possible, you should not feel obliged to answer any material that you find objectionable or that makes you feel uncomfortable. You may also withdraw at any time without consequence and with no impact on your employment. Withdrawal from the study can occur by notifying either the primary researcher, Shireen VanBuskirk at 6bsav@queensu.ca or my supervisor, Dr. Peter Chin, at peter.chin@queensu.ca. If you withdraw from the study, you may request the removal of all or part of your data.

What will happen to my responses? Your responses will be kept confidential. Only researchers will have access to this information. The data may also be published in professional journals or presented at scientific conferences, but any such presentations will be of general findings and will never breach individual confidentiality to the extent possible. Should you be interested, you are entitled to a copy of the findings. All data will be stored in a locked filing cabinet and a secure computer file accessible only to the researchers. According to Queen’s University’s policies, the data will be securely stored for five years and then destroyed.

What if I have concerns? Any questions about study participation may be directed to Shireen VanBuskirk at 6bsav@queensu.ca or project supervisor, Dr. Peter Chin (613-533-6210) peter.chin@queensu.ca. Any ethical concerns about the study may be directed to the Chair of the General Research Ethics Board at chair.GREB@queensu.ca or 613-533-6081.

Sincerely,

Shireen VanBuskirk,
Doctoral student, Queen’s University
Appendix 3: Letter of Information - Student Participants in Classroom Observation

USING COMMUNICATION TECHNOLOGY TO FOSTER SCIENTIFIC LITERACY

This research study is being conducted by Shireen VanBuskirk, a graduate student working with Dr. Peter Chin in the Faculty of Education at Queen’s University in Kingston, Ontario. This study was granted clearance by the General Research Ethics Board for compliance with the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans, and Queen’s policies.

What is this study about? The purpose of this research is to explore how communication technology can be used to support student engagement in science education. This study will examine the use of communication technologies to develop interest, involvement, interaction, and engagement in science education. The study will involve interviews with teachers and groups of students, surveys and anonymous classroom observations. The classroom observation section of this study will involve up to four class periods of observation by the principal investigator, Shireen VanBuskirk, while the class is involved in learning activities that may involve the use of communication technologies. These learning activities are the regular activities that you and your teacher would be involved in regardless of this research. The time involved is approximately five hours, during which you will be participating in your regular classroom activities. The observation data will be anonymous (it will not identify any individuals); rather, it will provide understanding and description of the activities and technologies in your classroom.

There are no known risks associated with your participation in this study. Participation is completely voluntary. You are free to withdraw at any time for whatever reason without consequence; withdrawing will not affect your standing in school.

We will keep all of these observations confidential. Only researchers will have access to this information. The data may also be published in professional journals or presented at academic conferences, but any such presentations will be of general findings and will never breach individual confidentiality to the extent possible. You will not be identified in any way if the results are published. All data will be stored in a locked filing cabinet and a secure computer file accessible only to the researchers. According to Queen’s University’s policies, the data will be securely stored for five years and then destroyed.

Any questions about study participation may be directed to the Shireen VanBuskirk at 6bsav@queensu.ca or my supervisor, Dr. Peter Chin, at (613-533-6210) or peter.chin@queensu.ca. Any ethical concerns about the study may be directed to the Chair of the General Research Ethics Board at chair.GREB@queensu.ca or 613-533-6081.

Sincerely,

Shireen VanBuskirk, Doctoral Student
Peter Chin, Faculty Supervisor
Appendix 4: Letter of Information – Student Survey Participants

USING COMMUNICATION TECHNOLOGY TO FOSTER SCIENTIFIC LITERACY

This research study is being conducted by Shireen VanBuskirk, a graduate student working with Dr. Peter Chin in the Faculty of Education at Queen’s University in Kingston, Ontario. This study was granted clearance by the General Research Ethics Board for compliance with the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans, and Queen’s policies.

