The Use of Epistemologically Considerate Texts in Ontario Classrooms:

Reading the ‘Nature of Science’

By

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Abstract

Unlike many textbooks, epistemologically considerate (EC) texts give the justification behind their claims and are used by some teachers to help their students become ‘scientifically literate’. Previous research has noted a range of positive and negative effects on students. For this qualitative grounded theory study, three Ontario teachers were interviewed who have experience with these tools, to provide data on their usage in the province. Findings suggest that teachers who use EC texts are dedicated science teachers, with a strong student focus, and thorough understanding of the Nature of Science (NOS). Teachers employed a variety of tools, most notably the use of inquiry projects, and some direct instruction to use these texts, and found generally positive effects on their students. Participants reported an improvement in scientific writing ability, understanding of NOS, critical thinking and other factors, while stating that this may come at the cost of confusion and stress for some students. They also noted that lack of time, lack of community and lack of resources – both material and intangible – as factors that may limit EC text usage. In the future, the creation of a teacher community whereby resources can be shared would be beneficial to the implementation of EC, as well as greater professional development for teachers interested in teaching about the NOS.

Keywords: Nature of Science, epistemology, literacy, classroom texts
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1.0 Context of the Study

At least a basic level of science understanding is necessary to thrive and be competitive in the 21st century (Trefil & O’Brien-Trefil, 2009). This basic level is generally referred to as ‘scientific literacy’ and is the overall aim of science education (DeBoer, 2000; Laugksch, 2000; Ontario Ministry of Education (OME), 2008; Osborne, 2014; Yore et al., 2004). It has been so since the early 1960s (DeBoer, 2000; Laugksch, 2000).

Defining scientific literacy, however, is an incredibly difficult task, with controversy about the term arising between many knowledgeable parties (Laugksch, 2000). Should scientific literacy be focussed on deep comprehension and evaluation of a few relevant concepts (Bisanz, Zimmerman & Bisanz, 1998)? Or should scientific literacy mean fundamental literacy: the ability to read and write in science (Norris & Phillips, 2003)? There are myriad definitions of scientific literacy and, with little consensus found among parties, it is important to note these definitions change frequently and are place-based, in that what it means to be scientifically literate in Ontario may not be what it means to be elsewhere (DeBoer, 2000). At present, the local Ontario Ministry of Education (OME) (2008) curriculum definition reads: “Scientific literacy can be defined as possession of the scientific knowledge, skills, and habits of mind required to thrive in the science-based world of the twenty-first century” (p. 3).

In Ontario, science is a mandatory subject until grade 10 (age 16), by which point students should ideally be scientifically literate (OME, 2008). The success of this education affects both the student directly, in their ability to survive in this environment, and the nation as a whole. Laugksch (2000) writes that societies with a high general level of scientific literacy are more likely to support scientific endeavours while simultaneously understanding more of what
science is able to accomplish. The Ontario science curriculum (OME, 2008) gives teachers guidelines as to how students should accomplish this literacy and emphasizes three goals of the program: “1) To relate science to technology, society and the environment; 2) To develop the skills, strategies, and habits of mind required for scientific inquiry; 3) To understand the basic concepts of science” (p. 4).

Achieving these goals is largely under the control of individual teachers, and the use of texts in the classroom can help achieve these aims (Chiapetta & Fillman, 2007; Lumpe & Beck, 1996; Suppe, 1998). Predominantly, teachers use textbooks in their classrooms which can be very useful but also have significant flaws (Chiapetta & Fillman, 2007; Lumpe & Beck, 1996). For example, traditional textbooks tend to use language that overstates the certainty in statements and does little to represent the processes of science (Chiapetta & Fillman, 2007; Suppe, 1998). To combat the problems found in textbooks, some authors have pioneered the use of non-traditional text types, which offer a deeper understanding of scientific processes (Yarden, Norris & Phillips, 2015).

Scientific processes to create knowledge, conducted by a community of scientific practitioners using agreed upon norms and values, form what is known as the ‘nature of science’ (NOS) (Osborne, 2014). Nature of science is often referred to the ‘how’ of science and is intricately related to the participants and social context of the science being performed (Osborne, 2014). Recently, addressing NOS through instructional practices has become more of a mandated priority for science teachers in Ontario (McNay, 2000; OME, 1998; OME, 2008) and around the world (DeBoer, 2000; McComas, Almazroa & Clough, 1998). Once more however, defining what NOS means is a contentious topic (McComas, Clough & Almazroa, 1998). Definitions, like
those of scientific literacy, are ever-changing and operate in a specific time and space (Abd-El-Khalick & Lederman, 2000).

McComas and Olson (1998) found numerous areas of overlap on NOS in curricula from around the world. In the Ontario context, the OME definition is less well defined, and makes mention to the three aforementioned goals of the curriculum. A more detailed definition comes from Osborne et al.’s 2003 Delphi survey of science professionals, wherein nine themes emerge as vitally important:

1) Scientific methods and critical testing; 2) Creativity; 3) Historical development of scientific knowledge; 4) Science and questioning; 5) Diversity of scientific thinking; 6) Analysis and interpretation of data; 7) Science and certainty; 8) Hypothesis and prediction; 9) Cooperation and collaboration

‘Epistemologically considerate texts’ – a term coined by Kloser (2013) – “[refers] to texts that make explicit at least some aspect of the history behind or the justification for its stated claims” (Kloser, 2013, p. 1233). Proponents of non-traditional, ‘epistemologically considerate’ (EC) texts, say that these tools can help address NOS, as well as content knowledge (Braun & Nueckles, 2014). Moreover, they argue, these texts provide an ‘authentic’ learning task, which is highly emphasized within the Ontario curriculum (OME, 2008), as well as educational reform movements (Lee & Songer, 2003). Epistemologically considerate texts do not usually include textbooks (which are written in an expository style) (Chiapetta & Fillman, 2007; Penney et al., 2003; Suppe, 1998), but do include scientific articles, which due to their argumentative nature contain a large amount of justification for their claims (Baram-Tsabari & Yarden, 2005; Braun & Nueckles, 2014; Suppe 1998). Teaching using primary scientific literature (PSL) is one approach used to increase students’ NOS understanding, but can be difficult due to the presence of
esoteric, jargon-heavy language (Baram-Tsabari & Yarden, 2005; Norris, Phillips & Yarden, 2015), so some education researchers (e.g., Yarden, Brill & Falk, 2001) have devised a technique for adapting primary scientific articles for easier use with high school students. This ‘adapted primary literature’ (APL) maintains the same structure as primary scientific literature, the same stance (argumentation) and the same epistemic elements (claims and reasoning used) and thus falls into the category of ‘epistemologically considerate’ (Kloser, 2013; Yarden, 2009; Yarden, Brill & Falk, 2001; Yarden, Norris & Phillips, 2015).

