Fostering Effective Written and Oral Communication in the Sciences:
Perspectives and Practices of Secondary School Teachers

By

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Abstract

Traditionally, the subject of science is not often associated with the liberal arts, and is in fact often held in juxtaposition with language-based and writing-based subjects. This binary of science versus the liberal arts is problematic for scientists since this can lead them to not see themselves as writers or communicators. However, communication skills are of great importance to science research. Effective communication in science is an asset, but science writing is often inaccessible – to both scientists and non-scientists – due to unclear writing. A method to help deconstruct the divide between science and liberal arts, as well as to begin fostering effective communication in science, is to integrate literacy strategies into the high school science classroom. This qualitative research project examines how three secondary school science teachers from the Greater Toronto Area foster effective written and oral communication in the sciences. These teachers’ instructional strategies, assessment practices, and challenges are examined. Data was collected via a semi-structured interview protocol. Audio recordings of these interviews were transcribed, coded, and analysed. Results of this study suggest that effective communication in science courses may contribute to success in science. Communication serves as a critical component of collaboration as well as assisting in better understanding science material. The participants also shared that fostering good communication skills in the science classroom has broader implications for students to become critical thinkers and engaged citizens in society. This research project aims to show the reciprocal benefits of bringing literacy into science, where not only do students have the opportunity to develop their communication skills, but literacy strategies can also help reinforce science concepts.

Key words: science communication, science writing, literacy, written communication, oral communication
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Chapter 1: INTRODUCTION

1.0 Introduction to the Research Study

Traditionally, assessment and evaluation in math and science education prioritize correct answers over and above the quality of students’ demonstration of written communication. This may not seem to be an important issue – after all, if the student provides the correct answer, what does it matter that he/she struggles with grammar? The problem becomes that students learn that grammar and spelling will not be taught in science class (McGlynn, 2013), and so it is deemed unimportant in that context. Communicating clearly is seemingly straightforward in science and math when all you have to do is provide an answer at the bottom of all your work. However, effective communication is critical in the maths and sciences. When students move on to undergraduate and graduate work, a requirement of lab reports is that they are clear enough that another person may reproduce your lab procedures with no difficulties. If students decide to move on to careers in research, they will be expected to publish research papers. Often, these papers will not only be relevant to the scientific community; the information may also be significant for the average layperson, and it is important that they too be able to access and understand this information.

Thus, being able to communicate scientific ideas effectively is an important, crucial skill. And yet, students graduating from the sciences are seemingly unprepared to communicate effectively; one study revealed that employers in botany research said that one of the skills most lacking in their new employees was written communication skills (Weiss, 2011). This lack of preparation can be traced back to the fact that most of the science writing available to students is unclear; one article explains that students are reading scientific journal articles that usually exhibit poor grammar and unnecessarily sophisticated words (Bredan, 2013).
within the scientific community where there is a strong belief that good science is suggested by complex prose (Bredan, 2013); students are immersed in this environment and so do not learn how to communicate effectively. To help combat this problem, secondary school science teachers can teach students effective written communication skills so they may be better prepared when they move on to higher science education.

While it would be beneficial for more time to be spent on effective communication in the science classroom, many secondary school teachers adhere to the belief that it is the duty of literacy teachers to teach literacy and science teachers to teach science (Thier & Daviss, 2002; McCoss-Yergian & Krepps, 2000). Thus, many science teachers believe students are entering the science classroom already equipped with the necessary literacy skills, so it is unsurprising that time is not being allocated for enhancing written communication skills1 (McCoss-Yergian & Krepps, 2000; Park & Osborne, 2006).

Even though many science teachers are hesitant to dedicate class time to literacy skills, it would be beneficial in the long run for students who decide to pursue the sciences. There is a huge amount of scientific literature available; however most of it is inaccessible to readers outside of the field, and this includes scientists from other disciplines (Bredan, 2013). This inaccessibility is not due solely to the fact that the content is highly specialized, but also because scientific writing is overly complicated and unclear (Bredan, 2013). This is problematic because science rarely exists in a vacuum; politicians, for example, would do well to be informed on the scientific factors of climate change when proposing legislation on environmental-related laws. Ensuring scientific writing is more accessible, has the potential to help promote scientific

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1 It is also important to note that within secondary schools there is heavy emphasis on learning content, and so teachers often feel that taking the time to teach literacy strategies takes away valuable time from learning subject-specific concepts (McCoss-Yergian & Krepps, 2000; Park & Osborne, 2006).
literacy\textsuperscript{2} in the greater populace. Not only would greater accessibility help layperson readers, but it could also help science students who move onto careers that involve direct communication with individuals or groups outside of science (e.g. hospital nurses communicate with laypersons on a daily basis). As one study reporting on botanists notes, post-secondary science students are taught to write research papers and dissertations, but government employers of botanists commonly also want their workers to be able to collaborate with non-biologists in business and the general public (Weiss, 2011). It is thus important that science students learn to communicate effectively following the conventions of different disciplines and for different audiences.

**1.1 Purpose of the Study**

The purpose of my proposed research is to learn how a sample of secondary school science educators are promoting effective written and oral communication skills in their classrooms. Since I hope to be a secondary science teacher in the future, I hope to find strategies that will help me in teaching my future students how to be strong science communicators. The hope is that this study will also benefit those teachers interested in improving their students’ communication in the sciences.

**1.2 Research Questions**

The primary research question guiding this study is: How is a sample of secondary school science teachers fostering effective written and oral communication in the sciences?

- What are these teachers’ perspectives on the role of written and oral communication in science education?
- What are their learning goals when fostering effective written and oral communication?

\textsuperscript{2} Scientific literacy: the possession of skills that bring together science concepts, facts, and processes with the capability to use language to clearly communicate ideas (Thier & Daviss, 2002).
- What instructional strategies, approaches, and learning resources do these teachers use to foster effective written and oral communication in the science classroom?
- What do these teachers observe as indicators of learning from their students?
- How do these teachers assess and evaluate students’ demonstration of effective written and oral communication in the science classroom?
- What, if any, challenges do these teachers experience when trying to foster effective written and oral communication in the science classroom?

1.3 Background of the Researcher

In my undergraduate education I was exposed to both the major sides of higher education: the sciences and liberal arts. I always found it difficult to choose a favourite subject since I did not prefer liberal arts over sciences and vice versa. I enjoyed both studies equally and could not see myself focusing on only one. Thus, in my undergraduate career I decided to pursue a major in Chemistry and minor in English. When others asked what I studied, I was always greeted with surprise that my two areas of study were so different. I began to notice that my peers in my chemistry classes would shy away from liberal arts courses because they would have to write essays. Conversely, in my English classes, my peers practically had a fear of taking any science-based courses. I became aware of a culture where science is often perceived to be a challenging and difficult to understand subject, meant only for the smartest of people. I came to see that the liberal arts and sciences were seen as completely different worlds, and rarely was a person a part of both.

Something that really concerned me was when I was speaking to a teaching assistant in a chemistry lab course. The TA mentioned that several of the students’ lab reports that he had marked were lacking basic writing skills. One student had included a page-long introduction that
was devoid of all punctuation. I began to realise that many science students were lacking good writing skills. This was a major issue since scientists are expected to communicate their work to others. The concern was not only one-sided: liberal arts students fearing the sciences was another issue. A lack of scientific literacy in a large portion of society can cause major problems. Journalists who do not understand what they are reporting when it comes to science can present misleading information. Politicians and members of government that do not understand science may pass legislation that is detrimental to the environment or the public’s health.

I came to realise that it is disadvantageous to compartmentalize educational subjects. We must work towards providing education that is more inter-disciplinary. Students grow to fear or disregard the subjects they do not pursue and it results in individuals lacking certain skills. While both writing skills in the sciences and a lack of scientific literacy in the liberal arts are both an important issue, I have decided to focus on trying to improve writing skills in the sciences. I believe that if we can show students how to better communicate their ideas, this makes the information more accessible to more people. This is a crucial step in inviting more people into the dialogue surrounding scientific issues. By making science more accessible, we can have a better informed public that can make better decisions when it comes to protecting our environment, or improving healthcare. Blurring the lines between different subject areas leads to more well-rounded students and allows students to see an issue or concept from many different perspectives. This, I believe, will lead to a society where citizens see an issue from multiple perspectives and come up with better solutions for a variety of areas relevant to today’s society.

1.4 Overview

To answer the research questions, I will be conducting qualitative research by interviewing three high school science teachers about how they foster effective communication
skills in their students. In chapter two I review the literature pertaining to integrating effective communication skills in science classrooms, where I explore the issues of communication in science, and bringing literacy into the science classroom. In chapter three I discuss the research design. In chapter four I present my research findings and in chapter five I discuss these findings and their significance in relation to the literature and the implications for my own practice as a beginning teacher.
Chapter 2: LITERATURE REVIEW

2.0 Introduction

In this chapter I will review the literature regarding the problems found in a large amount
of scientific writing. I will examine the issues that make scientific writing inaccessible for a
broader audience and what efforts are being made to make science more comprehensible for a
public audience. I will then look into the ways literacy can be incorporated into the high school
science classroom to both aid students in understanding difficult concepts as well as improving
their communication in the sciences. Finally, I will examine why it is important for students to
learn literacy skills in the context of the science classroom, based on theoretically positive
outcomes for the scientific community and the general population.

2.1 The Issue of Communication in Science

2.1.1 Traditional Conventions

Communication in science is usually thought of as conveying both authority and
objectivity (Martin, 2012). Authority, in order to show the experimentation that was undergone
was worthwhile, and objectivity to ensure bias was avoided in the reporting of results (Martin,
2012). Conventions that demonstrate authority include a standardized article organization
consisting of headings like introduction, methods, results, conclusion; the use of many filler
words that emphasize another word (e.g. clearly evident, very high); and relatively dramatic
statements to justify the conducted experiment (Martin, 2012) (e.g. academic achievement in this
country is at an all-time low, spelling disaster for the nation’s success). Conventions that
illustrate objectivity include using the passive voice, as opposed to the active voice to remove the
scientist from the experiment (Martin, 2012) (e.g. the solution was heated vs. I heated the
solution). These conventions are used by scientists to distance themselves from the experiment
and subject, creating the impression that the scientist is unbiased since it seems the experiment has occurred almost without human interference; logically, and sequentially (Martin, 2012). The problem becomes that these conventions often create a report that is uninteresting to read as well as impenetrable. Bredan (2013) mentions that while there is a huge volume of scientific literature available, it is not only inaccessible to individuals outside of science, but also inaccessible to scientists from other fields due to the lack of clarity. As early as 1884 there have been articles feeling the need to remind science writers that they should be avoiding abstract and overly complex diction, and to cater their writing to a broad audience (Bredan, 2013). This suggests that despite the emphasis on clarity in scientific language, this argument for greater accessibility is not new.

The writing conventions mentioned above emerged during the Enlightenment in the seventeenth century in an effort to make scientific writing more clear (Martin, 2012). This was in response to ornate and elaborate language that was commonly found in prose and poetry (Martin 2012). The scientific community felt flowery language and the use of metaphors hid truth and clear reasoning (Martin, 2012). The mentality being that science should not need to be interpreted; its meaning should be direct and clear. And yet, there are journal editorials urging scientists to write their research clearly, with the senior editor of Nature tellingly stating “most papers are written badly” (Bredan, 2013).

2.1.2 Poor Writing Skills

There is an impression that if science writing is understandable, it must not be professional enough. Science writing is often riddled with excessive passive voice, verbosity, overly long sentences, grammatical and syntax errors, and needless repetition (Bredan, 2013). Additionally, unnecessary jargon is used to make the work sound more complex and to be seen
as so-called “real science” (Boon, 2013). Bredan (2013) notes that he has never come across any kind of commentary Praising the quality of science writing. He also points out (2013) that the criticism of science writing has been happening for some time and is ongoing. This is not to say all scientific reporting is poorly written; however, it would be safe to say that most scientists do not identify themselves as writers (Martin, 2012). It is odd to think many scientists would not consider themselves writers considering that scientists are expected to report and communicate their experimental findings. It is also important to note that the purpose “of writing is to communicate the thoughts and ideas of the author to the reader clearly and concisely” (Bredan, 2013). Obviously, clear communication is a skill that should be expected of scientists.

The issue of many scientists not seeing themselves as writers can be traced back to the divide that occurs in education. In academia, there is an emphasis on specialization and separation; disciplines and departments are divided, preventing collaboration and encouraging insularity (Taylor, 2009; Roth, 2009). Education becomes compartmentalized as a student progresses through schooling: a person is either good at math, or a good writer; he/she is good at science or is artistic. The sciences and maths are commonly contrasted with liberal arts, where the former are perceived as objective and the latter often perceived as subjective (Martin, 2012). The divide is further perpetuated with the idea that the human brain is divided into two main hemispheres (the right side being the creative, intuitive, and arts-inclined side, while the left is responsible for logical problem-solving and reasoning) (Martin, 2012). The myth claims a person tends to use either the right or left side more, leading to that person being more skillful in either arts-related subjects or STEM-related subjects (Wanjek, 2013). This school of thought has been debunked by research (Nielsen, Zielinski, Ferguson, Lainhart, & Anderson, 2013), and yet the idea still pervades popular thought (Wanjek, 2013). Brock University, of Ontario, Canada, has
even created an entire advertising campaign suggesting that an education at Brock University nurtures “Both Sides of the Brain” (Brock University, 2010). In 2011, car company Mercedes Benz created a series of eye-catching print ads spelling out that the left brain is the scientist and mathematician, while the right brain is creativity and passion, amongst other left brain–right brain stereotypes (Ads of the World, 2011). However, the brain is not divided in an academic vs. creative way. Whether a person is thinking logically or creatively, connections are made throughout the brain (Wanjek, 2013). This divide becomes problematic when scientists adopt the fixed mindset that they should not care about their writing, since they are not inclined to be good writers anyway (Martin, 2012). The divide in disciplines is problematic in a broader sense as well. In the real world, problems are not segregated like they are in the classroom (Warner, 2010). Rarely do humans encounter an only-math problem, or only-science problem. However, in school (especially in high schools wherein students have more of a variety of subject specialist teachers), each discipline is taught separately and leads students to believe they must think a particular way in science class vs. English class. Curriculum is organized in a fragmented way so that subject areas become isolated and knowledge is not connected to its real-world context (Britzman, 1986). This de-contextualization of knowledge and skills is concerning since knowledge becomes a list of facts that the student sees as something to memorize as opposed to a tool to understand and navigate the world (Britzman, 1986). In the real world, a bell does not ring to signal that it is time to stop learning how to write because it is time to learn about atoms – so why should schools create this environment? It causes students to believe the skills learned in one subject are not connected to others (Britzman, 1986), which can be problematic when our

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3 The campaign advertises that Brock University is a place for well-rounded individuals to learn both inside and outside the classroom (i.e. fostering the side of the brain in charge of academic pursuits, as well as the creative side of the brain in charge of other activities and hobbies) (Brock University, 2010).
changing world needs well-rounded individuals to respond to ever-evolving challenges (Ontario Ministry of Education, 2002).