What is this study about? The purpose of this research is to explore how communication technology can be used to support student engagement in science education. This study will examine the use of communication technologies to develop interest, involvement, and engagement in science education. You will be asked to complete a survey asking for items such as what types of communication technologies you use and in what contexts you use them. It will take you about 10 minutes to complete.

There are no known risks associated with your participation in this study. Participation is completely voluntary. You are free to withdraw at any time for whatever reason without consequence; withdrawing will not affect your standing in school. Withdrawing can be done by just not completing or submitting the survey. You are not obliged to answer any questions that you find objectionable.

We will keep your responses confidential. Only researchers will have access to this information. To help us ensure confidentiality, please do not put your name on any of the research study survey sheets. The data may also be published in professional journals or presented at scientific conferences, but any such presentations will be of general findings and will never breach individual confidentiality to the extent possible. You will not be identified in any way if the results are published and nothing will connect you to your responses. All data will be stored in a locked filing cabinet and a secure computer file accessible only to the researchers. According to Queen’s University’s policies, the data will be securely stored for five years and then destroyed.

Any questions about study participation may be directed to the Shireen VanBuskirk at 6bsav@queensu.ca or my supervisor, Dr. Peter Chin, at (613-533-6210) or peter.chin@queensu.ca. Any ethical concerns about the study may be directed to the Chair of the General Research Ethics Board at chair.GREB@queensu.ca or 613-533-6081.

Sincerely,

Shireen VanBuskirk, Doctoral Student
Peter Chin, Faculty Supervisor
Appendix 5: Letter of Information – Student Focus Group

“USING COMMUNICATION TECHNOLOGY TO FOSTER SCIENTIFIC LITERACY”

This research is being conducted by Shireen VanBuskirk under the supervision of Dr. Peter Chin, in the Faculty of Education at Queen’s University in Kingston, Ontario. This study was granted clearance by the General Research Ethics Board for compliance with the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans, and Queen’s policies.

What is this study about? The purpose of this research is to explore how communication technology can be used to support student engagement in science education. In particular, it explores how communication technologies have been used in your educational experience to promote interaction, interest, and deeper learning. The participation in the focus group portion of the study will involve an hour-long session in a group of 6-8 students and will take place at the school, after class. The conversation will examine examples of how communication technology has influenced your learning. The focus group session will be audio taped and transcribed. If you wish to review the transcripts of your interviews they will be available to you. If you need alternate arrangements for transportation to your home after the focus group session this will be provided (please indicate this need on your consent form). There are no known physical, psychological, economic, or social risks associated with this study.

Is my participation voluntary? Yes. You should not feel obliged to answer any material that you find objectionable or that makes you feel uncomfortable. You may also withdraw at any time without consequence. Withdrawal from the focus group will not affect your standing in school. Withdrawal from the study can occur by notifying either the primary researcher, Shireen VanBuskirk at 6bsav@queensu.ca or my supervisor, Dr. Peter Chin, at peter.chin@queensu.ca. If you withdraw from the study, you may request the removal of all or part of your data.

What will happen to my responses? Your responses will be kept confidential. Only researchers will have access to this information. The data may also be published in professional journals or presented at scientific conferences, but any such presentations will be of general findings and will never breach individual confidentiality to the extent possible. Should you be interested, you are entitled to a copy of the findings. According to Queen’s University’s policies, the data will be securely stored for five years and then destroyed.

What if I have concerns? Any questions about study participation may be directed to Shireen VanBuskirk at 6bsav@queensu.ca or my supervisor, Dr. Peter Chin, at (613-533-6210) or peter.chin@queensu.ca. Any ethical concerns about the study may be directed to the Chair of the General Research Ethics Board at chair.GREB@queensu.ca or 613-533-6081.

Sincerely,

Shireen VanBuskirk,
Doctoral student, Queen’s University
Appendix 6: Teacher Consent Form

“USING COMMUNICATION TECHNOLOGY TO FOSTER SCIENTIFIC LITERACY”

Please sign one copy of this Consent Form and return to Shireen VanBuskirk in the self-addressed, stamped envelope provided. Retain the second copy for your records.