Research in the last decade has shown that using APL, PSL and other EC texts can have mixed results (Ford, 2009; Osborne, 2009). On the positive side, EC texts can increase: students’ understanding of content, trust in scientific content, interest in scientific content, confidence with scientific content, understanding of NOS, scientific reading skills and scientific practical skills (please see Chapter Two for sources, or Yarden, Norris & Phillips, 2015 for a summary). On the contrary, other papers have shown that in some circumstances EC texts can have deleterious consequences. For instance, leading to decreases in students’ understanding of content and interest, or having no effect on NOS understanding (please see Chapter Two for sources). Clearly then, using EC texts can have mixed results, and may or may not be a helpful tool in the fulfillment of Ontario curriculum guidelines.

Researchers have created numerous techniques that they recommend for the implementation and usage of EC texts (please see Chapter Two for sources, or Yarden, Norris & Phillips, 2015 for a summary), yet no one method has appeared to be ideal for students’ learning. What is apparent from studies however, is the importance of the teacher and the teacher’s pedagogical content knowledge in activities using EC texts (Brill, Falk & Yarden, 2008; Osborne, 2009). Thus, the usage of EC texts in Ontario classrooms is still debatable; in particular
how to teach using EC texts in an effective manner that helps students learn. It is important to know how teachers are implementing the use of EC texts in Ontario classrooms.

1.1 Purpose of the Study

The purpose of this qualitative study is to examine some Ontario science teachers’ use of EC texts in their classrooms. I gathered data by interviewing Ontario science teachers with EC text experience about their: background, use of EC texts in the classroom, perceived effects on their students, and perceived factors that affected their implementation and success. From these texts, I built a grounded theory (Corbin & Strauss, 1990; Corbin & Strauss, 2014; Glaser & Strauss, 2009; Merriam, 2002; Taylor, Bogdan & DeVault, 2015) of which Ontario science teachers are using epistemologically considerate texts, how they are using them, to what effect, and what limits their further implementation. EC texts can be positive tools to achieve expectations set by the Ontario curriculum, and understanding how teachers use these texts may help inform teaching practice in Ontario and help other teachers effectively use these resources. Furthermore, if we can understand what the effect of using these texts on students may be, teachers may come to decisions regarding their inclusion in school science classes. This study offers a snapshot of what contemporary EC text usage looks like in Ontario science classrooms.

1.2 Research Questions

The central research question guiding my study was: how are epistemologically considerate texts being used in Ontario classrooms? I used the following subsidiary questions to further focus my inquiry:

1) What are the backgrounds and characteristics (etc.) of teachers who are using epistemologically considerate texts?
2) Which teaching strategies do teachers report as the most and least effective in the use of EC texts?

3) What are the perceived effects of using EC texts on students?

4) What supports and challenges have teachers faced in their use of these texts?

1.3 Background of the Researcher

Throughout my studies in Biology at the University of British Columbia, I enjoyed the opportunity to read and analyze primary scientific literature – something that was engrained in my family where scientific knowledge, hard work and productivity are heavily favoured. As a child I was exposed to research science through my family members, and through my academically-demanding high school: I had always imagined that this would be the path I would tread. I have a deep connection to academic science which, I have to come to realise, most high school students do not share.

As an English-speaking, straight, cis-gendered, private-school-educated, white settler Canadian with a family background in science, I acknowledge that many doors have been opened wide for me, which for some students are closed firmly. Despite institutional racism and academic prejudices limiting equity and diversity in the subject area, I believe that the study of science and biology has the power to reach every student, and positively impact their lives. As an educator, I seek to find ways to entertain and inspire students so that students may leave the classroom with positive ideas of science. This will help contribute to scientific literacy, which is absolutely necessary for life in the 21st Century. I believe critical literacy (the ability to analyze sources) is one skill that is becoming increasingly important, as misinformation spreads wide across the internet, and the body of information available to citizens increases. I am interested to
learn how the use and analysis of EC texts in science classrooms may build this skill. I seek to understand how it is already being used by teachers, so that it may hopefully advance as an aim.

1.4 Overview

Scientific literacy is an all-important goal of the Ontario science curriculum (OME, 2008), I analyse through this qualitative research study how EC texts are being used in Ontario as a tool to enhance this. In Chapter Two I assess current knowledge on epistemologically considerate content: their potential effects - both positive and negative, and how EC texts are reportedly being used by teacher-researchers. In Chapter Three, I explain the chosen methodology (qualitative grounded theory) and research design used in my study. Chapter Four contains the findings of my research, answering my research question. In Chapter Five I pose broad and narrow implications from the findings, recommendations based on these implications, as well as areas for future research.
Chapter Two: Review of the Literature

2.0 Introduction

I begin this literature review by discussing the positive and negative aspects of using epistemologically considerate texts reported in the research literature. I then review research on implementation of epistemologically considerate (EC) texts, noting some specific methods as well as discussing general trends in science instruction. Finally, I discuss challenges for teachers in EC implementation.

2.1 Reported Effects on Students

In this section of the literature review I briefly synthesize the positive and negative effects associated with using epistemologically considerate texts in the high school classroom. One of the major issues in attempting to synthesize these findings is that where one paper may report positive findings in one area, another will contradict it or that within the same paper there will be both benefits and drawbacks to using these types of text.

2.1.1 Potential positive effect: Comprehension of content

The Ontario science curriculum merits teaching specific content expectations, which it expects all science teachers to fulfill (Ontario Ministry of Education (OME), 2008). Some research papers suggest that using EC texts in the classroom may actually increase all students’ comprehension of these content expectations.

In a quantitative questionnaire-based study with German high school students Braun and Nueckles (2014) found that although students comprehended little of previously unseen content on New Caledonian crows, there was no negative effect on text comprehension depending on whether students read a purely scientific article, a modified version, a popular journalistic version or a textbook account of the content – comprehension was not limited by medium. Baram-Tsabari and Yarden (2005) found similar results. Moreover, Braun and Nueckles note
that modified research articles can elucidate some evidential structures for learners with low scientific knowledge content, leading to their greater comprehension (2014). In a qualitative study Schmidt, Kowalski and Nevins (2010) found similarly that students of all abilities were able to critically analyse and comprehend scientific articles equally. Similarly, using two high-achieving students Brill, Falk and Yarden (2004) showed that given enough time, students can achieve a very high level of deep comprehension.