Since our evolving society needs more well-rounded individuals, encouraging writing and literacy within science is a good way to start bridging the gap between the different subjects in school. However, the idea that scientists should not attempt to over-complicate their work should not be confused with the notion that the experimental findings should be “dumbed down;” rather, that the author of a scientific work should make sure the reporting is clear and concise (Boon, 2013). It should not be interpreted that the use of jargon should be avoided (since, in many cases this is not possible); merely that if another, less particular term can still be used to effectively communicate the author’s meaning, then that more common word should be used instead (Plotnick, 2014). Since scientific writing is inevitably dealing with complex topics, there is an even greater need for clarity so that the text is as understandable as possible (Bredan, 2013).

Along with the overuse of jargon, scientific writing can become bogged down with overly verbose sentences. This verbosity is done, again, in an effort to make the scientific work sound more complex (Gopen & Swan, 1990). A clear example of this overuse of words can be seen in large subject-verb gaps (Gopen & Swan, 1990). Readers expect a verb to soon follow a subject, but many times in poor scientific writing there will be a huge subject-verb gap (Gopen & Swan, 1990), e.g.:

In this experiment, [Co(NH$_3$)$_5$Cl]Cl$_2$, a coordination complex with a central atom that has coordinate bond(s) to one or more ligands, was synthesized from [Co(NH$_3$)$_4$CO$_3$]NO$_3$ and their electrical conductances and infrared spectra were measured.
The subject, \([\text{Co(NH}_3]_5\text{Cl}]\text{Cl}_2\), and the verb, (has), are separated by eight words. The sentence would be much more clear if the subject-verb gap were not so large and obstructed by information that does not need to be in that gap. E.g.:

In this experiment, \([\text{Co(NH}_3]_5\text{Cl}]\text{Cl}_2\) was synthesized from \([\text{Co(NH}_3]_4\text{CO}_3]\text{NO}_3\) and their electrical conductances and infrared spectra were measured. These cobalt cations are known as coordination complexes, which is when a central atom or ion has coordinate bonds to one or more ligands.

By moving the extra information to the next sentence, the reader does not lose track of what was the main purpose of the experiment. The purpose of the sentence becomes lost when the sentence is elongated so ineffectively.

Writers will use elaborate phrases, unnecessary words, and complex grammatical constructions which disrupts reading comprehension in an effort to make the science sound more complex (Bredan, 2013). This seems ironic considering science writing was originally meant to avoid ornamental and unnecessary language (Martin, 2012).

2.1.3 Scientific Writing for a Broader Audience

The scientific community is starting to recognize that science should be made more accessible to the public since the number of global issues involving science and technology is growing at a rapid pace (Leshner, 2003). Osterrieder (2012) also notes that there is a growing public interest in science, and public engagement should be a focus for scientists. Professional scientific communicators exist as a sort of middle-man between scientists and non-scientists, explaining complicated concepts in a clear way, while still remaining faithful to the evidence (Boon, 2014; Grossman, 2014). Journalists are a popular example of science communicators; however sometimes the journalists reporting do not always have the sufficient knowledge to present the material authentically to the public (Boon, 2014; Hodge, 2011b). Oftentimes,
scientific explanations or conclusions are so obscure that reporters must try and interpret them, or turn to science contacts for help (Hodge, 2011b). This is problematic because it takes away the power from the scientist to deliver his or her message, and the original intentions from the article or report can be lost (Hodge, 2011b). There also exist professionals who are hired by scientific groups specifically for the purpose of translating that science into language accessible by the public (Garnes, 2014).

The question should be asked – why should the scientific community care if a broader audience can or cannot understand the published scientific reports? It could be argued that it should not be a scientist’s job to engage a reader like a murder mystery novel. This is a fair argument; however it is important to consider that scientific research does not occur in a vacuum. Research will rarely become funded if the research that is being conducted is not relevant to the interests of society (Boon, 2014). Funding is not the only issue; it is becoming increasingly apparent that many people are not engaging with scientific reports. Health officials, for example, are monitoring the increasing rate of parents in the U. S. choosing not to vaccinate their children, and this has been linked to the recent measles outbreak in Disneyland in California (The Associated Press, 2015). It is critical for citizens to engage with science, or develop a kind of science citizenship, since “a range of major policy decisions revolve around scientific topics, and…a healthy democracy relies on an informed electorate” (Boon, 2014, para. 3). The more scientists are able to share research in an accessible way, then the better position the public will be in to make informed decisions on important science legislation, such as vaccinations or climate change. From this perspective, it could be argued that the scientific community has a responsibility to make its writing more accessible to aid in a more scientifically literate citizenry.

Keeping this need for accessibility in mind, science teachers should consider the
importance of why their students need competent literacy skills within a science context. Students can also be told that learning literacy skills in science class is an important skill because scientific findings often have an audience outside of the scientific community.

It is also important to note that it is not always useful to present the scientist and non-scientist binary when it comes to communication (Garnes, 2014). If a physicist is asked a question about biology, that physicist is in the same position as a non-scientist (Garnes, 2014). At the Leibniz Institute for Molecular Pharmacology (FMP), research is conducted by biologists, chemists, physicists, and pharmacologists (Hodge, 2011a). At this organization, scientists of different backgrounds are working together and are using different scientific processes and language, and as a result, “students and lecturers often have difficulties understanding each other very well” (Hodge, 2011a, para. 2). Thus, more effective communication would not simply be a benefit for those outside the scientific community; those inside the community would also be assisted.

2.1.4 A Shift in Scientific Communication

There is a realisation that having the original scientist discuss his or her scientific findings with the public is a good idea. As was mentioned previously, when journalists try to interpret a scientific work, things can get lost in translation (Hodge, 2011b). When the translation comes from the scientist, there is less of a chance of misinterpretation. Social media has provided more avenues for scientists to inform the public on their work; informal communications such as Twitter and blogs have been embraced as a means of giving their research a larger audience (Boon, 2013). These more informal methods of information dissemination provide scientists with the chance to practise their writing skills. Less formal communication platforms also have fewer
barriers to publication, making it easier for the information to reach the public\(^4\). Post-secondary institutions are also realising the importance of having their science students be able to translate complex science into comprehensible information. An initiative called “Mind the Science Gap” was started at the University of Michigan where Masters of Public Health students were required to post weekly articles where the students translated scientific publications or recent areas of scientific interest into blog posts for a broader audience (Maynard, 2013). The project was started in an effort to teach public health students “how to convey complex information effectively to a non-expert audience” (Maynard, 2013, para. 5). In the area of public health this is extremely important since these students will go on to work in healthcare and need to communicate with non-experts on a daily basis whether it be patients in hospitals, or the media.

2.2 Bringing Literacy into the Science Classroom

2.2.1 Incorporating Literacy into Science Aids in Student Comprehension

Incorporating literacy into science is not just important in the sense of communicating science; it can also be beneficial in terms of effective teaching. As children in their early years learn language, they learn it through experience (Thier & Daviss, 2002). Their understanding of the world becomes solidified as their linguistic capabilities grow; they make sense of the world through language (Thier & Daviss, 2002; Grant & Fisher, 2010). Since understanding of the world occurs through language, it is important that teachers also create space for students to develop effective written communication in the science classroom. While learning about science, students can use language to structure their understandings of the science content (Thier & Daviss, 2002; Grant & Fisher, 2010).

\(^4\) It should be noted that with fewer barriers to publication, also comes the issue of a lack of reliability in published information due to there being no obligatory peer-review process.
Since many science concepts are abstract, students can have difficulty in comprehension. Students often understand the words used, but may not fully comprehend the whole idea being expressed (Thier & Daviss, 2002). When an activity like writing is encouraged in the science classroom, it can enable students to better express their understanding of scientific ideas in a medium that they can see and contemplate; language acts as a scaffold where language is used to organise, then internalise new concepts (Thier & Daviss, 2002). The way science is communicated can sometimes be unfamiliar to students. By having students write about the concepts they are learning in their own style of writing, it can make the new information more familiar and easier to understand. Writing, listening, and speaking also allow students to reflect on their own understandings (Thier & Daviss, 2002). When students listen to others’ interpretations of a concept, they are forced to reflect on their previous understandings and evaluate what makes the most sense (Thier & Daviss). Allowing students to explain themselves through writing and speech provides them the opportunity to construct new conceptions of information and then explore those conceptions (Thier & Daviss, 2002). The idea that providing explanations aids in learning was studied by Chi, Leeuw, Chiu, & LaVancher (1994), and Chi, Bassok, Lewis, Reimann, & Glasser (1989). The studies found that students who generated explanations of new content understood the content much better than those who did not generate explanations, and also scored much higher in knowledge testing (Chi, et al., 1994; Chi, et al., 1989). When students create explanations for the content they are studying, they are providing justifications for their understandings, expanding on information, and relating to other concepts (Chi, et al., 1989), which allows for a deeper understanding of the new content (Chi, et al., 1994). Prompting students to explain newly learned content in both writing and speech is an
opportunity to improve communication skills along with strengthening understanding (Willoughby, 2005).

Weiss-Magasic (2012) also encourages writing in the science classroom, and says that students should be exposed to different types in order to assess student understandings of science concepts as well as enhance their scientific literacy. An initiative in Seattle schools has prescribed that students do more technical writing exercises in science classrooms (Ramage & Stokes, 2012). A study of the writing program found teachers reporting that they were better able to assess their students, and student learning improved because students were able to develop their own meanings and mentally process a concept through writing (Ramage & Stokes, 2012). Technical writing (observations, hypotheses, conclusions, etc.) should be modelled in the classroom so students can go on to relate their lab experiences, just like practicing scientists do⁵ (Weiss-Magasic, 2012). This allows students to construct their own understandings of experiments and data; without the thoughtful analysis, a student does not really understand an experiment (Ramage & Stokes, 2012). A student must think before he/she writes about a concept, so by encouraging writing, students are forced to think and then have the potential to understand the new scientific information (Ramage & Stokes, 2012). Creative writing (e.g. science fiction stories, responses to science cartoons/parodies, presentations about famous scientists, etc.) can also allow students to make connections from what they are learning in science to other topics in their lives (Weiss-Magasic, 2012). In addition to making connections, students are more likely to understand and remember concepts in the context of a story as opposed to a more technical format (Butzow & Butzow, 1990). Technical writing shows students can communicate in the traditional lab report style of science writing, while creative writing

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⁵ The use of a lab notebook is encouraged for these activities (Weiss-Magasic, 2012).
shows students can take the information learned in the classroom and use that information in different contexts (Weiss-Magasic, 2012).

Plummer, Davis, & Brazier (2011) also encourage both technical writing as well as creative writing (with a focus on poetry) in the science classroom. By allowing students to write about what they have learned in science in a narrative form, students can clarify their own ideas in a familiar language form and better conceptualize scientific ideas (Plummer, et al., 2011). A study was conducted where grade three students were told to differentiate between how a scientist would see the world, and how a poet would see the world (Plummer, et al., 2011). For example, in describing a toad’s habitat, students were told to describe the habitat in a literal way as well as describing it in an original poem (Plummer, et al., 2011). By using both strategies, students were able to better understand the scientific information because they were thinking about the same information in multiple ways (Plummer, et al., 2011). Plummer, et al. (2011) assert that science concepts are more easily learned through writing.

It is clear that incorporating literacy can help science students to better comprehend the complex topics found in science, but what language skills are students specifically learning? Thier & Davis (2002) list four skills that effective literacy instruction can foster:

- Reading, not only to know the meaning of the words, but to understand, retain, and apply the meaning of what is read
- Communication; writing and speaking clearly and concisely to present meaning to others
- Listening attentively to gain understanding of what others are saying
- Media literacy, or critical thinking; the ability to detect hidden meaning, and critically analyze and evaluate whether information is useful, and objective
While all are helpful in understanding science, the last point is a key skill in literacy as well as science (Thier & Daviss, 2002). Science encourages combing through information to detect flaws and bias (Thier & Daviss, 2002). This is especially important in the data age where non-refereed information is prevalent on the Internet (Thier & Daviss, 2002).

2.2.2 Using Science to Develop Literacy Skills

Science can also be seen as a tool to develop literacy skills (Thier & Daviss, 2002). Students learn effective communication (writing, speech, etc.) as they convey their ideas and understandings of the science they are learning (Thier & Daviss, 2002). For literacy to be learned effectively language must be used purposefully; students should be learning literacy by doing, not through exercises and drills (Thier & Daviss, 2002). What is meant by doing is that students should be engaging in inquiry-based activities that also allow them to develop their literacy skills. When students use literacy skills meaningfully, in inquiry-based activities in the science classroom, they are at the same time internalizing science concepts since these concepts become meaningful (Thier & Daviss, 2002). Activities such as exploratory talk are especially good for students to make sense of the guided inquiry they are encountering (Thier & Daviss, 2002).

Essentially, science and language act as reciprocal skills to strengthen each other: science provides meaning and purpose for improving literacy skills, and literacy skills provide a lens to focus and clarify science concepts (Thier & Daviss, 2002).

2.2.3 Engaging with Science

Science is often mistakenly thought of as being solely an empirical subject, and thus texts beyond the traditional textbook are not often used (Fang, 2013). However, the social aspect of

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6 Inquiry-based activities here refers to activities that involve students participating in active learning that “emphasizes questioning, data analysis, and critical thinking” (Bell, Smetana, & Binns, 2005).
7 Exploratory talk here refers to students thinking out loud and discussing a concept with a partner to ensure understanding (Thier & Daviss, 2002).
science is not being nurtured when language and literacy are not given an important position in learning science (Fang, 2013). A key aspect of science is to engage with different scientists’ findings and ideas and to critique them, thus, science has a social aspect since scientists are engaging with each other’s work (Fang, 2013). By not including language and literacy in the science classroom, student learning is undermined because students are not prepared to be critical consumers of scientific knowledge (Fang, 2013). There is a risk that students may take in information as fact without taking the extra step of being skeptical and investigating the author’s methods to see if there is a bias and/or weakness in the presented information (Fang, 2013).