Name (please print clearly): _______________________________________

1. I have read and retained a copy of the Letter of Information and have had any questions answered to my satisfaction.

2. I understand that I will be participating in the study called “Using Communication Technology to Foster Scientific Literacy”. I understand that this means that I will be asked to participate in three individual interviews of up to one hour each. I will have the opportunity to review the transcripts of these interviews, if I wish. There will be up to four classroom observations in my classroom. I will be asked to distribute a student survey (duration 10 minutes) to my class during class time. The total time involved is approximately nine hours. There will also be surveys and a focus group involving voluntary participants of my students.

3. I understand that my participation in this study is voluntary and I may withdraw at any time without consequence. If I withdraw, I may request the removal of all or part of my data. I understand that every effort will be made to maintain the confidentiality of the data now and in the future. The data may also be published in professional journals or presented at scientific conferences, but any such presentations will be of general findings and will never breach individual confidentiality to the extent possible. Should you be interested, you are entitled to a copy of the findings. In accordance with Queen’s University’s policies, data will be retained for five years, and then destroyed.

4. I am aware that if I have any questions, concerns, or complaints, I may contact Shireen VanBuskirk, 6bsav@queensu.ca; project supervisor, Dr. Peter Chin (613-533-6210); peter.chin@queensu.ca; or the Chair of the General Research Ethics Board (613-533-6081) or chair.GREB@queensu.ca at Queen’s University.

I have read the above statements and freely consent to participate in this research:

Signature: ___________________________ Date: _______________________

I acknowledge and consent to the interview sessions being audio-taped.

(signature) ______________________

If you would like to receive a copy of the study, please provide a postal or email address:

________________________________
________________________________
________________________________
Appendix 7: Student Participants - Classroom Observation Consent Form

“USING COMMUNICATION TECHNOLOGY TO FOSTER SCIENTIFIC LITERACY”

Please sign one copy of this Consent Form and return to Shireen VanBuskirk in the self-addressed, stamped envelope provided. Retain the second copy for your records.

Name (please print clearly): ________________________________

1. I have read and retained a copy of the Letter of Information and have had any questions answered to my satisfaction.

2. I understand that I will be participating in the study called “Using Communication Technology to Foster Scientific Literacy”. I understand that this means that a researcher, Shireen VanBuskirk, will observe typical classroom activities that use communication technologies in an educational context. The time involved will be approximately five hours (four class periods) during which students will be participating in their regularly scheduled classroom activities. Observations will be anonymous and will not identify particular individuals.

3. I understand that my participation in this study is voluntary and I may withdraw at any time without consequence. I understand that every effort will be made to maintain the confidentiality of the data now and in the future. The data may also be published in professional journals or presented at academic conferences, but any such presentations will be of general findings and will never breach individual confidentiality to the extent possible. Should you be interested, you are entitled to a copy of the findings.

In accordance with Queen’s University’s policies, data will be retained for five years, and then destroyed.

4. I am aware that if I have any questions, concerns, or complaints, I may contact Shireen VanBuskirk, 6bsav@queensu.ca; project supervisor, Dr. Peter Chin (613-533-6210); peter.chin@queensu.ca; or the Chair of the General Research Ethics Board (613-533-6081) or chair.GREB@queensu.ca at Queen’s University.

I have read the above statements and freely consent to participate in this research:

Student’s Signature: ________________________________ Date: _________________________
(if 18 years of age)

Parent’s Signature: ________________________________ Date: _________________________
(Required for students under the age of 18)

If you would like to receive a copy of the study, please provide a postal or email address:
________________________
________________________
________________________

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Appendix 8: Student Survey Consent Form

“USING COMMUNICATION TECHNOLOGY TO FOSTER SCIENTIFIC LITERACY”

Please sign one copy of this Consent Form and return to Shireen VanBuskirk in the envelope provided. Retain the second copy for your records.

Name (please print clearly): ________________________________________

1. I have read and retained a copy of the Letter of Information and have had any questions answered to my satisfaction.

2. I understand that I will be participating in the study called Using Communication Technology to Foster Scientific Literacy. I understand that this means that I will be asked to complete a brief survey (approximately 10 minutes) in class.