Kloser (2013) showed that although students spent the same amount of time reading both traditional textbooks and epistemologically considerate texts, after the task the students found the EC text easier to comprehend overall, although the students did have more questions about content when reading EC texts. In this paper, students mentioned the use of visual representations in science papers as particularly helpful to their comprehension; compared to textbook versions the students claimed these explained content more effectively.

2.1.2 Potential positive effect: Comprehension of the nature of science

Epistemologically considerate texts have been shown to increase students’ understanding of the nature of science (NOS) in some circumstances. Problems arise in this area, in that papers tend to define NOS differently, or analyse different aspects of it. In a 2014 study Braun and Nueckles showed that EC texts increase students’ understanding of the constructive and argumentative nature of science. Interestingly, students starting the study with a good understanding of NOS did not increase their understanding as much as students with little NOS knowledge.

Additional studies (that use different NOS measurement criteria), have reported that reading EC texts can increase students’ NOS understanding (Brill & Yarden, 2003; Clark et al., 2009; Falk, Brill & Yarden, 2008; Hoskins, Stevens & Nehm, 2007; Kloser, 2013) – most
notably understanding the method and methodology as well as the justification for the authors’ conclusions (Brill & Yarden, 2003). Kloser (2013) found that students’ understanding of the scientific evidence at the end of the course correlated with a scientifically sophisticated epistemological stance. Even in young children (grade 6) Shanahan (2010) found that students could comprehend the uncertainty behind scientific discoveries - one aspect of NOS.

Hoskins, Lopatto and Stevens (2011) and Gottesman and Hoskins (2013) found that after a course using EC texts students’ epistemology regarding the nature of knowledge became more sophisticated (from innate and fixed, to flexible and relative). In their earlier study (Hoskins, Lopatto & Stevens, 2011), students’ scientific epistemologies also increased; they understood the creativity, motivation and collaboration inherent to scientific enterprise. The authors note that this shift in personal and scientific epistemology usually occurs a lot more slowly as students age (Hoskins, Lopatto & Stevens, 2011). Schommer (1993) found that these nuanced, sophisticated personal epistemological beliefs also predict students’ academic achievement, even outside science class. Thus EC content may increase students’ academic success in other subjects by enhancing epistemological beliefs.

2.1.3 Potential positive effect: Student relationship to science as a discipline

Using cutting-edge research may increase students’ interest in the subject matter compared to traditional text types (Kloser, 2013; Norris et al., 2009; Yarden, Brill & Falk, 2001), perhaps because of the novelty of this knowledge or the relevance of these topics to students’ lives (Norris et al., 2009). In a course using only abbreviated versions of scientific articles (abstracts and figures) Schinske et al. (2008) assessed pupil interest in the article analysis and found an overwhelmingly positive view of scientific articles. Some studies (Gottesman & Hoskins, 2013; Hoskins, Lopatto & Stevens, 2011; Hoskins, Stevens & Nehm, 2007) have found
students actually become interested in science as a whole through reading research articles. This group at CCNY found that undergraduate students became interested in the job of being a scientist, and noted increased engagement with science. This culminated in more positive views of science and scientists as people.

Kloser (2013) found that the epistemic structure of scientific papers (Braun & Nueckles, 2014; Suppe, 1998; Yarden, Norris & Phillips, 2015) not only increased interest, but also increased trust in the statements made by the authors, and trust in the scientific process as a whole – as students could see exactly how the conclusions arose.

2.1.4 Potential positive effect: Student self-confidence

The use of EC texts can have a positive influence on students’ sense of self-efficacy and confidence in science. In both high school students (Kloser, 2013) and university freshmen (Gottesman & Hoskins, 2013) participants felt more confident in comprehending and criticizing science than after a course using traditional textbooks. Even in younger students (grade 6) Shanahan noted that students felt encouraged in their ability to read after completing the research article (2010). This boost in confidence may be attributed to the supportive atmosphere offered by the teacher while analysing the text (Yarden, Brill & Falk, 2001).

One common theme is that students had to overcome initial doubts to end up more confident. Koeneman, Goedhaart and Ossevoort (2013) and Schinske et al. (2008) showed that despite initial trepidation, secondary school students grew confident in their ability to analyse research papers. Clark et al. (2009) show similarly in college undergraduates.

In a long-ranging librarian-led study, Schmidt, Kowalski and Nevins (2010) showed that after overcoming their doubt high school students gained a sense of confidence that persisted until college applications and beyond. Furthermore, in Kozeracki et al.’s 2006 study using
undergraduates this long-lasting confidence extends beyond simply scientific skills into personal self-confidence, confidence in submitting postgraduate applications and presentation skills. Hoskins, Stevens and Nehm (2007) and Hoskins, Lopatto and Stevens (2011) also reported increased confidence in scientific skills that transferred across classes and disciplines.

2.1.5 Potential positive effect: Scientific reading skills

Naturally, courses where reading and analysing content is heavily weighted, students may become more competent at these skills. The identification of epistemic statements and main conclusions from papers – implying the deeper fundamental literacy mentioned by Norris and Phillips (2003) - was improved in high school students studying an EC-based course (Koeneman, Goedhaart & Ossevoort, 2013).

Furthermore, in line with scientific literacy research highlighting the need for a critical stance when analysing scientific knowledge, numerous authors have showed EC courses increased critical thinking skills in high school students (Baram-Tsabari & Yarden, 2005; Brill & Yarden, 2003; Norris, Stelnicki & DeVries, 2012; Yarden, Brill & Falk, 2001) and undergraduates (Clark et al., 2009; Gottesman & Hoskins, 2013; Hoskins, Lopatto & Stevens, 2011; Hoskins, Stevens & Nehm, 2007; Segura-Totten & Dalman, 2013; Wenk & Tronsky, 2011).

2.1.6 Potential positive effect: Scientific practical skills

EC texts can also have an effect on students’ understanding of the practical inquiry of science: doing science experiments. Baram-Tsabari and Yarden (2005) showed that reading adapted primary literature increased students’ scientific creativity skills and their ability to think of the next experiment, while Gottesman and Hoskins (2013) showed that students designing the
next experiment had improved planning skills. Furthermore, Janick-Bueckner (1997) and Kozeracki et al. (2006) noted that UCLA students felt more capable of doing research.