Healthy skepticism is defined by Thier & Daviss (2002) as being open to new information while also being doubtful of arguments that are not supported by convincing evidence. Parkinson & Adendorff (2004) argue that using popular science articles in the classroom is helpful in combating the idea that all science texts should not be questioned since in these texts scientific ideas are still open for debate. Another method to encourage skepticism and critical questioning of science is to conduct controversial debates (e.g. the global warming debate), with the added element of discussing how it connects to political issues (Santos, 2014). Debates encourage students to research and explain their reasoning for a certain stance, thus fostering critical thinking.

Fang recommends appropriate trade books\(^8\) that vary in content, genre, format, readability, etc. be a staple in the science classroom to help students more easily engage with science (2013). Fisher, Grant, & Frey (2009) also agree that students need to be given manageable texts discussing a scientific topic. In an effort to stay informed, scientists read a variety of sources, so to emulate that learning, it would be ideal for students to also read a variety of texts on a subject within the science classroom (Grant, & Fisher, 2010). Popular science

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\(^8\) I.e. books intended for a general audience.
articles are another example of a more accessible text for students and are valuable since they are “conceptually simpler than academic texts,” helping students better understand science (Parkinson & Adendorff, 2004, p. 394). The use of trade books in the U. S. has been encouraged recently in an effort to integrate reading and writing in science instruction (Schussler, 2008). The National Science Teachers Association (NSTA) in the U. S. creates a list every year of recommended trade books in the science classroom for grades K-12 (Fang, 2013). As opposed to traditional textbooks, trade books can accommodate students with diverse backgrounds in culture, ability, background, interests, and reading levels (Fang, 2013). Trade books can also put scientific information into a context for students, often portraying science as it happens, or exists, in the real world (Fang, 2013). These books can allow students to make connections to their own lives, critically assess if science is portrayed accurately, which characters have the power to influence science, paraphrase technical science vocabulary, use other sources to find more information about science ideas mentioned, and consider how culture influences science development (Fang, 2013).

While trade books offer the option of being an entertaining and less confusing alternative to traditional textbooks, there is also a risk that students can acquire misconceptions about a science topic if the information is not presented in an accurate way (Schussler, 2008). One study analysing 50 trade books found numerous inaccuracies in the text and illustrations (Schussler, 2008). Thus, it is important that teachers properly check any trade books they would like to use prior to introducing them to students (Schussler, 2008). Fisher & Grant (2010) also urge that the textbook not be discounted as a good resource for the science classroom since it can provide a lot of information and support for students. Students must learn to read different types of texts in order to be successful in science (Fisher & Grant, 2010).
As was discussed previously, Thier & Daviss (2002) encourage students to be *doing* to better understand science concepts (i.e. doing hands-on activities). Providing hands-on activities is a good way to have students engage with science, but it is also necessary for them to communicate their understanding both during and after the activities (Thier & Daviss, 2002). Studies have shown that true comprehension occurs when students are able to relate new information into their personal views and already-established understandings (Thier & Daviss, 2002). Teachers can encourage this kind of learning by making sure activities allow for students to engage with them and ask questions (Thier & Daviss, 2002).

Froschauer also stresses that reading, writing, speaking, and listening are key methods to developing vocabulary and understanding science (2014). This is because students must think about what they are analyzing when they write or speak on a scientific topic (Froschauer, 2014). The way students will learn how to write effectively is to mimic effective writing (Froschauer, 2014). This is done by first reading what others write and analyzing the writing. Teachers need to provide a variety of authors as well as writing styles for students to examine (Froschauer, 2014). Again, the lists of trade books created by the NSTA are recommended as a good resource for teachers (Froschauer, 2014). Teachers may also want to provide students with published scientific articles from peer-reviewed journals so students can see what scientific writing looks like in post-secondary education and beyond. A teacher can see if his or her school board provides access to these journals through subscribed databases. There does not seem to be a particular database focused on providing teachers with well-written journal articles currently, which may be worth creating in the future for education purposes.
2.2.4 Importance of Background Knowledge and Scientific Vocabulary

It is important to not forget that strategies such as making connections to their own lives/the outside world, inference, and summarizing will not help students in science comprehension alone (Fisher, Grant, & Frey, 2009). Sufficient background knowledge and an appropriate scientific vocabulary are still necessary (Fisher, et al., 2009). Students need the knowledge and vocabulary first, then can move onto using the above cognitive strategies to clarify the new information (Fisher, et al., 2009). When students are told to have discussions with partners, they should be encouraged to use the new terminology just learned in their explanations (Fisher, et al., 2009). Creating a list of new terminology on chart paper or the board can be put up as reminders for students on what terms they should be using in these discussions. Students can also be asked to provide self-explanations to the class using the new terminology to assess their understanding of the newly learned material (O’Donnell, D’Amico, Schmidt, Reeve, & Smith, 2008). These self-explanations also work to reinforce the information since it creates more neural pathways for the student to retrieve information (O’Donnell, et al., 2008).

2.2.5 New Territory for Science Teachers

Many science teachers do not feel confident in their ability to integrate literacy into their science classroom (Thier & Daviss, 2002; McCross-Yergian & Krepps, 2000; Park & Osborne, 2006). Especially moving into secondary schools, education becomes compartmentalized (as was mentioned earlier), so that the idea pervades that it is the duty of English teachers to teach literacy and science teachers to teach science⁹ (Thier & Daviss, 2002; McCoss-Yergian & Krepps, 2000). Additionally, teachers in content areas outside of literacy often do not feel

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⁹ Interestingly, many secondary teachers believe skills such as reading should have been learned in the elementary grades, and so it is not the responsibility of secondary teachers to be teaching these skills in their classroom (McCoss-Yergian & Krepps, 2000). These teachers often expect students to have the necessary literacy skills required for his or her class (McCross-Yergian & Krepps, 2000; Park & Osborne, 2006).
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confidence in their preparation to teach literacy (McCross-Yergian & Krepps, 2000; Park & Osborne, 2006). This indicates that it may be beneficial to provide more explicit literacy preparation in pre-service teacher programs for secondary school teachers. It is also important to keep in mind that within secondary schools there is heavy emphasis on learning content, and so teachers can feel that taking the time to teach literacy strategies takes away valuable time\(^\text{10}\) from learning subject-specific concepts (McCross-Yergian & Krepps, 2000; Park & Osborne, 2006). Interestingly, Park & Osborne (2006) note that many content-specific teachers do not feel literacy strategies are important.

It is true that science teachers should not be expected to teach their students literacy on top of science; however it can be a huge advantage for science teachers to learn tools to effectively integrate some literacy into the science classroom. Implementing literacy strategies is an effective method to improve subject comprehension (McCross-Yergian & Krepps, 2000). It is important to provide science teachers with effective strategies and techniques that will allow them to integrate literacy into their lessons in a meaningful way (Thier & Daviss, 2002). Luckily within Ontario, resources are available for teachers to implement literacy strategies in a cross-curricular fashion.

The Ontario Ministry of Education has provided an entire “Think Literacy Library” resource for teachers to implement literacy strategies within different subjects from grades 7-12 (Ontario Ministry of Education, 2015). The website provides general documents that focus on reading, writing, and oral strategies that can be implemented in any course (Ontario Ministry of Education, 2015). The documents are especially helpful because they provide detailed outlines of the activities teachers can use to develop each particular literacy skill, effectively walking the

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\(^{10}\) McCross-Yergian & Krepps (2000) also acknowledge that secondary school teachers frequently reference that they feel short on teaching time as it is.
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teacher step-by-step on how to conduct the activity (Ontario Ministry of Education, 2015). In addition to the general documents, there are focused documents catering to particular subjects. There are Science (Grades 9-10) Oral Communication, Science (Grades 9-10) Writing Strategies, and Science (Grade 10) Reading Strategies documents that provide literacy strategies that cater to science specifically (Ontario Ministry of Education, 2015). Hopefully, additional documents will be provided in the future for senior-level science classrooms.

2.2.6 Critical Thinking in the Science Classroom Leads to Informed Citizens of Tomorrow

Throughout the twentieth century, science became a progressively more important element in the lives of Canadians (Ontario Ministry of Education, 2008a; Ontario Ministry of Education, 2008b). Science has had a huge impact on our society since we regularly use life-saving pharmaceuticals, computers, and other technologies, and this impact will continue to grow (Ontario Ministry of Education, 2008a; Ontario Ministry of Education, 2008b). Consequently, it has become a goal for science education and the Ontario Ministry of Education (2008a; 2008b) to ensure all students are able to exhibit scientific literacy. It is important to acknowledge that what it means to teach science has changed; no longer should we be satisfied with teaching facts and expecting students to regurgitate information from a “mental bag of facts” (Thier & Daviss, 2002, p. xvi). The key take-away for students should be strategies such as analyzing, comparing, contrasting, inferring, and applying the scientific knowledge from class (Thier & Daviss, 2002). Students should be learning how to use information meaningfully in their lives (Thier & Daviss, 2002). Palincsar, Anderson, & David (1993) found that when teachers have students working collaboratively to solve problems in science class, students develop the skills of finding solutions to ambiguous problems, predicting, analysing evidence,

11 The Ontario Ministry of Education (2008a; 2008b) defines scientific literacy as “possession of the scientific knowledge, skills, and habits of mind required to thrive in the science-based world of the twenty-first century” (pg. 3).
and communicating ideas to others. By encouraging a collaborative work environment in a science classroom, this allows for more opportunities for students to communicate (developing their communication skills) with each other and to share ideas to solve a problem. These problem-solving activities also provide opportunities for students to use science in ways that are relevant to their own lives (e.g. knowing how to build an electric circuit for wiring and lighting a garage). Truly understanding science involves making informed personal and societal decisions and then having the literacy skills to be able to effectively communicate why these decisions are made (Thier & Daviss, 2002). This is what Thier & Daviss (2002) assert we should consider the scientific literacy\(^{12}\) of today. However, according to an expert panel report released by the Council of Canadian Academies in 2014, only 42% of Canadians are able to show that they have the necessary knowledge to understand basic concepts and general media coverage on scientific issues. On a positive note, the report also found that 93% of Canadians are moderately to very interested in scientific discoveries and technological developments (Council of Canadian Academies, 2014), so Canadians are in fact interested in science, but they are struggling with scientific understanding. Having students engage with news articles reporting about science is an example of an activity students can undergo to help them critique scientific accuracy and truly test their scientific literacy (Schielke, 2013; Murcia, 2007).

The world is changing with regard to what kind of knowledge the average citizen should possess. According to Gaffney (2005) and Thier & Daviss (2002), scientific literacy is necessary for everyone. To truly understand the modern world, a person must understand science; this provides a person with the ability to predict and have some control over his or her environment (Gaffney, 2005). With scientific knowledge, hopefully comes the ability for individuals to feel

\(^{12}\) Scientific literacy according to Their & Davis (2002): the possession of skills that bring together science concepts, facts, and processes with the capability to use language to clearly communicate ideas.
agency when making informed decisions about science and society (Gaffney, 2005). Society then has the opportunity to benefit when these individuals can come together to make informed judgements about our shared resources like air and water (Gaffney, 2005). Humanity is arguably making the biggest impact on the planet than at any point in history thus far, and that is why it is so important to be scientifically informed; science can remind individuals that we are an element within an entire system and this planet is something we must share (McDonald, 2014). Most large-scale decisions made by the Canadian government involve some aspect of science, so scientific literacy is not only important for scientists, but for politicians, businesses, and average citizens (McDonald, 2014). Citizens and workers of the twenty-first century need to understand how to apply scientific knowledge to not only understand and communicate about their world, but to make decisions and changes to that world (Thier & Daviss, 2002).

Ensuring individuals are well-informed with regard to science is also important so that the electorate is not easily swayed by political powers trying to influence policy in a government’s favour, but not in favour of the planet as a whole (Kozachkov, 2014). From an economic standpoint, many of the highest-paying jobs in North America require some sort of training in science (e.g. doctors, engineers, surgeons, dentists; which are also important and highly necessary in society) (Kozachkov, 2014). Outside of these jobs, there are others that would not seem to need science, but do require analytical thinking and the ability to diagnose a problem in order to fix it; the skills fostered in science education (Kozachkov, 2014).

Knowledge of science aids in informed decision-making. Reports about global warming and climate change are an almost daily presence in the media. Television programs offer advice with regard to health, like what vitamins (if any) we should be taking or what kinds of food we should avoid. Governments pass laws that affect homeowners, such as banning certain
pesticides. Governments also pass laws regarding restrictions on oil tankers and pipelines that carry potentially hazardous cargo. It is necessary for citizens to be critical of the news they consume, and for these citizens to think critically they must be well-informed. This begins with teachers showing students how to engage with scientific concepts and to truly understand these scientific ideas. If language is the key to learning and comprehension, then it is critical for literacy to be incorporated into the learning of science.

2.3 Conclusion

In this literature review I examined the issues surrounding writing in science; specifically the issues of scientists adhering to conventions that make science inaccessible for a wider audience as well as poor writing often found in science papers. I then looked at the research discussing how incorporating literacy into science can not only help students better understand science, but also improve their writing skills within the sciences. There is a large gap in the research on how writing in the sciences can be improved. Indeed, the issue of why science should be more accessible and how to make science more accessible to the public has not received sufficient attention to date. Additionally, it would be beneficial for studies to be conducted to show the benefits of why scientific literacy is an important skill in today’s society. In terms of assisting teachers, there is a gap in the literature of how teachers can better teach their students to be scientifically literate. More research on what specific methods and resources are effective for promoting scientific literacy in high school classrooms is necessary.

Through my research, I aim to contribute to the existing literature of how science teachers can better incorporate literacy in a meaningful way to help their students improve their science writing. In chapter three, I will go on to discuss my research methodology where I
provide an explanation of the procedures carried out for the purposes of my qualitative research study.
Chapter 3: RESEARCH METHODOLOGY

3.0 Introduction

Within this chapter I provide a thorough explanation of the research methodology. I begin by reviewing the general approach, procedures, and data collection instruments before expounding more specifically on participant sampling and recruitment. I then go on to provide descriptions of the participants, the ethical review procedures that were followed, and the limitations, as well as the strengths, of this qualitative study.