3. I understand that my participation in this study is voluntary and I may withdraw at any time without consequence. Withdrawing will not affect my standing in school. I understand that every effort will be made to maintain the confidentiality of the data now and in the future. The data may also be published in professional journals or presented at scientific conferences, but any such presentations will be of general findings and will never breach individual confidentiality. Should you be interested, you are entitled to a copy of the findings.

4. I am aware that if I have any questions, concerns, or complaints, I may contact Shireen VanBuskirk, 6bsav@queensu.ca; project supervisor, Dr. Peter Chin (533-6210); peter.chin@queensu.ca; or the Chair of the General Research Ethics Board (533-6081) or chair.GREB@queensu.ca at Queen’s University.

I have read the above statements and freely consent to participate in this research:

Signature: ___________________________ Date: ___________________________

If the student participant is a minor (under the age of 18):

Parent’s Signature_____________________________ Date: ___________________________

If you would like to receive a copy of the study, please provide a postal or email address:

________________________________________________________________________

________________________________________________________________________

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Appendix 9: Student Focus Group Consent Form

“USING COMMUNICATION TECHNOLOGY TO FOSTER SCIENTIFIC LITERACY”
Please sign one copy of this Consent Form and return to Shireen VanBuskirk at the Focus Group session. Retain the second copy for your records.

Student Name (please print clearly): ________________________________________

1. I have read and retained a copy of the Letter of Information and have had any questions answered to my satisfaction.

2. I understand that I will be participating in the study called “Using Communication Technology to Foster Scientific Literacy.” I understand that this means that I will participate in an hour-long focus group discussion session. The focus group will be held at the school, after class, and will involve 6-8 students. The focus group discussion will be audio taped and transcribed. I will have the opportunity to review the transcripts of my portion of these transcripts, if I wish.

3. I agree not to discuss the details of the focus group discussion, in order to maintain the confidentiality of other participants.

4. I understand that my participation in this study is voluntary and I may withdraw at any time without consequence. If I withdraw, I may request the removal of all or part of my data. Withdrawal will not affect my standing in school.

5. I understand that every effort will be made to maintain the confidentiality of the data now and in the future. The data may also be published in professional journals or presented at scientific conferences, but any such presentations will be of general findings and will never breach individual confidentiality. Should you be interested, you are entitled to a copy of the findings. In accordance with Queen’s University’s policies, data will be retained for five years, and then destroyed.

6. I am aware that if I have any questions, concerns, or complaints, I may contact Shireen VanBuskirk, 6bsav@queensu.ca; project supervisor, Dr. Peter Chin (613-533-6210) or peter.chin@queensu.ca; or the Chair of the General Research Ethics Board (613-533-6081) or chair.GREB@queensu.ca at Queen’s University.

I have read the above statements and freely consent to participate in this research:

Student Signature: _____________________________________ Date: _____________________

I acknowledge and consent to the interview sessions being audio-taped.
(signature)__________________________________________

If the student participant is a minor,
Parent’s Signature________________________________  Date: ______________________

I will need alternate arrangements for transportation home after the focus group session, going to:

__________________________

If you would like to receive a copy of the study, please provide a postal or email address:

__________________________

__________________________
Appendix 10: Teacher Interview Questions

Sample Questions

Describe your teaching experience (current & past courses, areas of expertise).
What kinds of communication technology do you include in your science teaching?
   Is this routinely included, or is it a new innovation/exploration in your pedagogy?

Why do you integrate communication technology into your teaching repertoire (what are your objectives)?

How often do you integrate communication technology in your teaching?

Is there a particular unit or project in your science curriculum that emphasizes or incorporates communication technology? Please describe it.

What kind of response do you observe from your students when you include facets of communication technology in their coursework?

Are there specific challenges to incorporating communication technology in your classes (e.g., technology/resource availability in the school, time to incorporate new projects in the curriculum, technical support, student participation, or student technical knowledge)?