Hoskins, Lopatto and Stevens (2011) note about their intervention using primary scientific literature with American undergraduates that:

Students changed significantly on summary variables that assessed self-rated ability to design experiments, visualize methods based on data, visualize lab activities based on the written account in the journal article, manipulate data, relate results of individual experiments to “the big picture,” critically review data, read science with appropriate skepticism, and explain results to others. (p. 373)

2.1.7 Potential negative effect: Comprehension of content

The effect of EC texts on student comprehension of content is contested, with studies in different contexts drawing contradictory conclusions. In a Canadian study, Norris, Stelnicki and De Vries (2012) found that students scored higher in comprehension after reading a secondary literature article (textbook style) than reading an APL article (an EC text) on the same topic. This finding has been echoed by other papers from around the world (Baram-Tsabari & Yarden, 2005; Brill, Falk & Yarden, 2004). Brill, Falk and Yarden (2004) posit that this is because the students lack the requisite automation and comfort level with the article structure, which may also lead to feelings of discomfort with the material (Scott & Simmons, 2006).

In contrast to many papers, Krontiris-Litowitz (2013) showed that undergraduate students did not increase their comprehension after a 2 year course using scientific articles. In addition, during his research on EC texts, Kloser (2013) found that although students rated the EC texts as easier to comprehend, they would prefer to study from a textbook. Kloser states this is because of the unfamiliar structure of scientific articles.
2.1.8 Potential negative effect: Comprehension of the nature of science

Braun and Nueckles (2014) show that despite the high school students’ improvement in their understanding of the argumentative and constructive nature of scientific literature, the use of EC content did not have an effect on the students’ understanding of the explanatory nature of science, ambiguity of scientific data or tentativeness of scientific knowledge. While noting undergraduate freshmen’s improvement in the majority of assessed NOS categories, Gottesman and Hoskins (2013) noted no significant improvement in students’ understanding of: the uncertainty about findings at the outset of an experiment (that scientists know what they will find); the collaborative processes involved in all aspects of experimentation; and the multitude of factors that may motivate a scientist.

2.1.9 Potential negative effect: Interest in science

Using scientific articles can be a daunting task for many students, and may act as a deterrence (Scott & Simmons, 2006). In a 2006 study, students anonymously reported that they strongly preferred working with traditional text types and found using the articles less helpful than the other course components like labs and lectures (Scott & Simmons, 2006). Indeed, the students studied by Baram-Tsabari and Yarden (2005) felt a lot more negative emotions when studying APL than when studying traditional texts and protested a lot more during the exercise.

2.2 Classroom Practice and Implementation of EC Texts

EC texts may have beneficial effects on students, yet there is no consensus on how best to implement these texts in an effective way in the classroom. In this section I report findings on how EC texts fit into wider trends in science instruction, discuss the importance of the teacher to EC text implementation, and note some methods researchers have used to introduce EC texts to the classroom.
2.2.1 EC texts and trends in science instruction

Present Ontario curriculum documents (OME, 2008) heavily favour Science, Technology, Society and the Environment (STSE) and Scientific Investigation Skills (SIS) over the previous content-laden curriculum (McNay, 2000; OME, 1998). This move to develop Scientific Investigation Skills is often used with the idea of ‘authentic inquiry’ as a way to learn and teach (Lee & Songer, 2003; OME, 2008). Reading EC texts may be a form of inquiry (Norris & Phillips, 2008; Phillips & Norris, 2009) or a stage of inquiry (Osborne, 2009) to meet Ministry SIS expectations. Since reading EC texts aligns with scientists’ real activities (Tenopir & King, 2004), these texts may also be ‘authentic’ (Lee & Songer, 2003). Hand et al. (2003) also state that teachers should move away from only inquiry-based experiments and toward analysis on the language of science and the thinking and problem-solving used by scientists.

In addition to SIS, the Ontario curriculum also mandates improvements to students’ critical thinking skills and particularly with when working independently, and with a variety of text types (OME, 2008). This critical stance to scientific literature is one that young readers of scientific articles rarely maintain but is a necessary part of science education (Yore et al., 2004). Like Hand et al. (2003), Yore et al. (2004) acknowledge the wide variety of scientific discourses and agree that evaluation of claims, evidence, fairness and certainty are crucial skills to it.

2.2.2 Importance of the teacher to EC text implementation

Teachers are an important resource when teaching using EC content. In studies where students were asked to read and understand APL without assistance, students fostered negative attitudes toward the task and moreover, had reduced comprehension (Baram-Tsabari & Yarden, 2005; Norris, Stelnicki & De Vries, 2012). Koeneman, Goedhaart and Ossevoort (2013) noted in particular the importance of the teacher as a vocabulary resource for students. The teacher may
act as a resource not only for the derived literacy (deciphering the text), but also for assistance in the development of fundamental literacy (Norris & Phillips, 2013). Yarden, Brill and Falk (2001, 2004) note that teachers act as a scaffold in students’ deliberate and purposeful reading of a research article. In their 2008 follow-up article Falk, Brill and Yarden state that teachers’ pedagogical content knowledge (PCK) explicitly molds the students’ comprehension, development of inquiry skills, enjoyment of and engagement with the activity. Teacher understanding of NOS (Abd-el-Khalick & Lederman, 2000; Brickhouse, 1990), and their valuation of it as an aim (Lederman, 1999), is also vital to effective instruction on it. Clearly then, teacher comfort with and understanding of EC content is vital for student comprehension of the material.

2.2.3 Methods for implementation

Some authors recommend strategies for the implementation of EC literature. Here I list some approaches demonstrated in the literature. The traditional approach, as used by Janick-Bueckner (1997) and Gillen (2006), usually uses three steps – reading, interpretation, and subsequent critical analysis. This has been shown to be as effective as other, more experimental techniques (Segura-Totten & Dalman, 2013). A comparable approach (Choe & Drennan, 2001) uses very similar steps, but the work is assigned as individual homework to be later brought together in class with colleagues. This technique works particularly well when analysing one issue from multiple angles. Like pieces of a jigsaw, the pieces come together to build a larger picture of the issues.

Despite publishing extensively on the benefits of using EC texts, Yarden’s team writes little on implementation strategies. Brill and Yarden (2003) do propose a question-asking
analysis, where a supportive atmosphere and the Socratic Method allow maximum student involvement in the text.