3.1 Research Approach and Procedures

This research study was conducted with a qualitative research approach involving a literature review and semi-structured interviews with teachers. It is appropriate to conduct qualitative research on integrating literacy strategies in science classrooms since it is an issue involving many variables that are not easily measured; qualitative research allows me to explore the topic at hand, with some degree of flexibility (Creswell, 2013). Since the research problem does have many variables involved (e.g. the tendency for education to be segregated, development of scientific writing conventions, new technologies allowing for more flexible communication, etc.), qualitative research allows the researcher to have a more complex understanding of the issue by interviewing individuals (i.e. teachers) who are immersed in an environment who can provide informed opinions on the issue (Creswell, 2013). Being able to speak with these teachers along with conducting a literature review allows for a broader understanding of the issue.

Creswell (2013) asserts that qualitative research allows for a more flexible writing style than quantitative research, so individuals can share stories and anecdotes instead of the researcher being restricted to using only statistics and formal academic writing. This is important
for my research problem, since to truly understand how to improve scientific writing, it is necessary to hear first-hand accounts of what is and is not working for students in the science classroom when it comes to writing. Lastly, qualitative research requires the researcher to position themselves within the study, so the researcher’s intents are transparent to a reader (Creswell, 2013). This reflexive element to the research is appropriate since I wish to eventually become a secondary science teacher. Not only does this research have the potential to add to the relevant literature, but it can also inform my own teaching practice in the future in terms of helping my own students. Since I have a subjective interest in this research, it could be argued that I may approach the data with my own biases; however because of the methods used to conduct this research, some biases can be transcended (Bogdan & Biklen, 2003). Qualitative research is not a quick process where the researcher speaks with one person and then writes an opinion article; the researcher must spend considerable time sifting through appropriate literature, followed by collecting and reviewing a large amount of data. All this data provides a better representation of the research problem than any “creatively prejudiced mind [might] have imagined prior to the study” (Bogdan & Biklen, 2003, p. 33). Furthermore, the primary goal of the researcher is to add to the existing knowledge of the subject, as opposed to passing judgement on the subject (Bogdan & Biklen, 2003).

**3.2 Instruments of Data Collection**

The main instrument for data collection used in this study is the semi-structured interview protocol. Semi-structured interviews provide the chance for participants to share their relevant experiences (Cresswell, 2013). The semi-structured format provides the interviewer with the ability to design and plan an interview that focuses on the research questions while still being flexible enough for participants to elaborate and possibly shed light on areas the interviewer had
not previously considered (Denscombe, 1998). Besides giving the participant room to develop ideas, it also provides opportunity for the interviewer to pursue a subject further. This is an appropriate method for my research since as the researcher, I would like to have a complex understanding of the factors involved in science writing, and hearing first-hand accounts from teachers on what the issues are, along with helpful strategies help to strengthen the final research findings. It is important to note that interviewees provided their own human experiences on the matter and these experiences are subject to interpretation (Bogdan & Biklen, 2003). The participants in these interviews conferred their own meanings on objects, people, and situations (Bogdan & Biklen, 2003), thus as I assessed and reviewed my data, it was necessary to remember that there is no absolute truth when it comes to integrating literacy strategies in the science classroom. Indeed, as the interviewer, I carried my own unavoidable conscious and unconscious biases, feelings, and motives, so it was not possible to be truly neutral in the interviewing process (Fontana & Frey, 2005). However, while true neutrality was not possible, this collected data can still help inform my research and add to the appropriate existing literature, helping future educators in this particular area of research.

Appropriate participants were recruited for the interviews, which were conducted in person with an audio recording device. The interview questions were broken up into four sections (teacher background; teacher beliefs; teacher practices; and challenges, supports, and next steps; see Appendix B). The first set of questions was intended to provide the interviewer with background information of the participant to highlight why he/she is a relevant participant for the research. The rest of the questions were designed to discover the participant’s views on literacy in science classrooms, the responsibilities of science teachers to teach literacy skills, teaching experience, and strategies in the classroom, as well as the challenges that may be
experienced in the science classroom when it comes to integrating literacy strategies. The interview questions were developed by examining the current appropriate literature and trying to respond to the issues facing effective communication in the sciences.

3.3 Participants

Here, I review the sampling criteria I established for participant recruitment and I review the pursued avenues for teacher recruitment. I have also included a section where I introduce each of the participants.

3.3.1 Sampling Criteria

Teacher participants were selected based on the following criteria:

- High school science teachers
- At least four years of teaching experience
- Integrated literacy strategies in the science classroom
- Assessed students on writing and oral skills in the science classroom

It was necessary for participants to be high school teachers since the research is focused on secondary science education. Participants should have had at least four years of teaching experience because this timeline provides enough time for the participants to have developed their own perceptions and ideas of how integrating literacy strategies in the science classroom affects student achievement. Participants must have integrated literacy strategies and then assess their students on writing and oral skills so they may comment in the interviews on student achievement.

3.3.2 Participant Recruitment

To recruit participants I relied on convenience sampling. Being immersed in a community of teacher colleagues and mentor teachers, I utilized these existing contacts and
networks to gather participants. I provided my information to these contacts to distribute as opposed to asking them to provide me with names and contact information of individuals they felt were suitable. This was done in an effort to make participants feel comfortable and not like they are being forced to participate in the study. Two participants were recruited after being referred to me by peers. One participant was recruited by emailing her after having already previously met.

3.3.3 Participant Biographies

Participant 1: Lily

Lily is a science teacher at a private school with approximately 500 students in a suburban neighbourhood. She has seven years of teaching experience and is currently teaching grade 11 and 12 biology, and grade 9, 11, and 12 learning strategies. Her teachable subjects are in general science and biology, and she also has her full special education qualifications. At the time of the interview, she was in the process of completing her chemistry qualifications. Throughout her career Lily has tended to teach grade 11U and 12U biology, and grade 9 academic science. Lily’s school demographic is strongly inclined towards academic, with few applied classes, although there are students with special needs. Lily mentioned that parents at the school tend to prefer their students to take academic classes. She described the school demographics as having a middle to high socio-economic background.

Lily developed an interest in incorporating literacy strategies into science when she noticed that students have trouble making inferences when doing science readings and in general struggle with science terms and English vocabulary use in the context of science. She felt their communication skills when answering questions are lacking. Her department at the school was also in the process of creating professional development (PD) at the time of the interview that
focused on improving students’ scientific literacy, which Lily believed was directly related to language and literacy. Lily mentioned that in her own studies she was not very focused on English and in hindsight wished to have invested more effort in English classes now that she sees the importance of communication in the sciences.

Participant 2: Fleur

Fleur is a science teacher at a suburban public high school with approximately 1200 students. She has seventeen years of teaching experience and is currently teaching 11U chemistry (one standard class and one enriched class) and 11U biology. Her teachable subjects are chemistry and biology. Throughout her career, she tended to teach grade 9 science and 11U biology or chemistry, however in recent years there have not been enough new chemistry teachers in the department so that is the reason she teaches a more senior timetable currently. For the first twelve years of her career, Fleur also taught grades 9 and 10 ESL. Fleur’s school also tends more towards academic as opposed to applied, and the school launched an enriched program in an effort to attract students. She mentioned that most students at the school want to be on the University pathway.

Fleur’s interest in literacy within science can be traced back to her interests in biology, chemistry, and English in high school. She expressed frustration at the prevailing idea that someone within science is only successful because they can solve difficult calculations, when scientists are expected to share results through publications and to communicate their research at conferences. Her interests in other languages brought her to teaching ESL, which necessarily considers literacy strategies. Finally, she mentioned that attending PD sessions that highlighted how to incorporate literacy into other areas helped her become more aware about the topic.
Participant 3: Ariana

Ariana is a science teacher in an urban public high school. She has eighteen years of teaching experience and is currently teaching grade 9 science, and 11 and 12 biology and chemistry. Her teachable subjects are chemistry, biology, and music. She also obtained her specialty in teaching English Language Learners (ELL). Throughout her career she has taught chemistry, physics, and biology, as well as general science in grades 9 and 10. She also has taught specific grade 9 courses designed for ELL students where students are taught in a way to foster language skills in the context of different subjects (e.g. science, geography, math, etc.). Ariana taught ten years at one school with a high ELL population and low socio-economic background. She then taught at an urban school with students of diverse backgrounds and overall middle to high socio-economic status. Before coming to her current school Ariana completed her PhD. At the current school, students are of an ethnically diverse background, and higher socio-economic background; there is also an exchange program so there are many students from China. The school is an academic, arts, and athletics school, so students need to audition in order to attend. The school is very inclined towards the academic stream, with highly motivated students.

Ariana’s interest in incorporating literacy into science came about through her observations that literacy is not usually associated with science. Her interest in scientific literacy and twenty-first century skills brought her to the belief that students need to learn collaboration and communication, as opposed to basic fact recall. Thus, literacy in the context of science can help students to improve their communication within the sciences.

3.4 Data Analysis

After the interviews had been completed, each audio recording was transcribed. The online website oTranscribe.com was used to aid in the process of transcription since it offered a
slower playback speed as well as a pause button which backtracked the audio slightly after each pause. Each transcript was printed and as I read through the individual transcripts, I coded the data line by line, and grouped the data within meaningful segments that emerged (Creswell, 2013; Alvesson & Sköldberg, 2009; Rowley 2012). These segments represented my research questions, and I named each segment (Cresswell, 2013). After all the data had been coded, I looked for similarities between segments and combined these into broader categories, identifying any themes that emerged (Creswell, 2013; Alvesson & Sköldberg, 2009; Rowley 2012). In addition to looking for similarities within the data, I looked for where the data diverged and if there was any relevant data that the participant did not speak to, and why that may be relevant to the study (Creswell, 2013).

3.5 Ethical Review Procedures

Each participant was presented with the informed consent letter prior to the start of the interview (Appendix A). Participants read and signed two copies of this letter, keeping one copy for themselves, providing their consent to be interviewed and audio-recorded. This consent letter provided an overview of the study, addressed ethical implications, and specified expectations of participants. There were no known risks to participating in the study. Each participant was assigned a pseudonym, and no identifying information such as name or school of work will be mentioned in my written work, oral presentations, or publications to maintain anonymity. All information is confidential and all data was stored on a password-protected computer; the data will be destroyed after five years. The only individuals who will have access to the research data will be myself and my course instructor.

Participants had the opportunity to read over the interview transcripts and to clarify or retract any statements before data analysis was conducted. Participants could withdraw from the
study at any time before its publication and could choose to decline answering any specific question(s).

### 3.6 Methodological Limitations and Strengths

In accordance with the Master of Teaching Research Project ethical parameters, the scope of the research study limits the interview participants to teachers only. I was not able to interview students, parents, conduct classroom surveys, or classroom observations. Additionally, I interviewed only three participants, so the provided data can inform the topic at hand; however the data cannot generalise the experience of all science teachers who integrate literacy strategies in their classrooms. Since I could not interview students or parents, I must rely on the teacher’s experience with regard to student understanding and achievement, as opposed to gathering student/parent interpretations. Surveys would have been beneficial since it is easier to collect data from a large group of people as opposed to individual interviews (Rowley, 2012). Observations in the field were also not possible, which could have provided valuable insight since it allows the researcher to note phenomena directly as they actually occur (Creswell, 2013). It allows the researcher to record data on what is actually being done in a classroom as opposed to relying on what someone says is being done in a classroom (Denscombe, 1998).

It should be noted that semi-structured interviews are not without their strengths. Interviews allow the participant to explain the intent behind their actions, while observation tends to focus on only describing the behaviour that occurs (Denscombe, 1998). Interviews also have the benefit of allowing for more detailed insights than a survey (Rowley, 2012). Participants can provide more depth to their answers and can speak in their own words. By interviewing teachers for my research, this also creates the opportunity to utilize teacher-generated knowledge (Zeichner, 2013). Interviews validate teacher voices and experiences,
which traditionally are not heard in education research (Zeichner, 2013). Teachers are in a valuable position of providing insider perspectives on teaching (Zeichner, 2013), and interviews are an ideal opportunity to listen to these insights. Interviews also provide the opportunity for teachers to reflect on their own practises and rationalise why they do the things they do; a practice that is endorsed in education (Ryan, 2005).

It should be noted that when interviewing Lily, the interview was conducted in a public coffee shop and there were several interruptions from an inquisitive child in the first half of the interview. This potentially led to disruptions in the participant’s flow of thought. Fleur’s interview took place in an unused classroom at her school of work and there were no interruptions, while Ariana’s interview was conducted in her home where there were some minor interruptions in the flow of the interview, such as the phone ringing.

3.7 Conclusion

To conclude this chapter, I provided a description of the qualitative research approach and procedure, which is appropriate due to a greater flexibility for the research study. The primary instrument of data collection was semi-structured interviews, which allowed for greater depth in participant responses. I addressed my sampling criteria for participants, how I recruited my participants (through convenient sampling), and provided participant biographies. The details of how the data analysis was conducted are discussed, followed by the ethical review procedures of providing an informed consent letter to participants. I proceeded to address the limitations and strengths of this study, including but not limited to: the small amount of participants, restriction of only interviewing teachers, and providing the opportunity to hear teacher voices. Next, in chapter four, I report the research findings.
Chapter 4: RESEARCH FINDINGS

4.0 Introduction

Within this chapter I report and discuss the common themes that emerged from analysing the three interview transcripts by comparing and contrasting the data from each participant (Lily\textsuperscript{13}, Fleur\textsuperscript{13}, and Ariana\textsuperscript{13}). The research findings are in response to the research question: how is a sample of secondary school science teachers fostering effective written and oral communication in the sciences? Five major themes emerged: Beliefs about Science and Language within Education, Preparing Students for the Future, Teacher Beliefs and Practices, Assessment, and Challenges. These themes are further divided into subthemes, and it should be noted that there are some overlaps between themes. Using research from the literature review, I will further examine these themes by connecting to my chapter two.

4.1 Beliefs about Science and Literacy within Education

The three participants shared their views on science and literacy-based courses (specifically English) and two subthemes emerged: The Subject Divide between Science and English, and Science Teachers’ Perceptions of themselves as Language Teachers. The data suggested that the subject divide between science and English contributes to science teachers not perceiving themselves as also being language teachers.