What benefits do you observe when students engage with the science content material by using communication technology?
Appendix 11: Student Survey Questionnaire
“USING COMMUNICATION TECHNOLOGY TO FOSTER SCIENTIFIC LITERACY”

1. Which of the following communication technology options do you use for *school work*:

<table>
<thead>
<tr>
<th>Technology</th>
<th>Frequently</th>
<th>Occasionally</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>Email</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Facebook</td>
<td>0</td>
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<td>0</td>
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<tr>
<td>Twitter</td>
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</tr>
<tr>
<td>YouTube</td>
<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>Text messaging</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Wiki</td>
<td>0</td>
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</tr>
<tr>
<td>Discussion Board</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>RSS feed</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Course website</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Podcast</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

2. How frequently do you use communication technologies for your *school work*?
   - Never
   - Several times per month
   - Several times per week
   - About once a day
   - Several (2-4) times per day
   - Many (5 or more) times per day

3. Which of the following communication technologies do you use for *personal reasons* (other than school work):

<table>
<thead>
<tr>
<th>Technology</th>
<th>Frequently</th>
<th>Occasionally</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>Email</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>Facebook</td>
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<td>YouTube</td>
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</tr>
<tr>
<td>Text messaging</td>
<td>0</td>
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<tr>
<td>Wiki</td>
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<tr>
<td>Discussion Board</td>
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<tr>
<td>RSS feed</td>
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<tr>
<td>Course website</td>
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<tr>
<td>Podcast</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

4. How frequently do you use communication technologies for *personal reasons*?
   - Never
   - Several times per month
   - Several times per week
   - About once a day
   - Several (2-4) times per day
   - Many (5 or more) times per day
5. For what reasons do you use communication technology for your *school work*?

________________________________________________________________________

6. How do communication technologies improve your *school work*?

________________________________________________________________________

7. For what reasons do you use communication technology for *personal communications*?

________________________________________________________________________

8. Do you prefer to create work or receive information using communication technology?

   o Create
   o Receive
   o Both

9. How do you rank your own *technical ability*?

   ______________________________________________________
   Low          medium          high          expert

   Why? ____________________________________________________________

10. How do you rank your own interest in *science*?

    ______________________________________________________
    Low          medium          high

11. How do you rank your own interest in *communication technology*?

    ______________________________________________________
    Low          medium          high
Appendix 12: Student Focus Group Questions

The following is the potential focus group questions. The exact questions would reflect the context as described by the teacher in the initial interview.

1. Think back. **Consider some experiences you have had that integrated communication technology into your school coursework. What were the benefits of using communication technology in your schoolwork?**
   Thinking of an experience in which you have used communication technology in a specific science project/assignment.

2. **How did communication technology help you communicate with your peers on a group project?**
   (Prompts – what software was used? Was communication using communication technology a project requirement? How frequently? What depth/purpose? What was the student perception of benefit?)

3. **How did communication technology help create a supportive student community where you (students) could work as a team, either officially or unofficially?**
   (Prompts – e.g., for editing drafts, checking facts/data? what software? Was CT communication a project requirement? How frequently? What depth/purpose? What was the student perception of the benefits?)

4. **How did communication technology support a connection to issues in your local community (city/province/country)?**
   (Prompts- What were the topic/contacts/information available/authenticity of issue/importance/interest/choice)

5. **How did communication technology encourage critical thinking/ deep questioning about a scientific issue?**
   (Prompts – how does this differ from traditional approaches such as textbooks? How did communication technology affect the choice/range/timeliness of topics?)

6. **How could communication technology be used to better support communication and collaboration for students at your school. What would you suggest?**
   (Prompts – what software / hardware / methods to integrate in courses / tech support / tech options?)

7. Our purpose today was to explore how communication technology can be used to encourage scientific literacy for students. Is there anything that we have missed? **Is there anything else that would be helpful, from either your school**
experience (science or otherwise) or out-of-school experience that you want to add?