UCLA professors (Clark et al., 2009) designed and implemented a research deconstruction course using undergraduates in seminar sessions. Although this method was reportedly very successful it should be noted that these professors hand-picked high-achieving students to be part of this experimental cohort. In this program students remove jargon from scientific literature, identify the hypotheses, examine the methodology and analyse the data in primary scientific articles.

Finally, Hoskins, Stevens and Nehm (2007) pioneered the widely published CREATE approach with undergraduates. The CREATE approach uses mini-lectures and seminars with a framework: Consider, Read, Elucidate the hypotheses, Analyse and interpret the data, Think of the next Experiment. This method has been used extensively by Hoskins et al. and was shown to be at least as effective as the traditional approach used by other professionals (Segura-Totten and Dalman, 2013).

2.3 Limitations on Teacher Uptake

While teachers are crucial for the implementation of EC texts, and pedagogical content knowledge (PCK) affects this implementation (Brill, Falk & Yarden, 2008), Osborne (2009) notes that many teachers do not possess this high-level PCK. In a 2014 article, Osborne writes that teacher education does not explicitly address the practices of science or the associated epistemology, so that teachers may struggle to address these without additional training. Ford (2009) and Osborne (2014) claim that content knowledge does not suffice when it comes to effectively teaching with EC texts, and that teacher education does not effectively address this. Indeed, Abd-El-Khalick and Lederman (2000) write that teachers themselves may have a skewed
view of the nature of science, and that even a developed view of NOS does not ensure teachers can teach about it effectively (Abd-El-Khalick & Lederman, 2000; Brickhouse, 1990; Lederman, 1999). The problem therefore is three-fold; teachers may not possess the requisite understanding of NOS (Abd-El-Khalick & Lederman, 2000; Brickhouse, 1990); their program may not address this deficiency, and will not teach them how to effectively teach about NOS (Osborne, 2014).

Outside of intrinsic teacher difficulties, Ford (2009) notes the potential complications in selecting texts to use in classrooms, stating the importance of disciplinary differences in epistemology and NOS. Levine (2001) (in Wenk & Tronsky, 2011) note that teachers and university lecturers tend to choose articles that are incredibly influential but which may not always conform to the curriculum nor to guidelines for EC text choice set forth in Muench’s 2000 paper. Furthermore, the use of EC texts requires teachers to be active readers of primary literature themselves (Osborne, 2009) and be up-to-date with scientific developments, which may be unrealistic (Ford, 2009).

One perspective often offered by proponents of EC content is that it is a truly authentic task. Osborne (2009) in a response to a wave of articles regarding EC usage, writes that authenticity is self-crafted, and requires a connection with the material and dedication toward the goal of authenticity. Within this high-school activity, that may mean adapting a scientist’s worldview and behaving in a scientific manner, which may be a difficult task for high school students. Merely having authentic scientific literature does not make analysing it in a high school classroom authentic.

2.4 Conclusion

‘Epistemologically considerate’ (EC) texts try to represent scientific endeavour in its true sense: with justification and history behind the claims made (Kloser, 2013). In this chapter, I
reviewed literature on EC texts in the classroom. Use of these documents can have mixed results, but may increase students’ comprehension, interest, trust, confidence, understanding of NOS, scientific reading skills and scientific practical skills. Furthermore, these texts may provide an authentic experience (Lee & Songer, 2003), using reading as a form of inquiry (Norris & Phillips, 2003) in line with Ministry of Education SIS and critical thinking expectations. Using EC texts, and teaching about NOS effectively may require specific teaching strategies and pedagogical content knowledge (Abd-El-Khalick & Lederman, 2000; Falk, Brill & Yarden, 2008; Osborne, 2014). The objective of this study was to create a theory of how some teachers in Ontario are using EC texts. I sought to understand how teachers’ personal understanding of the subject has affected their teaching strategy, and what effects on students they have noted. I finally analyzed what barriers are in place to prevent wider acceptance of this learning tool.
Chapter Three: Research Methodology

3.0 Introduction

In this chapter I describe the research methodology used in this study. I begin the chapter by discussing qualitative research as an approach and then specifically define grounded theory as a research methodology. I then describe the methods of data collection and my sampling procedures, including the sampling criteria and recruitment protocol. Short biographies of research participants are then given. The data produced in this study were analysed in line with qualitative research standards; these procedures are explained. The ethical considerations of my interview-based research study are then reviewed. A discussion of the potential strengths and limitations of my chosen qualitative methodology follows. In the final section of this chapter I give a brief rationale for my chosen methodology and preview the following chapters of this project.

3.1 Research Approach and Procedures

I began this study by thoroughly examining the literature related to this topic (Chapter Two) and used these findings to inform my qualitative research design. This study uses semi-structured interviews with three teachers to generate a grounded theory of how and why teachers are using epistemologically considerate (EC) texts in Ontario.

Qualitative studies like this one are important to understand the uniqueness of personal experience and gain an in-depth understanding of a topic (Merriam, 2002), to change the issue or produce useful knowledge (Flick, 2007). Although it is hard to provide a generic definition for qualitative research (Flick, 2007), Denzin and Lincoln (2000) define qualitative research as “a situated activity that locates the observer in the world. It consists of a set of interpretative material practices that make the world visible” (p. 3). Qualitative research is generally performed
in the participant’s natural setting (Denzin & Lincoln, 2000; Jones, 1995) and analyses their subjective viewpoint and their construction of reality (Corbin & Strauss, 2014; Flick, 2007). Qualitative research requires researchers to analyse subjects’ inner experiences and internal formation of meaning (Corbin & Strauss, 2014; Taylor, Bogdan, & DeVault, 2015). This analysis requires deep connection with the participants and the data (Corbin & Strauss, 2014; Denzin & Lincoln, 2000; Taylor, Bogdan, & DeVault, 2015). This process, however, is flexible, and qualitative research allows the researcher to follow leads in data, connect with participants and take a holistic viewpoint, rather than focussing only on one topic (Corbin & Strauss, 2014).

Researchers produce qualitative research to impact the world (Denzin & Lincoln, 2005) whether by exploring and describing areas not yet thoroughly researched, discovering relevant contextual variables (Corbin & Strauss, 2014; Marshall & Rossman, 1995) or by understanding the processes behind phenomena (Marshall & Rossman, 1995). Once analysis has been completed, qualitative researchers have an obligation to share their research with the world (Corbin & Strauss, 1990).