4.1.1 The Subject Divide between Science and English

All three participants commented on the subject divide that exists between science and English courses. Lily noted that while literacy skills “should be the foundation of every single subject,” it is often associated with only English classes in high school, isolating literacy from other subjects. Fleur also said that it was unfortunate that science was isolated from English

\textsuperscript{13} Note: pseudonyms have been used in order to protect participants’ privacy. Short participant biographies are provided in chapter three.
because she admired the types of writing assessments present in those courses; however she then noted that due to the challenge of time constraints – which will be addressed later – that it is not possible for science teachers to spend as much time on literacy activities and assessments due to the large amount of content in science. She shared that it was aggravating that people equated science – especially chemistry – only with numeracy and solving equations because a scientist is expected to apply for grants, and write persuasively in order to earn those grants. The subject divide is also obvious to students; Ariana mentioned that there are times where the class will be doing a literacy activity and she paraphrased students making comments such as, “well y’know this is science class or this is, it’s not math class, and it’s not English class, why do we have to […] concentrate on literacy skills?” Students see the compartmentalization of subjects in high school and may find it odd if there is crossover. Ariana also felt that literacy skills did not tend to be a focus in science classes, in general.

The isolation of science from other subjects (indeed, the isolation of all subjects in high school from each other) was discussed in chapter two; Britzman (1986) states that the division of subjects from each other is problematic since students learn that skills acquired in one subject are irrelevant to others. Ariana spoke to this belief when she paraphrased some students’ reactions to doing literacy activities in science class.

As was discussed in the literature review, the so-called “real world” beyond high school does not operate in such a segregated way where English and science do not cross paths. A variety of skills from different disciplines are necessary for different careers and tasks. All three participants recognized the isolation of science from English and identified problems with this disconnect.
4.1.2 *Science Teachers’ Perceptions of themselves as Language Teachers*

When asked if science teachers are also language teachers, Lily and Ariana both agreed that science teachers are language teachers. Lily stated that there is a duality at work in science; she believes students need their English skills for comprehension of science but science also needs to be thought of as its own language (in terms of having its own terminology and jargon). She likened the experience of learning science to learning a foreign language due to all the new terms, on top of being able to communicate to others through the use of English skills. Ariana stressed that science teachers “definitely need to be” language teachers; however she then went on to say that she felt it was very difficult for science teachers to think of themselves as language teachers since their post-high school experiences do not usually allow the opportunity to take language-based courses. She detailed how science majors take on many lab courses on top of their lecture courses and so taking an optional language course is not usually considered. Ariana felt she really learned how to communicate effectively in a science context once she was doing her PhD, and she goes on to say that most science teachers would not have taken that route; they would have taken their last language course in grade 12. As a result of this science-focused schedule, she mentioned that science teachers tend to have a numeracy focus and so their second teachable will be within sciences or mathematics as opposed to something literacy-based. This academic background may speak to why Fleur did not feel science teachers are language teachers. She stated, “We aren’t language teachers” however she believed science teachers should be incorporating language because “Everybody uses it. For every single subject.” Fleur thought it was unfortunate that science teachers were not language teachers because she thought it would be beneficial to be doing more English-style assessments (i.e. essay writing) in science class, as mentioned previously.
Fleur’s and Ariana’s points about science teachers not seeing themselves as language teachers is echoed in the literature review. Thier & Daviss (2002), McCross-Yergian & Krepps (2000), and Park & Osborne (2006) are in agreement that many science teachers do not feel confident in their ability to integrate literacy into their science classroom. Teachers in content areas outside of literacy often do not feel prepared to teach literacy and these teachers may also feel that since they are short on time as is, taking time to teach literacy would be far too straining (McCross-Yergian & Krepps, 2000; Park & Osborne, 2006). Fleur echoed this sentiment with her comment on how she felt literacy skills were important in the science class but there just was not as much time to focus on it due to the large amount of content in science.

Although all three participants felt literacy skills in science were important, Ariana and Fleur spoke to the fact that many science teachers would not consider themselves language teachers due to the isolation of science from language-based courses. This suggests that it may be beneficial to provide more explicit literacy preparation in pre-service teacher programs for secondary school teachers.

4.2 Preparing Students for the Future

Through the three interviews a theme emerged where all the participants commented that their reasoning for including literacy in the science classroom is to better prepare students for an ever-changing and evolving world. In the subtheme Fostering Science Citizenship and Critical Thinking in Science, participants share how incorporating literacy into science helps students engage with science, which can lead to more scientifically engaged citizens. In the subtheme Developing Twenty-First Century Skills, participants discuss the importance of communication and collaboration, which can be fostered through literacy integration in science.
4.2.1 Fostering Science Citizenship and Critical Thinking in Science

Fleur felt science citizenship, a term she mentioned in the interview, was very important to foster in the science classroom. Fleur believed that everyone, even if an individual was not pursuing science studies, should still be aware of scientific happenings in the world because society is dependent upon scientific advancements. Fleur’s understanding of science citizenship can be linked to the discussion in the literature review about encouraging critical thinking and scientific literacy in science to better prepare students for the future. Fleur also mentioned that interest in science is on the rise due to science spokespeople such as William Sanford “Bill” Nye, popularly known for his children’s science show Bill Nye the Science Guy and appearances in popular media discussing science (“2015 Commencement,” 2015). However, for people to really understand science developments, they need to be engaging with science through reading articles, watching relevant programmes, and processing the information. Lily and Ariana both also agreed that scientific literacy is something they wanted to promote in their classrooms. Lily’s department had been recently given the opportunity to create professional development (PD) at her school and the staff decided that one of the biggest issues facing students was scientific literacy, and so this would be the focus for their resource development.

The Ontario Ministry of Education (2008a; 2008b) has recognized that our world is changing and that science is becoming a progressively more important element in the lives of Canadians. As such, it has become a goal for science education to ensure all students are able to exhibit scientific literacy (Ontario Ministry of Education, 2008a; 2008b). Scientifically informed citizens are an important component of a thriving society since with scientific knowledge, hopefully comes the ability for individuals to feel agency when making informed decisions about

14 The Ontario Ministry of Education (2008a; 2008b) defines scientific literacy as “possession of the scientific knowledge, skills, and habits of mind required to thrive in the science-based world of the twenty-first century” (pg. 3).
FOSTERING EFFECTIVE COMMUNICATION IN THE SCIENCES

science and society (Gaffney, 2005). Informed citizens can elect environmentally responsible
government officials and communicate and share scientific ideas with others. Our changing
world requires a deeper understanding of concepts, as opposed to the regurgitation of facts;
students need to learn the skills of the twenty-first century to thrive.

4.2.2 Developing Twenty-First Century Skills

A common theme emerged amongst the three participants of how literacy skills are
important due to the fact that these skills are transferrable to other areas and disciplines. Lily
spoke of how one of her goals for her students is for them to be able to apply the knowledge
learned in class to new situations. She found that often students have a shallow understanding of
a concept because if she rephrased a definition slightly with new words, students will not identify
that she is talking about the same concept because the definition is not stated directly as it was
the first time. Lily commented that she tries to foster a deeper comprehension with her students
so they are then able to apply the information to new contexts. These different contexts could be
a formal lab report, or a news article, which the latter would also serve to help develop science
citizenship and awareness of national or global science issues. When asked how effectively she
felt students are able to communicate their science knowledge in their writing and speech, Lily
replied that she found it was their weakest area; she commented students in general can
memorize information in order to answer shallower fact recall questions, but she thought
students often struggled in the higher-level communication and application questions.

Ariana identified twenty-first century skills as both communication and collaboration,
with the former supporting the latter. To stress the importance of these new skills, Ariana tells
her students, “gone are the days where you just have to memorize all these facts in science. It’s
[…] more about being able to communicate this in a variety of ways, be able to apply those
understandings into different contexts.” When basic facts can be looked up on a search engine in a matter of seconds, it is no longer as important to be proficient at fact recall. It is more important to take those facts and apply them in a useful way; to communicate and collaborate with others in order to find new solutions to problems. Ariana even suggested that these skills may actually be considered more important than the facts being learned. To help facilitate the teaching of these new skills Ariana discussed how she needed to adjust from the more traditional lecture-style of teaching to having students communicate to her their understandings. Additionally, she said it is important to allow students to discuss ideas with peers in an effort to simulate what real scientists do. An important aspect of Ariana’s teaching is that she keeps abreast of how scientists, and students, communicate to each other. She wants students to be able to relate to how scientists connect with each other (e.g. conferences) and simulate that in her classroom to show that this is a relevant skill. She also spoke to the importance of modelling student communication (e.g. Twitter) in her classroom to engage students.

Fleur agreed that clear written communication is important and she wants her students to write in a clear and understandable way. She also discussed how if students are to pursue science, they would not only be expected to solve equations, they would be expected to write persuasively for research grants, as was mentioned previously. Not only would writing be necessary, but scientists are also expected to attend conferences to share their findings with others, “so [being a scientist] is actually all about communication” as Fleur succinctly states. Lily echoed this sentiment by saying that whether it is words or numbers, there is always some form of communication happening in science. A strategy Fleur uses often is to have her students “talk science” with each other, where students practise explaining a scientific concept to each other. Lily also said she encourages her students to speak with a partner after she asks a question, since
talking through a concept allows a student to process the information. This on-task talk echoes Ariana’s ideas about removing the focus from teacher-led discussion where students are more passive, and moving the focus to more active student learning.

As was discussed previously, our changing world calls for more scientifically literate citizens, but also the new skills of communicating and collaborating with others. Communicating with others through informed dialogue, as Fleur and Ariana mentioned, are excellent ways for students to gain a deeper understanding of scientific material (Froschauer, 2014; Thier & Daviss, 2002).

### 4.3 Teacher Beliefs and Practices

A large theme emerged about the participants’ beliefs and practices when integrating literacy in the classroom, which is divided into five subthemes: Benefits of Combining Literacy and Science, Recurrent Integration of Literacy Strategies, Differences between Science Disciplines, Use of Technology in the Science Classroom, and Written and Oral Communication.

#### 4.3.1 Benefits of Combining Literacy and Science

The three participants all thought of incorporating literacy strategies into science in different ways. The specific classroom activities and strategies the participants mentioned will be discussed in greater detail in chapter five. Ariana talked about how she likens scientific processes to stories: “I often use terms like ‘the story thus far’ […] I use little things like the flashback, y’know going back in time and then trying to be able to allow students to recognize, I’m teaching a concept but I’m teaching it with a storyline so then at least they’ll be able to make connections to it.” Ariana felt that by using story metaphors, students are better able to relate to what is happening in, for example, a chemical reaction, where there is a beginning, middle, and end.
Ariana commented that when more literacy-based activities are done with students, they are more engaged, motivated, and enjoy science since the activities feel more real and authentic.

Lily thought of language as being a foundation for any subject, including science, and felt that when students do not have that strong foundation it impedes their ability to communicate their understandings effectively. Fleur echoed Lily’s sentiment by saying that language is an essential component for all subjects and feels that having strong language skills helps a person experience greater success in science. However, literacy skills go beyond knowing how to speak and write properly. In language-based classes students are expected to develop inferencing skills (Ontario Ministry of Education, 2007a; 2007b) so that even if something is unknown to them, they can use contextual clues to make sense of the new information. Lily found that many students struggle with making inferences, so she looks for opportunities to introduce new terms to students and encourage them to use textual clues to find the meaning. For example, she uses the word “lethal” on a test every year within the following sentence: “This gene is lethal, […] if this is the case, how many organisms will die?” Instead of using a simpler word or telling students what the word means, she tells them to interpret the word meaning based on the sentence. As mentioned previously, Lily said she tries to move students from shallower fact recall and term memorization to deeper questions and term understanding.

In the literature, the importance of sufficient background knowledge and an appropriate scientific vocabulary were stressed (Fisher, Grant, & Frey, 2009). Students need to know the relevant knowledge and terminology in order to engage with science and to help them make inferences about the new information they are consuming (Fisher, Grant, & Frey, 2009). It is important to note that science provides a context for students to learn literacy strategies, so students need that background in order to develop effective communication.
4.3.2 Recurrent Integration of Literacy Strategies

When it came to incorporating literacy strategies into their science classroom, the three participants discussed how they try to include these techniques in a daily and as recurrent as possible way. As was mentioned above, Fleur frequently makes use of on-task talk so students can discuss concepts with peers. These talks are usually triggered by Fleur providing a science news article for the class to read. Ariana also expressed the importance of critically thinking about a concept so that ideas can be exchanged with others. Lily frequently mentioned that she finds it challenging to integrate literacy strategies due to the limited time and apparent lack of resources (these challenges will be addressed further below). Due to these challenges, Lily’s approach is to find easy ways to embed literacy. For example, when teaching new terms Lily tries to break down complex ones into parts and help students identify the origins of words (e.g. hydrolysis, where “hydro” means water, and “lysis” means splitting). By breaking down scientific terms, it allows students to connect this new term with prior knowledge, creating connections. Her rationale for conducting this activity is that this allows for a deeper understanding of the term, as opposed to a superficial memorization, which she pointed out could be problematic for students on tests or exams if a student has a momentary lapse of memory. Another simple tactic she mentioned is the strategy of continually requiring students to infer the meaning of words based on context, discussed above.

Ariana had more experience both in teaching and in incorporating literacy so she expressed a lot of comfort in including literacy strategies in her science classes. Ariana felt it is important to provide students with a variety of ways for students to express their understanding of science, including oral and written communication. For Ariana, variety was not only important in methods for students to communicate, but also important in lesson delivery. She believed
teachers should not feel tied to only using slideshow programs for students to take notes, but also make use of the board for drawing diagrams or writing out processes to allow “students to think in different ways.” Ariana also stressed the importance of finding an appropriate teaching strategy that would cater to the concept one is trying to teach. For example, she would not ask students to draw out the concept of floating or sinking densities; that idea would be better explored through a lab activity. Similarly to Lily, Ariana discussed the importance of vocabulary and ensuring students are aware of correct definitions and terms, echoing Lily’s strategy of explicitly teaching students new terms. Ariana pointed out that in science, the same word is often used to represent different concepts in science (e.g. nucleus refers to atomic nucleus and the cellular nucleus), thus she gives her students a variety of activities to help them practise the correct use of terminology (such activities will be discussed further in chapter five).

Having a variety of ways students can engage with science is mentioned in the literature (Froschauer, 2004). Froschauer stresses that reading, writing, speaking, and listening are key methods to developing vocabulary and understanding science (2014). Having students use these strategies on a regular basis, as ongoing practise, can help them improve these skills (Winstein, 2014).

**4.3.3 Differences between Science Disciplines**

When asked if there were differences between chemistry, biology, and physics, in terms of integrating literacy strategies, both Lily and Fleur commented that biology is usually perceived to be the subject where reading and writing is most important. Lily said that in chemistry and physics there is not as much written expression; the communication leans more towards mathematical problem-solving as opposed to written expression (although she did say that written communication is still present in chemistry and biology). Fleur did not teach physics,
so she could not comment on that, but agreed that students in biology tend to expect more reading, writing, and presentation, and less lab work. In contrast, Ariana felt that the pedagogy and teaching strategies she used were not very different across the three domains. Her approach mirrored her daily teaching philosophy discussed previously, where the strategy used needed to be a good fit for the concept. She found some activities were flexible enough to be used in any of the science domains.

Although not discussed at length, the perceived differences between the three main subject domains in science were touched upon in the literature review. Garnes (2014) notes that if a physicist is asked a question about biology, that physicist is in the same position as a non-scientist in terms of being able to answer that question. It would seem that as one moves up in science academia, the divide becomes greater between the three major domains. This can already be perceived by students in high school since in Ontario the science courses diverge from general content to specialized biology, chemistry, and physics in grade 11 and 12 (The Ontario Ministry of Education, 2008a; 2008b).

4.3.4 Technology Use

The three participants expressed a range of opinions on the use of technology in the science classroom. Lily overall felt the need to limit technology in her classroom because she believed that students are already so exposed to technology in their daily lives via smart phones and other technologies. She suspected that constant screen-time limits students’ literacy and language development, mentioning that students will email her using text message abbreviations as opposed to using proper grammar and spelling. In an effort to help students develop their literacy and language skills, Lily believes there needs to be more human interaction in the classroom. Lily also pointed out that plagiarism via technology can be an issue; she found that
students often copied answers from the Internet and shared each other’s answers, so because of this she does not see what the students are actually capable of. However, Lily was not completely opposed to technology, and discussed how she would use videos and science simulations as supplements to her lessons to provide a more visual component to explaining a concept. She also mentioned that her school had its own online school system that was new that year (called Edsby) that mimicked a Facebook interface where students can have written discussion with each other and the teacher.

In contrast, Fleur voiced that she wished she could use technology more in her classroom. Fleur also used an online learning platform that modelled Facebook (called Edmodo) where she posts tools that may help students such as online flashcards (e.g. QuizLet). Within class she said she sometimes uses online surveys like Kahoot.it where students can respond with answers via their personal devices or by using devices from the school’s iPad cart. However, she commented that she would like to use technology more because her usage was mostly through knowledge delivery, such as using PowerPoint for students to take notes, or showing videos.

Ariana expressed that technology really supports her teaching because technology allows students to communicate their understandings through a variety of different mediums (e.g. video and podcast projects). She was thankful for having access to online learning platforms so students can collaborate and share ideas together through that program. Ariana also stressed the importance of students accessing real scientists’ work. Though Ariana did not elaborate on this last point, this could be assumed to be access to scientific journal articles and databases where current research findings are published. As was mentioned previously, Ariana enjoys modelling student communication in her classroom, so using social media platforms like Twitter is a valuable tool in her teaching. Ariana also discussed the low-tech options she uses in her class, for
example if a teacher cannot (or would prefer not) to use Twitter, he/she can ask students to write Tweets on chart paper, and limit them to only using 140 characters, simulating the actual technology. Other low-tech options were mentioned, such as students expressing their understandings through puppets, or manipulatives like Play-Doh.

It is logical that technology emerged as an aspect of each participant’s teaching since technology is growing at a rapid pace (Leshner, 2003). It was interesting to see a spectrum of beliefs from the participants when it came to technology’s integration in the science class and it may be worth exploring in other research how much technology benefits (or impedes) student literacy skills. Fleur’s response that she would like to include technology more suggested that teachers may want to incorporate technology more in their teaching but certain obstacles (e.g. school funding, teacher training, etc.) may prevent that from happening.

4.3.5 Written and Oral Communication

The three participants shared that clear written and oral communication is a highly necessary skill in the sciences. As discussed previously, Lily found that students’ communication of their science understanding is their weakest area in class. When it came to comparing written to oral communication, Lily thought that while both are important, there is greater opportunity for written communication than there is for oral in the science classroom; she wished to find more opportunities for oral communication in her classroom. In connection with assessment, Lily stated that she could not evaluate participation in her classes, though she wished she could, so this may suggest to students that oral communication is not as valuable as written, since oral communication is not evaluated as often. Although it is not evaluated, Lily really valued participation since she said it allows students to process information before they verbalise their understandings.
Fleur and Ariana both suggested that they try to include a balance of both written and oral communication in their classes by providing many different writing and on-task talk activities. Ariana thought that students needed both oral and written practice because oral communication supports a student’s ability to do the written component. She stressed that oral communication is very important so students can collaborate during process tasks, such as completing labs.

Ariana’s point about oral communication being important during a process such as a lab echoes Thier & Daviss (2002) who said it is important for students to engage in inquiry-based activities that also develop their literacy skills. Fleur’s on-task talk activities are cited as especially good for students to make sense of the guided inquiry they are encountering (Thier & Daviss, 2002). Again, providing a variety of activities and opportunities for students to communicate seems to be an important factor in both the interviews and the literature.

4.4 Assessment

This theme will focus on participants’ views on the assessment of students’ demonstration of written and oral communication in science. Two subthemes emerged, where the first focuses on the participants’ rationale behind how they do assessment, including what each participant felt is important to focus on within assessment. The second subtheme addresses what assessment strategies and tools the participants said they use in their classrooms.

4.4.1 Assessment Rationale

The trend in Lily’s assessment rationale is that she tries to provide students with ongoing practise. Lily mentioned giving students frequent pop quizzes that would not be evaluated, but only served as a check-in for herself and the students to know how they are progressing. Lily also talked about how one of the goals in her department’s PD project is to develop an article
program that aims to progressively build analysis skills, where each grade focuses on a particular skill. Lily wanted to focus on the ongoing progression of skills and knowledge.

Similarly, Fleur valued trying to integrate literacy assessment whenever possible, in a daily ongoing way, as opposed to a large final project at the end of the course. Fleur felt that an ideal situation would be that students are given a writing task like a simple essay, she marks it so students receive feedback, and then she can assign another paper so students have multiple chances to work on those writing skills. However, Fleur conceded that this is simply not possible because of how copious the marking then becomes, so this tension of assessment that is best for students, versus how much marking Fleur is capable of doing was a challenge she expressed. As a result, she pares down her assessments into shorter, less thorough responses to articles to make the marking more manageable.

Ariana’s assessment rationale echoed her rationale of finding an appropriate teaching strategy for a concept. Similarly, any assessment being done should be complimentary to how a concept was taught, for example, she would not give a multiple choice test if that is not how the concept was initially taught to the students. She stressed that she cannot teach an idea one way then assess it with a different method. Ariana mentioned that she does not wish to “mislead the students” so that if they are doing a drawing activity in class, that activity should be assessed in a formalized way. Ariana had a similar rationale to Lily where she tried to implement a progression of skill-building with writing lab reports. Instead of having students write up a full lab report every time, Ariana has students focus on parts of the report (e.g. introduction and purpose) and then build up to a formal lab report near the end of the course. The reasoning behind this is that Ariana felt students often do not see how the different elements work together.

\footnote{For example, in grade 9 students work on learning how to summarize, in grade 10 they focus on reading comprehension, grade 11 the focus is on application of concepts, and grade 12 would focus on asking “what if” questions to take a topic further.}
in a final lab report, so she would rather they understand each part before tackling the full piece altogether.

The idea of providing ongoing feedback to students parallels one of the fundamental principals in the Ontario *Growing Success* document to support student learning and achievement (Ontario Ministry of Education, 2010). Emphasis is put on Assessment as Learning as opposed to the big final task, so students are given multiple chances to improve their skills before being assigned an evaluative mark. This shift in emphasis may support student engagement and success (Ontario Ministry of Education, 2010).

### 4.4.2 Assessment Strategies and Tools

Lily remarked that the majority of her department’s evaluations are done through tests and exams; however they did also assign students assignments. In response to the plagiarism issue that was raised by Lily in the context of technology, she talked about doing in-class independent writing tasks where students are given questions and are allowed to use both online and book resources, but must work individually on the task in a limited timeframe. To assess oral communication, all three participants mentioned having students do presentations in front of the class as well as looking to see which students are participating. Although Lily said she could not evaluate students’ participation, it is a method all three participants mentioned using to look for which students are (and are not) understanding the material.

In an effort to provide students with frequent feedback as well as creating a manageable marking load, Fleur has students peer mark each other’s work. She talked about how during certain activities (e.g. debates) that she will walk around observing students through informal assessment. Ariana also discussed circulating the room and looking at student notebooks to assess students comprehension (or lack thereof). When asked what Fleur looked for when
assessing a student’s ability to communicate effectively (both written and orally), she mentioned that important items would be a student supporting their statements with specific examples and using their own words, as opposed to reciting verbatim from definitions. Ariana agreed that having students express understandings in their own words is important. She extends this exercise in a more formal way by asking pairs of students each week to highlight the main ideas from the week. Fleur said she uses rubrics, although not very often. Within tests and exams, she detailed how the department is starting to change how these evaluations are scored, where the communication mark is awarded in a holistic, overall way based on how students answer questions involving writing. Fleur suggested there is some tension in trying to implement this newer method: “We’re starting to change the way that we score our tests, so um, this brings up a whole can of worms about levelled marking.” Perhaps utilizing levelled marking and rubrics is somewhat challenging due to many people perceiving science as prioritizing correct calculations and answers over the quality of students’ demonstration of written communication, as Fleur mentioned previously.

Echoing her belief of allowing students to express themselves in a variety of ways, Ariana also tries to have variety in her assessments. She talked about using rubrics to assess communication, but also to provide a holistic mark of a student’s overall quality of work when drawing a microscope diagram with titles and labels, for example. Similarly to Fleur, Ariana mentioned not using rubrics as often, saying she uses ranking systems usually, although she appreciated how rubrics give a greater sense of a true evaluation of a student’s achievement.

The use of rubrics for assessment purposes did not come up in the literature review, although it is reasonable to see why Fleur and Ariana would use them at times to assess student

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16 A mark would be awarded based on if students used proper notation, laid their answer out in an organized way, an answer’s clarity, etc.
communication since rubrics are readily available for English teachers to assess essay writing in the Ontario English curriculum (via the Achievement Chart) (Ontario Ministry of Education, 2007a; 2007b). Participation is also an indicator for student comprehension and links back to previous discussion about how science conversation helps to develop literacy skills as well as science understanding (Froschauer, 2004).

4.5 Challenges

The participants mentioned many challenges they experience when trying to implement literacy strategies in the science classroom. Three subthemes emerged of how these challenges can be grouped: inexperience challenges, nature of the job challenges, and student challenges.

4.5.1 Inexperience Challenges

Lily and Fleur both voiced concerns that stemmed from having some inexperience with integrating literacy into science. Lily felt that she, along with her teaching partners in the department, did not have enough background in English and literacy to then feel confident in teaching their students literacy skills, hence their desire to develop PD and other resources for the department. Lily thought that while incorporating literacy into science was being discussed in the education community, she did not feel supported with resources. She mentioned trying to find guest speakers and literature to assist science teachers specifically in learning literacy skills so they may then teach it to their students. Both Lily and Fleur voiced some concern with integrating literacy skills when they already had to teach so much science content; Fleur cited how a grade 9 culminating project became scaled down over the years where the literacy component was cut out.

Fleur also voiced desire for teacher training, especially with respect to assessment. She felt insecure in how she should assess students in their communication. Fleur talked about how
she was sometimes called to lead PD sessions but would prefer to have more opportunities to attend these sessions, so she may learn from others. Resources were also something Fleur expressed a desire for, however she specified that she really needs “worked-out examples” of lessons where she can see how the teacher executes a lesson, the result of the lesson, and the tools and strategies used by the teacher, as opposed to others’ simple ideas on how to implement literacy strategies in science.

These inexperience challenges strongly parallel the challenges discussed in the literature review. It was cited by several authors that secondary science teachers in general do not feel very confident in their ability to teach literacy (McCross-Yergian & Krepps, 2000; Park & Osborne, 2006). The desire for PD is logical since many science teachers (like Lily) do not have an English background to support them, so this suggests that it may be beneficial to provide more explicit literacy preparation in pre-service teacher programs for secondary school teachers.

4.5.2 Professional Capacity Challenges

All three of the participants, especially Lily and Fleur, voiced frustration with not having enough time. Lily specifically mentioned not having the time to look for resources, and the actual integration of literacy. She also discussed how it was difficult because she felt all the science curriculum being taught is important, so it would not make sense to remove those components in order to bring in literacy. The lack of time helps to explain why Lily adopted more “easy integration” methods as opposed to devoting an entire period to developing literacy skills. She noted that in an effort to save teachers time, teaching certain literacy skills should become more efficient in the high school years because she found that in grades 9, 10, 11, and 12 she repeats teaching concepts every year, such as writing bibliographies or lab reports. Echoing her department’s desire to create a progression of skills through the years, she wishes there was
some standard where students learn these skills so there are no redundancies in the upper years. With respect to PD sessions, Lily mentioned that along with time, there needs to be consideration for funding of those sessions (i.e. reimbursing teachers if sessions occur outside of school hours, or hiring a substitute if the sessions occur during school hours).

A lack of time was also a big issue for Fleur since it limited how much she could mark and evaluate her students. She expressed wanting to provide her students with more thorough assessments, but since she is the sole marker, the load is not manageable (and students do not receive feedback often enough). Providing much denser writing assignments also means she does not have the time to prepare other interesting elements in the course since all she is doing is marking. Interestingly, she noted that time management can also be an issue for students. She mentioned being wary of giving students video and audio projects sometimes because students can become so absorbed in a small design aspect of the task that the class time is now gone and the students are nowhere near done the project.

Ariana did not mention time being an issue as often as the other two participants; however she did mention that a lack of time means she does not have as many opportunities to collaborate with other teachers and share ideas. Ariana suggested that teaching involves a lot of juggling and multitasking because she mentioned needing to provide accommodations for different students such as teaching at different rates (e.g. a slower pace for her ELL students), and providing different materials to cater to their level of understanding. With her ELL students, she talked about needing to revisit concepts frequently and providing supplementary materials to aid in their understandings, along with breaking up readings into smaller segments. However, she noted this latter strategy can be challenging in grade 12 where curriculum expectations are higher, and there is a lot of content students must learn. Ariana also brought up how many high
school classes are starting to grow in size, saying that she has a class of 35 students. While she expressed not having trouble managing such a large class (she mentioned this being due to her own comfort in teaching along with the fact that all her students were high-functioning and on-task most of the time), she did concede that other classes in other contexts could be very challenging to manage for teachers.