Although there are common aims to all qualitative research, the actual structure of the research can have many different forms (Creswell, 2013; Flick, 2007). Creswell (2013) notes that each of these many types of qualitative research possesses a specific purpose and structure. In this study, I generated a grounded theory (Glaser & Strauss, 2009). A grounded theory is a substantive theory that uses highly descriptive data and inductive reasoning to form a theoretical explanation of why or how a phenomenon occurs (Corbin & Strauss, 1990; Corbin & Strauss, 2014; Glaser & Strauss, 2009; Merriam, 2002; Taylor, Bogdan & DeVault, 2015).

I sought to understand the use of epistemologically considerate texts in Ontario, generating knowledge about how and why some teachers use them to potentially inform other
teachers’ teaching practice. Qualitative research to create a grounded theory was the ideal choice for my research question because it allowed me to obtain richly textured data from my participants on their construction of knowledge about EC content in the classroom. I hoped to understand their unique experiences and thought processes, which was best achieved through qualitative research. My research question is not thoroughly understood, and performing this research increases understanding of the phenomenon and relevant contextual variables, and may eventually help other teachers: fulfilling some of the aims of qualitative research.

3.2 Instruments of Data Collection

Methodology and methods need to be tailored to the research question (Flick, 2007), and I chose to use a grounded theory for this study for the above reasons. In qualitative research, data collection and data analysis are simultaneous (Corbin & Strauss, 2014; Denzin & Lincoln, 2000; Merriam, 2002). We have already spoken of the deep connection between data and analyst, indeed, according to Merriam, the human is the main instrument of data collection and analysis (Merriam, 2002). Thus, biases and viewpoints of this individual need to be identified and analysed (Merriam, 2002), not for the positivist ideals of eliminating human error, but to add additional value and understanding to the analysis given these data (Peshkin, 1993). In a grounded theory in particular, researchers play an even more important role than other qualitative research. The researcher assumes the role of interpreting and making constant comparisons (Corbin & Strauss, 1990; Corbin & Strauss, 2014; Denzin & Lincoln, 2000) as well as systematic coding of data, and interacting with the participant to ask productive and concept-relating questions (Corbin & Strauss, 2014).

Data collection was in the form of face-to-face semi-structured interviews. Interviews, observations and documents are traditional sources for qualitative work (Merriam, 2002). Given
that a large part of my research project focuses upon epistemology and beliefs about teaching/learning, I found semi-structured interviews were the ideal data collection methods. Interviews like these allow the most effective discussion of beliefs in science teachers (Luft & Roehrig, 2007), and have been used by qualitative researchers very widely (DiCicco-Bloom & Crabtree, 2006; Luft & Roehrig, 2007). Semi-structured interviews use a formalized set of questions, but allow flexibility from this course, allowing the researcher ask additional questions and follow leads and tangents (DiCicco-Bloom & Crabtree, 2006). Semi-structured interviews allow collection of data on teacher’s thought processes that may not have been obtainable by observation or other methods of data collection (Patton, 1990). In addition, other methods of data collection such written self-reports may not always represent the most complete or accurate information, and in the teacher population may represent intentions not practices (Munby, 1982).

Furthermore, in a grounded theory study the researcher must follow new leads (Corbin & Strauss, 1990; Corbin & Strauss, 2014). Using a formally structured interview would have reduced my ability to adapt, and thus the quality of the data (DiCicco-Bloom & Crabtree, 2006). In a qualitative study, accuracy of data is increased by richness of participants’ explanation and analysis (Hussey & Hussey, 1997 in Dearnley, 2005), which is enhanced by thoughtful interview technique (DiCicco-Bloom & Crabtree, 2006). Although this study analysed only verbal data, face-to-face interactions can give the researcher access to additional information in the form of body language and non-verbal cues (Gordon, 1975), thus increasing accuracy of research. The reliability of a study can be increased by the use of probing questions (Barriball & While, 1994). Probing questions allows for: clarification, better content recall, easier access to sensitive issues and an opportunity to address inconsistencies between answers (Barriball & While, 1994). The semi-structured interview used in this study allows prompts and probing questions not found in a
structured interview, thus improving reliability.

I organised my interview protocol into 4 sections. This may be found at Appendix B. These are: personal information, ‘defining terms’, experience with EC content, thoughts on implementation. I scripted 23 questions, with numerous prompts. Examples of questions include:

- What do you think the Ontario Science curriculum means when it talks about scientific literacy?
- Could you walk me through the activities you use in a typical class studying EC content?
- Do you feel like EC content is accessible to every Ontario science teacher?

3.3 Participants

In this section I will discuss factors that affect qualitative research sampling, my own sampling criteria and procedures, as well as biographies for the three teachers who volunteered to be part of my study.

Sampling for qualitative research generally attempts to obtain data to effectively study a phenomenon through deliberately selected sources, not a random sample (Flick, 2007; Marshall, 1996). Grounded theory in particular relies heavily upon the use of theoretical and purposive sampling (Corbin & Strauss, 1990; Corbin & Strauss, 2014; Denzin & Lincoln, 2000; Glaser & Strauss, 2009; Marshall, 1996; Merriam, 2002). This method required that I create sampling criteria for the initial selection of applicants, but as the theory develops, and new avenues of explanation are required, seek additional sources (Corbin & Strauss, 1990; Corbin & Strauss, 2014). I started my study with three teachers, and found that these sources had valuable insights into all my research sub-questions. As such, I did not need to locate any additional participants.

Marshall (1996) notes that in qualitative research, unlike quantitative research, there is no necessary sample size: just enough to answer the research question effectively. Qualitative
researchers must however, acknowledge that their data cannot be generalized. The constructivist nature of qualitative research means that each individual provides a unique perspective (Merriam, 2002; Taylor, Bogdan & DeVault, 2015). The sample chosen locates the study in time, space and situation: giving it context (Marshall, 1996).

3.3.1 Sampling criteria

It is important to note that my research topic has had such little work completed on it that my potential sample net was very wide, and the knowledge gaps equally so. As such, my sampling criteria were not as rigorous as some other studies.

The following are the sampling criteria I used for the study:

- Participants must possess a valid Ontario College of Teachers certification and have worked in Ontario before the study. Teachers must have some knowledge of Ontario classrooms, as participants with experience from elsewhere would not assist in the development of an Ontario-based theory.