Time is already a valuable commodity for secondary teachers (McCross-Yergian & Krepps 2000), so taking time to also teach literacy skills can feel like an obvious strain. It is unfortunate that literacy is an important priority for the Ontario Ministry of Education (Queen’s Printer for Ontario, 2011) and yet science teachers do not feel supported in teaching literacy skills.

4.5.3 The Challenges of Students and their Effects on Teachers

All three participants mentioned how some challenges they experience revolve around students, or challenges that students experience in class. Lily talked about how student motivation and attitude towards teaching strategies are a factor in learning (e.g. she mentioned students had not “bought into,” or showed interest into, the idea of engaging with the new online learning platform quite yet). Fleur also mentioned that students’ attitudes can be a challenge teachers deal with if they are not motivated to participate in a lesson, for example. As was mentioned previously, students’ abilities to time manage is something teachers need to consider when assigning certain projects, so that students can make good use of school resources during the school day. Fleur also touched on how students’ presentation anxiety (particularly ELLs) can affect their ability to orally communicate effectively. She said ELL students are usually more comfortable with expressing themselves in writing and can be very nervous speaking in front of the whole class. With regard to presentation anxiety, Ariana also noted that ELL students can be
wary of speaking in front of large groups, so using puppets can provide a greater comfort level for the student since attention is focused on the puppet as opposed to the student.

Although Ariana’s school had a high socioeconomic background, she did acknowledge that for teachers teaching in low socioeconomic areas, it is important to consider that students do not always have parents at home to help their child with homework. As a result, certain activities like journals where the student writes to a parent/guardian and the parent/guardian responds may need to be reconsidered, or the teacher should make themselves available as a writing buddy for the student.

This subtheme stresses the fact that teachers at the end of the day are supporting students, and need to be constantly cognizant of student engagement, abilities, and challenges. In terms of providing students with literacy-building activities, teachers should consider providing students with a variety of opportunities to communicate their understandings, as mentioned previously. This variety will ensure that students’ strengths are seen. Flexibility on a teacher’s part is also worth considering for certain activities (e.g. for students who are anxious presenting in front of others, the teacher can suggest the student present in front of a small group, or only to the teacher).

4.6 Conclusion

To conclude this chapter, I reported and discussed the emergent themes from the interview transcripts. Through the interviews and my own literature review I have learned that the topic of integrating literacy strategies into science is one with a lot of context to consider. In Beliefs about Science and Literacy within Education, the participants discuss the educational divide between science and English and the consequences of this divide. In Preparing Students for the Future, I explored the participants’ views on science citizenship and developing twenty-
first century skills. In Teacher Beliefs and Practices, the participants detailed their approaches to including literacy in science as well as their opinions on literacy within a science context. In Assessment I presented the participants’ approaches and rationale to assessing student communication in science. Finally, in Challenges, I reported on the many hurdles and difficulties experienced by the participants when implementing literacy into science. Next, in chapter five, I discuss the implications and recommendations as a result of this study.
Chapter 5: IMPLICATIONS

5.0 Introduction

Within this chapter I provide an overview of the key findings and their significance from this research study, namely, how a sample of secondary science teachers foster effective communication in the sciences. I discuss the implications of the research findings in terms of both the broad implications for the educational research community, as well as the narrow implications relevant to my own professional identity and practice. I go on to make recommendations for the educational community based on the research findings. Finally, I point out areas where further research is needed and provide concluding comments on the significance of the research study.

5.1 Overview of Key Findings and their Significance

This research project began when I started to think about my own experiences in post-secondary education and the segregation of subject areas, particularly the sciences and liberal arts. I began thinking about how the educational divide of subjects can serve to make students believe they are only skilled in one area of education; one is either a science person or a liberal arts person, either a calculations person or an essay-writing person. Within my own Chemistry major I found fellow students were often wary of writing and their writing skills had room for improvement. I wanted to know if science teachers at the high school level were incorporating strategies to help students develop competent writing skills within the context of science. After exploring the research, I realised that I also wanted to explore oral communication, so I broadened my research question to ask, how is a sample of secondary school science teachers fostering effective written and oral communication in the sciences? I set out to find what perspectives these teachers have on the role of written and oral communication in science
education, as well as the instructional strategies they use to foster effective science communication. Additionally, I wanted to learn how these teachers assess and evaluate their students on communication.

I conducted a literature review in chapter two that examined the issues surrounding writing in science; specifically the issues of scientists adhering to conventions that make science inaccessible for a wider audience as well as unclear writing\(^\text{17}\) often found in science papers. I then looked into the research discussing how incorporating literacy into science can not only help students better understand science, but also improve their writing skills within the sciences.

Within chapter three I presented my research methodology which outlined the qualitative study, consisting of a literature review and three semi-structured interviews. Three female high school science teachers from the Greater Toronto Area were recruited for the study. I also addressed the recruiting procedures, ethical considerations, strengths, and limitations, of the study. The consent letter and interview questions provided to participants can be found in Appendix A and B, respectively.

I presented my research findings in chapter four, where five major themes emerged: Beliefs about Science and Language within Education, Preparing Students for the Future, Teacher Beliefs and Practices, Assessment, and Challenges. Many of the findings linked to and supported the literature review. For example, the subject divide between science and English and the potential consequences of this divide. Participants also voiced their interest in fostering critical thinking and science citizenship, as well as twenty-first century skills. In terms of integrating literacy into science, the participants echoed many strategies found in the literature, while also providing insights on how they assess students in science communication. The

\(^{17}\) I.e. poor use of the passive voice, verbosity, overlong sentences, grammatical and syntax errors, and needless repetition (Bredan, 2013).
challenges voiced by participants were those that arose from feeling inexperienced in implementing literacy into science as well as the ongoing impediments teachers in general may experience, such as a lack of time for marking and planning.

I now go on to address the implications, recommendations, and areas of further research based on the research findings.

**5.2 Implications**

Within this section I illustrate the implications of the research study. I examine the broad implications that would apply to the educational research community, such as students, teachers, administrators, initial teacher education (ITE), the Ontario Ministry of Education, and the Ontario provincial government. I then discuss the narrow implications that apply to my own professional identity as a teacher and researcher.

**5.2.1 Broad: The Educational Research Community**

This research study has illustrated some of the consequences of the subject divide between science and English. Since different subject areas are typically compartmentalized into different periods in high school, with different teachers teaching each subject, this may suggest to students that one becomes either a person strong in science or a person strong in English. This can be problematic since it limits what students believe they are capable of, so a student in science may not see themselves as a writer despite the fact that communication is so important in the sciences, which has been discussed at length in the literature review and research findings. This subject divide affects teachers as well, since science teachers may have difficulty thinking of themselves as language teachers because their specialty is in science. The participants’ comments in the interviews echoed this idea of science teachers not seeing themselves as language teachers. This disconnect between science and language has the potential to make
teachers feel uncomfortable in integrating literacy strategies into their science classroom since they may not feel confident in their ability to do so. Two participants, Lily and Fleur, shared comments about feeling inexperienced with what strategies or assessment tools to use when integrating literacy into science. Lily especially voiced concerns about the lack of resources available for a teacher wishing to implement literacy into science. These inexperience challenges suggest that teacher education programs are not sufficiently preparing secondary science teachers to teach their students literacy strategies in the context of science. The concern about teacher resources for teaching literacy in a science context also suggests that school administration and/or the Ontario Ministry of Education is either not providing enough resources for science teachers or not advertising these resources effectively to teachers.

Through the literature review and research findings, this research study has emphasized the benefits of integrating literacy into science. Not only can literacy-based activities help students improve their science communication, it can also assist students in better understanding science concepts. Science and literacy reciprocally work together in improving communication skills and concept understanding. For secondary science teachers, integrating literacy into science may be seen as difficult, especially if they feel inexperienced in teaching literacy-based activities or strategies. Teachers may also have the belief that teaching literacy skills will take away valuable time teaching science concepts, which is a valid concern. However, teachers should also keep in mind that since the literacy skills can be taught in the context of science, teachers can teach science content while also teaching literacy skills at the same time.

Communication skills include both written and oral expression, and so both are important skills for students to develop. Through the participant data, it was suggested that there may be less opportunity for oral communication in the science classroom compared to written, and that
written expression is evaluated more often than oral. This emphasis on written over oral may suggest to students that oral communication is not as important as written, which can be problematic. One participant, Ariana, believed that oral communication was important in order to support written expression, as well as allowing students to collaborate during activities. This idea that written expression is perhaps more valued over oral in the classroom is interesting because it is not clear why this discrepancy would emerge. Perhaps ITE programs have not prepared secondary science teachers in evaluating oral communication, and placed an emphasis on written communication. Another possibility is that perhaps written expression has traditionally been more valued in assessing a student’s achievement in science.

A key finding that emerged from the participants’ comments was the idea of providing literacy activities and assessment in an ongoing and recurring way. For students, this is beneficial because it provides them with ongoing practise and feedback to better improve their communication skills. While beneficial for students, this may also present challenges for teachers since it requires teachers to provide relevant activities and feedback continuously throughout the course. Teachers may feel overwhelmed in trying to provide students with meaningful tasks and keeping up with marking and providing feedback.

When trying to integrate literacy strategies in the science classroom, the participants voiced how some of their challenges were not specifically to do with implementing literacy, but with challenges that teachers in general may face (i.e. lack of time and lack of teacher collaboration). For teachers, the challenge of not having enough time affects multiple areas. Teachers may not have enough time to plan effective literacy activities/tasks for a science context, to mark and provide feedback for these literacy tasks, and to allocate class time for literacy tasks while also addressing science curriculum. The lack of time for these different areas
may lead to frustration and an attitude that it is not worth the stress of implementing literacy strategies into science. Not having many opportunities to collaborate with other teachers about incorporating literacy into science can also impede science teachers from learning effective and helpful strategies for their own teaching. This lack of time affects students as well, since they do not get the benefit of learning effective science communication skills if their teacher is too burnt out to implement effective literacy skills into their science class. Students also miss out on a greater variety of literacy activities if teachers do not get the opportunity to share ideas with each other. If teachers are increasingly feeling that there is not enough time for them to effectively teach their students, it may suggest that school administration is not providing enough opportunity for teacher collaboration. It is also possible that class sizes are too large for teachers to be able to provide ongoing and useful feedback for every student. The issue of large class sizes is related to the amount of funding school boards receive from the Ontario provincial government, which limits the number of teachers board can hire. This suggests the government is not funding schools enough so that teachers can have a more manageable marking load to benefit students.

5.2.2 Narrow: My Professional Identity and Practice

This research study has served to not only inform me of the many aspects of improving written and oral science communication, but has also helped me learn about the components and nature of qualitative research. The research has reaffirmed my beliefs to integrate literacy strategies into my science classes. I begin this section by addressing the implications of the research for me as teacher, then go on to discuss the implications of the study as a researcher.

The issue of the subject divide between science and English addressed earlier is something I need to consider going into the teaching profession. I plan on becoming a science
and English teacher but recognize that my science teacher peers may not see themselves as language teachers. Since I have conducted research on the topic of integrating literacy into science I can act as a potential resource in this area for other teachers. I also want to make it a priority to teach literacy in my science class so students see that just because science and English are two separate subjects in school does not mean there is no room for cross-curricular integration, and that the two subjects actually support each other.

After conducting the literature review and analysing the interview transcripts I see that cultivating critical thinking and the twenty-first century skills of communication and collaboration are so important for me to do in my future teaching. It is helpful that these skills can be fostered through implementing literacy into science, since students gain the skills just mentioned while also getting the benefit of improving their science communication and gaining a better understanding of the science material. The three participants brought up excellent ideas that can help develop critical science discourse, communication, and collaboration. These include newspaper article analyses, case study analyses, controversial debates, simple essays, science demonstrations, think-pair-shares, class discussions, research pamphlets, mini conferences, journaling, and magazine/newspaper creation. I want to make literacy a regular part of my science teaching to show students the connections between science and English but also to help them develop critical thinking in science, collaboration, and effective communication skills.

A theme that emerged in the research findings was that of providing students with literacy activities in a recurrent and ongoing way. Ongoing feedback was also found to be an important aspect. This philosophy has always made sense to me since repeated practice always helped me in better understanding concepts in my own schooling. I would like to provide multiple opportunities for my students to develop their science communication skills, along with
providing them with helpful feedback so they can improve. From my studies in the Master of Teaching program the concept of Assessment as Learning addressed in the *Growing Success* document echoes this idea of providing students with ongoing and frequent feedback (Ontario Ministry of Education, 2010). I think it is an important part of teaching and aim to make it a regular part of my own teaching.

As mentioned previously, it is important for students to practise both written and oral communication in science, so I aim to try and include many opportunities for students to “talk science” with each other, to borrow Fleur’s term from chapter four. Having students do think-pair-share on science topics will allow them to consolidate and extend their thinking with partners, and can act as a precursor to a writing task. I plan on trying to include a balance of both written and oral communication in my classroom so students see the value in both types of communication. However, I do feel somewhat unprepared in evaluating students on their oral communication since that has not been addressed extensively in my own ITE. I foresee having difficulty in creating rubrics or checklists that would serve to properly measure a student’s ability in orally communicating.

In terms of general assessment, I have learned from my participants that rubrics and checklists are helpful tools when assessing both written and oral communication, so these will be an important part of my assessment practice. Fleur mentioned in her interview that her department was experimenting with giving one Communication mark on tests based on students’ written communication throughout all the questions. This is an intriguing idea that I would like to try in my own future teaching. I have also learned that it is not necessary to evaluate every piece of work students complete in my class, and that Assessment as Learning is a valuable way
to monitor student progress. As a result, I will provide ongoing feedback and practise to students to help prepare for the larger tasks that will be evaluated.

The challenges listed above, namely a lack of time, resources, and teacher collaboration, have me feeling concerned about implementing literacy strategies while also dealing with the many other expectations of being a teacher. I expect that it may be challenging to find time to collaborate with other teachers during my day, so I plan on continuing to subscribe to teacher resource pages online and through social media. My participants also shared advice for new teachers that I plan on taking. These include taking part in professional development whenever possible, finding a mentor teacher, subscribing to science organizations, collaborating with teachers whenever possible, being aware of school board-specific targets, staying aware of how both scientists and students communicate, and observing other teachers whenever possible. Lily shared that it would be good for teachers to try implementing literacy strategies into science at the beginning of their teaching career because it can be hard to deviate from original plans as time passes. Finally, Ariana reminded me to not be afraid to try new things even if they do not work right away.

As a researcher, this experience has been at times extremely engaging and interesting and at other times challenging and tedious; however I have learned a lot about both my topic and the qualitative research process, so this has been a rewarding experience. This project has reaffirmed to me the importance of teaching practices being supported by research. I think it can be easy for individuals to think a certain way of teaching is optimal based on their own anecdotal evidence, but going forward as an educator, I wish to be more critical of new teaching methods as they are presented.
Looking back at the methodology of this study, it would have been helpful if I could have conducted student surveys in addition to the semi-structured interviews. This would have helped me to see how students feel about literacy activities being integrated into science. Observing my participants teaching their classes would have also been extremely helpful so I could collect first-hand evidence of what strategies they were using and how engaged their students were in the activities.

5.3 Recommendations

Within this section I make my recommendations for the educational community, specifically making recommendations to teachers, school administration, ITE programs, and the Ontario Ministry of Education and Ontario provincial government.

5.3.1 Teachers

The educational subject divide between science and English which has been previously discussed is something that secondary science teachers should keep in mind when discussions around communication in science arise. Since many science teachers will probably not have taken language courses while completing their science degrees, it is important for them to be cognizant of how they speak about their own writing abilities in front of their students. If students hear that their science teacher sees himself/herself as being strong in numeracy, but not literacy, it may reinforce the binary of science and literacy being opposites. Science teachers may also feel inexperienced in trying to implement literacy into science, so they should seek out professional development (PD) whenever possible to help support their teaching. Teachers should also consider observing others teaching, and collaborating with their peers to develop new pedagogical strategies. English teachers may also want to consider conducting certain class activities or units where science is a topic to help show that the subjects do not need to be
compartmentalized, and there is room for cross-curricular integration (e.g. a unit on media literacy could focus on the topic of global warming in the news). Teachers in all departments may want to think of ways they can make cross-curricular connections in their classes.

Science teachers should familiarize themselves with the benefits of combining literacy and science, namely that students not only develop their communication skills, but literacy activities also serve to reinforce the science content. Literacy strategies also provide opportunities where teachers can foster critical thinking and science citizenship, as well as collaboration in their students. Critiquing popular science articles and conducting debates on controversial science topics can help students develop critical thinking skills. Science teachers should be conscious that it is important to provide students with a balance of opportunities to practise both their written and oral communication in the classroom. There should also be multiple chances for students to be assessed in both forms of communication so students see that both skills are important within science. Teachers may also want to share with their students how scientists communicate so students understand a teacher’s reasoning behind certain communication activities. Events like mini-conferences can model for students what so-called “real” science communication and collaboration looks like.

Providing students with different forms of science writing can help broaden student perspectives on what science communication looks like; for example, having students read science fiction, peer-reviewed journal articles, popular news articles, etc. Essentially, students should be exposed to a variety of science writing. Not only should students be reading different writing forms, but they should also be experimenting with different writing. Thus, teachers should provide opportunities for students to write, for example, fiction with accurate science
elements. Students can also be given a science notebook where writing associated with lab work is done (i.e. observation tables, predictions, hypotheses, post-experiment discussions, etc.).

5.3.2 School Administration

School principals and other administrators may want to consider encouraging more cross-curricular integration across different subject areas, particularly in science and English, where the divide is arguably very prevalent. This may help students see that problems that need solving in our society today are not science-only problems, but problems that require skills from several areas. Administrators should also be aware that many of their science teachers will probably not feel comfortable implementing literacy into their classes, and so should provide relevant PD to support these teachers. Dedicated time and space should also be provided where teachers can collaborate more with each other in order to share ideas and support each other.

5.3.3 Initial Teacher Education Programs

The literature review and participant data suggests that secondary science teachers do not feel prepared to implement literacy into their science classrooms. A conjecture could be made that ITE in Ontario is not teaching secondary science teachers how to effectively also teach literacy. ITE programs should explicitly illustrate to science teacher candidates how to implement literacy activities into science. Particular attention needs to be paid to how science teachers can assess and evaluate their students in literacy, since the research participants voiced that this was a specific area where they required support. ITE programs need to also show science teacher candidates how to provide opportunities for both written and oral communication, since the research findings suggest written communication may be favoured over oral.
5.3.4 Ontario Ministry of Education and Ontario Provincial Government

The participant data suggested that science teachers wishing to implement literacy strategies can find it difficult to find resources to support their efforts. The Ontario Ministry of Education has created a “Think Literacy Library” resource which provides documents that help to implement reading, writing, and oral strategies in subjects from grades 7-12 (Ontario Ministry of Education, 2015). There are specific documents that address implementation strategies for grades 9 and 10 science; however there are currently no documents for grades 11 and 12 (Ontario Ministry of Education, 2015). The Ontario Ministry of Education should consider providing additional resources to support science teachers with integrating literacy, but also better advertising current resources so teachers are aware of their existence. It is unfortunate that literacy is an important priority for the Ontario Ministry of Education (Queen’s Printer for Ontario, 2011) and yet science teachers do not feel supported in teaching literacy skills.

The research participants shared that as teachers they sometimes feel restricted in providing effective literacy strategies in their science classes due to limited marking time. It is possible that class sizes are too large for teachers to provide ongoing and useful feedback for each and every student as frequently as teachers would like. Large class sizes are related to how many teachers a school can hire based on the funding given to schools by the Ontario provincial government. The Ontario provincial government should seriously consider increasing funding to schools so more teachers can be hired to better accommodate all students. If class sizes are too large then teachers must be selective in what to assign students in order to keep their marking load manageable. This results in students possibly missing out on more practise of their science communication skills.
5.4 Areas for Further Research

Through conducting the literature review and reporting the research findings, there were some areas that emerged as important to further investigate. This research study was conducted to show how integrating literacy into high school science classes has the potential to improve science communication. It would be helpful to look into other ways that writing and other forms of communication in the sciences can be improved. For example, should post-secondary science programs require students to take a literacy-based, or communications course in conjunction with science courses? Or should science program coordinators consider making writing and other forms of communication an important aspect of science courses? Additionally, the issue of why science should be more accessible to both scientists and the public should be examined. As has been previously discussed, accessibility of science is important as we move into an evolving world where science and technology is developing at a faster and faster rate. This relates to the important skill of scientific literacy, and having enough knowledge of science to understand scientific developments that are reported on in popular media. This research study touched on the importance of scientific literacy, but was not explored extensively. It is important to research effective strategies and resources that teachers can use to better teach their students how to be scientifically literate.

Many literacy strategies were discussed in this research study to help student communication in the sciences, and participant answers suggested that these activities can also be helpful for English Language Learners (ELL). ELL and strategies around teaching ELL were not examined in this study, but it would be interesting to see research investigating how effective these literacy strategies are in helping ELL students to both learn science material and develop their English language capabilities.
After examining the research findings, I find that it is still not extremely clear what the most effective assessment strategies are when it comes to evaluating student science communication. Participants mentioned using rubrics, checklists, and casual observation to check on student achievement in communication; however it would be beneficial if future studies could evaluate the effectiveness of different strategies, and whether there are other useful methods.

Student enjoyment and engagement was not measured within the scope of this research study, so it would be useful for future research to examine students’ opinions of literacy activities within the context of science. This could perhaps be conducted through surveys and/or observation of classes.

5.5 Conclusion

The subject of science is not often associated with the liberal arts, and is in fact often held in juxtaposition with language-based and writing-based subjects. However, this research study has illustrated that continuing to create the binary of science versus the liberal arts is problematic for scientists since this can lead them to not see themselves as writers or communicators, when communication is actually of great importance to science research. Scientists are expected to write journal articles publishing their findings, persuasive arguments for research grants, and communicate their findings to other scientists at research conferences. One way to start deconstructing the binary of science versus liberal arts as well as to begin fostering effective communication in science is to integrate literacy strategies into the high school science classroom.

This research study was conducted in order to learn how a sample of secondary school science educators are promoting effective written and oral communication skills in their
classrooms. I set out to investigate what these teachers’ perspectives were on the role of written and oral communication in the sciences, and what instructional strategies, approaches, and learning resources they use in order to foster effective science communication. Additionally, I wanted to learn how these teachers assess and evaluate their students, as well as what challenges they experience when integrating literacy into the science classroom. All three participants felt that students need to be able to have good communication skills in order to be successful in science. Through the interview data, communication emerged as an important skill to facilitate collaboration in the classroom as well as to help better understand science material. The participants also shared that fostering good communication skills in the science classroom had broader implications for students to become critical thinkers and engaged citizens in society where science and technology is evolving and such an important part of our lives.

With this research I aimed to show the reciprocal benefits of bringing literacy into science, where not only do students have the opportunity to develop their communication skills, but literacy strategies can also help reinforce science concepts. I also hope to have illustrated the problems with poor science communication where I explain traditional science writing conventions as well as poor writing skills that serve to often make science writing impenetrable.

It would be recommended for high school science teachers to examine the research findings in order to gain insights on the benefits of integrating literacy into their science classrooms. Several strategies have also been mentioned, so this study may act as a resource for teachers interested in implementing literacy strategies in the classroom. The study may also be of interest to high school principals to show the benefits of encouraging more cross-curricular approaches, specifically with literacy and science, in high school classrooms. Additionally, ITE programs in Ontario should consider these research findings when developing their programming
for secondary science teacher candidates. Since literacy is an important priority for the Ontario Ministry of Education, ITE programs should be better preparing their secondary science teacher candidates to foster literacy in their future classrooms.

As a future educator, this research study has served to inform me of the importance of communication in science, and how effective science communication can be fostered through utilizing particular literacy strategies. I plan on using the research findings from this study to inform my own future teaching, and I hope this knowledge will also assist other educators in their teaching. Through this research I hope to have reinforced that it is problematic to think that a scientist need only be brilliant at solving an equation; a scientist must also be able to explain what has been done, and so, as one of my participants so concisely worded it: “it is actually all about communication.”
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Appendix A: CONSENT LETTER

Date:

Dear _______________________________,

My name is Georgina Mantelos and I am a student in the Master of Teaching program at the Ontario Institute for Studies in Education at the University of Toronto (OISE/UT). A component of this degree program involves conducting a small-scale qualitative research study. My research will focus on how science educators are promoting effective written and oral communication skills in their classrooms. I am interested in interviewing high school teachers who integrate literacy strategies in the science classroom. I think that your knowledge and experience will provide insights into this topic.

Your participation in this research will involve one 45-60 minute interview, which will be transcribed and audio-recorded. I would be grateful if you would allow me to interview you at a place and time convenient for you, outside of school time. The contents of this interview will be used for my research project, which will include a final paper, as well as informal presentations to my classmates and/or potentially at a research conference or publication. You will be assigned a pseudonym to maintain your anonymity and I will not use your name or any other content that might identify you in my written work, oral presentations, or publications. This information will remain confidential. This data will be stored on my password-protected computer and the only people who will have access to the research data will be my course instructor, Professor Eloise Tan. You are free to change your mind about your participation at any time, and to withdraw even after you have consented to participate. You may also choose to decline to answer any specific question. I will destroy the audio recording after the paper has been presented and/or published, which may take up to a maximum of five years after the data has been collected. There are no known risks or benefits to participation, and I will share with you a copy of the transcript to ensure accuracy.

Please sign this consent form, if you agree to be interviewed. The second copy is for your records. I am very grateful for your participation.

Sincerely,

Georgina Mantelos
georgina.mantelos@gmail.com

Eloise Tan
Course Instructor
eloise.tan@utoronto.ca
Consent Form

I acknowledge that the topic of this interview has been explained to me and that any questions that I have asked have been answered to my satisfaction. I understand that I can withdraw from this research study at any time without penalty.

I have read the letter provided to me by Georgina Mantelos and agree to participate in an interview for the purposes described. I agree to have the interview audio-recorded.

Signature: _____________________________________________

Name: (printed) _____________________________________________

Date: ______________________________________________
Appendix B: INTERVIEW QUESTIONS

Thank you for participating in this research study. The study aims to learn about how effective written and oral communication can be promoted in the science classroom. The interview should last approximately 45-60 minutes. I will ask you a series of questions about your own background as an educator, followed by your own teaching beliefs, teaching practices, and finish off with any challenges and supports you may have encountered. I want to remind you of your right to choose not to answer any particular questions. Do you have any questions before we begin?

Background Questions

1. What brought you to becoming a teacher?
2. What are your teachable subjects?
3. How long have you been teaching?
4. What grades and subjects are you currently teaching?
   a. Which grades and subjects have you tended to teach throughout your teaching career?
5. Which types of students do you tend to have within your classes? (e.g. academic? Applied? ELL?)
6. Can you tell me about the school you currently teach in, for example, in terms of size, demographics, and program priorities?
7. What experiences contributed to your interest in teaching science? (e.g. personal, professional, educational?)
8. As you know, I am interested in learning how science teachers promote effective written and oral communication skills. Can you tell me how you developed an interest in this topic? (e.g. any experiences that contributed to this interest and commitment; your own school experiences in K-12 or post-secondary; professional development, experience in terms of the accessibility of science, etc.)

Teacher Beliefs

9. From your own teaching experience, how important do you feel written communication is in the sciences? Why?
10. How important do you feel oral communication is in the sciences? Why?
11. Are science teachers language teachers?
   a. Should they be? Why or why not?
   b. Is developing literacy skills in science classes equally as important as developing them in other subjects, such as English or History? Why?

Teacher Practices

12. What goals do you have in terms of your students’ communication skills in the science classroom?
   a. How do you create opportunities for them to attain these goals?
13. Can you provide some specific strategies/examples of how you implement literacy strategies in class? (e.g. particular activities, types of lessons, etc.)
   a. What resources do you find most helpful?
   b. What role, if any, does technology play in your teaching?
14. How effectively do you feel students are able to communicate their science knowledge in their writing? In their speech?
15. Have you noticed any developments in terms of overall student success in the science classroom when literacy skills are taught?
16. What indicators do you look for from your students to help you know that they can effectively communicate science concepts?
17. How do you assess students’ written communication in the science classroom? Oral communication?
   a. Are students’ writing skills weighted towards their final science grade?

Challenges, Supports, and Next Steps

18. What range of factors and resources support you when teaching literacy in the science classroom?
19. What challenges do you encounter in this work? How do you respond to these challenges?
20. What kinds of resources or factors would further support you to meet these challenges?
21. When trying to integrate literacy strategies in the science classroom, are there any challenges or differences you have experienced when dealing with the different subjects (biology, chemistry, physics)?
22. What advice do you have for beginning science teachers who are committed to fostering effective written and oral communication as outcomes of science education?