- Participants must have experience working with epistemologically considerate texts, but I sought a range of experience from the participants. I thought it likely that teachers change in their implementation and practice using epistemologically considerate texts over time. Much may be learned by comparing the knowledge of comparatively EC-inexperienced with comparatively EC-experienced teachers.

I also attempted to find participants with a range of professional and academic backgrounds, i.e., teachers from the TDSB, TCDSB and Independent school boards, as well as teachers with professional, undergraduate and graduate degrees. I additionally did not want to limit teachers to subject areas, and reached out to participants with a variety of scientific foci.
3.3.2 Sampling procedures

There are three main methods for finding a sample: convenience, judgement (purposeful) and theoretical (Marshall, 1996). This study used convenience and judgement sampling techniques to answer the research question and generate a grounded theory (Corbin & Strauss, 1990; Corbin & Strauss, 2014; Glaser & Strauss, 2009). I attempted to find participants to “maximize the depth and richness of the data to address the research question” (DiCicco-Bloom & Crabtree, 2006, p. 317). Convenience sampling refers to choosing easiest-to-find participants (Marshall, 1996), which in this study referred to the search for Toronto-based teachers. Purposeful, or judgement-based sampling, seeks to find the most knowledgeable interview participants (Marshall, 1996). In my case, this referred to limiting potential participants to those teachers with a range of epistemologically considerate content experience. In this study I planned on using theoretical sampling, but was constrained by the availability of research participants, and time. Theoretical sampling means using multiple recruitment attempts and selective criteria to improve and adapt interpretive theories grounded in the initial samples (Corbin & Strauss, 1990; Corbin & Strauss, 2014; Glaser & Strauss, 2009). Were I to continue my research with more participants, I would use theoretical sampling to add more detail to my grounded theory.

I focussed my search for participants around Toronto to utilize the links I have already built within the teaching community, and also because this area has the highest number of teachers in Ontario – so I was more likely to find a sample here. I reached out to academics in the field who I knew had done work in Ontario to find participants, as well as looking at publications by the Canada-wide Science Fair to find teachers that I knew were using EC content in their classroom. I also used snowball sampling (Marshall, 1996) to increase the likelihood of finding appropriate participants. I asked participants to inform other individuals of the study, or
recommend these individuals to the researcher, based on the assumption that teachers who use EC content may potentially know about other teachers using these tools.

### 3.3.3 Participant biographies

Michelangelo is a male teacher, teaching in the Toronto Catholic District School Board. He is a Head of Department at his school and has been teaching there for ten years. He has been Ontario College of Teachers (OCT)-certified for over 25 years. He completed academic research in a Biology discipline at a Canadian university, after completing an honours undergraduate degree in Biology and Psychology. He then obtained a Bachelor of Education (B. Ed.), before further pursuing his teaching studies into a Master of Education and Ph. D. He teaches grades 9-12, and is strongly focussed on getting students to apply their knowledge to real life situations, as opposed to pure content recall. He teaches in a school with a high Socio-Economic Status (SES).

Donnatella is a female teacher, teaching in the Peel District School Board. She is a Science teacher at her school and has been teaching there for six years. She has been OCT-certified for over five years. She completed a Master of Science degree in a Biology discipline at a Canadian university, after completing an honours undergraduate degree in Biology. She then pursued a B. Ed. She teaches grades 9-12, and is strongly focussed on improving students’ scientific literacy, and bridging the gap between laypeople and the scientific community. She has chosen to work in an inner city school with a high immigrant population and fairly low SES.

Raphael is a male teacher, teaching in the Peel District School Board. He is a Science and Special Education Teacher at his school and has been teaching there for three years. He has been OCT-certified for over 15 years. He completed a B. Sc. degree in Biology at a Canadian university, and then pursued a B. Ed. at an American institution. He teaches grades 9-12, and is strongly focussed on technological incorporation in the classroom. Raphael has intimate
experience with academic science through his family, many of whom pursued a career in this field. Raphael also prioritizes getting students connected to science and to scientists, hoping to provide them with a fun science experience in their time at school. Raphael teaches at a school with a fairly high immigrant population, and lots of English Language Learners (ELLs).

3.4 Data Analysis

Grounded theory requires simultaneous data collection and analysis, with the analyst becoming an all-important part of the research (Corbin & Strauss, 1990; Corbin & Strauss, 2014). Grounded theorists code emerging data as they collect it (Charmaz, 2000; Corbin & Strauss, 1990; Corbin & Strauss, 2014). The interpretation of data affects how grounded theorists collect future data through the process of theoretical sampling (Charmaz, 2000; Corbin & Strauss, 2015).

The coding process entails reading each line of the transcript carefully and determining the actions and events within each line of the interview dialogue (Charmaz, 2000; Flick, 2007). The codification process requires constant comparison between participants and situations, as well between the same person at different stages of the interview (Charmaz, 2000). This technique of close-reading and line-by-line coding ensures consistent analysis and leads to a deep understanding of concepts mentioned line by line, as one compares them to concepts mentioned earlier in the interview and elsewhere (Charmaz, 2000). These codes are then collated into larger categories (Charmaz, 2000; Flick, 2007). These categories shape the analytical framework and are elaborated upon in memos written by the analyst. Memos form an intermediate between categories and final theory generation. Through memo writing, grounded theorists can elaborate on the processes behind the phenomenon, identifying the assumptions, and exploring connections between codes. Moreover, the memo writing links theoretical ideas
with actions (empirical evidence) stated in the interview (Charmaz, 2000; Corbin & Strauss, 1990; Corbin & Strauss, 2014; Glaser & Strauss, 2009).

I used the above-mentioned data analysis process: analysing the interview transcript line by line, interpreting meaning, adding codes, creating categories of these codes and memos evaluating them, finally bringing categories together into themes. Categories were analysed to ensure internal homogeneity (all the information is connected) and external heterogeneity (all the information is different than other categories) (Patton, 1990). Themes collate information from categories to create meaningful contributions to the research question. These are my research findings, presented in Chapter Four.

3.5 Ethical Review Procedures

This study is unique in its ethical positioning. Grounded theories can be interpreted as somewhat positivist, in their search for a potentially generalizable theory (Charmaz, 2000). In addition, this research topic deals explicitly with scientific papers that are based upon positivist, quantitative research. Science teachers using these tools are likely to be most familiar with quantitative research, and may not have fully comprehended how this qualitative study would function.

Qualitative research, as a discipline, has general ethical and philosophical standards. Christians (2000) notes that the ethics of qualitative research are rooted in ‘Utilitarianism’ – the philosophy proposed by John Stuart Mill. Utilitarianism states that individuals maintain complete freedom (liberty) except the liberty to harm others (Christians, 2000). Mill also established that ‘inductive experimentalism’ should be the method of discovery in the social sciences. This approach however maintains a basis in positivism, and may not be the most relevant to modern-day qualitative research (Christians, 2000). Mill did however inspire the scientific neutrality
elaborated upon by Max Weber and in use in most qualitative research today (Root, 1993).

Christians (2000) mentions four areas to guide our ethical obligations in this research project: informed consent, deception, privacy and confidentiality, and accuracy. I will now address these topics. Before beginning the interview I asked participants to sign a consent letter that outlines overview of the study, expectations of the participant and address ethical considerations of the study. Miller and Bell (2012) argue however that ethics approval from a board and a signature at the beginning of the study does not truly meet the standards of informed consent. Instead, they state that “‘consent’ should be ongoing and renegotiated between researcher and researched throughout the research process” (p. 61). Informed consent means discussing the nature and potential consequences of the study with the participant (Christians, 2000; DiCicco-Bloom & Crabtree, 2006; Miller & Bell, 2012; Punch, 1994). Punch (1994) however notes that sometimes revealing the potential consequences may deter participants and may “kill many a project stone dead” (p. 90). Consent in this study was free, open and frequently discussed between researcher and participant.

Stanley Milgram’s psychology experiments in the 1960s and 1970s brought the morality of deception in science clearly into the foreground (Christians, 2000). In this study I did not deliberately deceive any participants.

Throughout this study I aimed to ensure the confidentiality and privacy of my participants. This entailed thoughtful consideration of: choice of venue for the interview and arrival there, the use and dissemination of data, use of pseudonyms, storage and disposal and information (Christians, 2000; DiCicco-Bloom & Crabtree, 2006). One potential issue here was the use of pseudonyms (Dearnley, 2005; DiCicco-Bloom & Crabtree, 2006). Dearnley found that despite her best efforts to anonymize her participants’ names, their questionable choice of
pseudonyms lead to easy identification (2005). It is for this reason that I have chosen to name my participants after the Teenage Mutant Ninja Turtles (not the Renaissance painters). It is possible, despite these pseudonyms, individuals may be easily recognizable purely by their responses, especially as EC texts seem to be used in limited capacity in Toronto (Christians, 2000; Dearnley, 2005; DiCicco-Bloom & Crabtree, 2006). Christians (2000) also raises questions about who ‘deserves’ to be anonymized. In the popular press we afford people in the spotlight little anonymity. Why should we allow participants anonymity, especially when their responses may lead us to question their ability/morality? In this paper I did not face this issue, but in line with the University of Toronto ethical standards, all information shall remain anonymous regardless of issues mentioned in the interview. All data collected is stored in a password-protected external drive and will be destroyed after five years. I will not share this information with anyone but my direct supervisor. I did not meet teachers on school property, nor shall I disclose identities of the participants to anyone but my direct supervisor.

I assured accuracy in this paper by utilizing the close line-by-line analysis of interview transcripts (Charmaz, 2000). Christians (2000) states that accuracy can be ensured by not fabricating or embellishing any work, which I did not do.

There are also ethical issues associated with this method of data collection. It is possible for instance to cause undue harm to participants by choice of traumatic or sensitive topics, or addressing this in an inappropriate manner (DiCicco-Bloom & Crabtree, 2006). There were no such problems in this study. However, as an additional precaution, by using the semi-structured interview technique I would have been able to avoid traumatic issues were the participant to become uncomfortable. Dearnley (2005) also found issues in sharing semi-structured interview transcripts to the participants after the interview. In this paper the author notes that participants
did not realize what they had said at the time, and were unhappy with how they were represented in the interview. To combat this I was clear with the participants about the data collection techniques used, and which I shared with them before data analysis (Dearnley, 2005).

Additionally, the close relationship between interviewer and participant can have ethical implications. Semi-structured interviews can lead to richly detailed comments from participants, particularly when building a rapport with the interviewee (DiCicco-Bloom & Crabtree, 2006; Leech, 2002). “Rapport means more than just putting people at ease. It means convincing people that you are listening, that you understand and are interested in what they are talking about, and that they should continue talking” (Leech, 2002, p. 665). Ramos states that this intent-filled, deep conversation can lead almost to a therapeutic relationship (1989). Indeed, the thoughtful ear of the researcher could be construed as manipulation, by giving participants an unnaturally caring environment through which to divulge a large amount of personal information (Sonnenfeld, 1983). In this study however, I maintained a collegiate relationship with the participant to maintain a respectful boundary, and did not find any great sharing of personal information, allowing me to obtain powerful usable data (Sieber, 1980).

This study had clearance from the ethical review board of the University of Toronto.

3.6 Methodological Limitations and Strengths

We have stated that the analyst is a valuable and important part of the data interpretation process (Corbin & Strauss, 2014; Glaser & Strauss, 2009) however it is clear that subjectivity of the researcher is prone to biases (Ramos, 1989). Biases in the selection of participants, and particularly based on grounds that would not affect the research question, is a major flaw in qualitative design (Hammersley, 2008). Ramos (1989) writes that “[i]n order for the final data to be trustworthy, the investigator must evaluate himself or herself as a data collection instrument”
(p. 60). This however, would not eliminate unknown biases, and may not be completed to a satisfactory standard.

Corbin and Strauss (1990) note that grounded theories have qualities of ‘good science’ yet have rebelled against these qualities that usually refer to positivist ideals. It can, accordingly, be difficult to decide what ‘good’ qualitative research is. This is what Denzin and Lincoln (2000) refer to as a ‘crisis of legitimation’ – one of three facing qualitative researchers now. The crisis of representation is that qualitative researchers cannot fully understand lived experience. The crisis of legitimation refers to how one can evaluate qualitative studies in the contemporary research paradigm. This is much more difficult than evaluating quantitative research. Finally, the crisis of praxis refers to the end product of qualitative research – a paper or theory. How can we produce meaningful work that changes the work if all we can produce is a paper? These three issues plague qualitative research (Denzin & Lincoln, 2000).

Hammersley (2008) argues that approaches to qualitative research, like feminist and postmodern approaches to inquiry have distorted the initial aim of qualitative research, which railed against the quantitative system in full control until the 1960s. Now, he argues, qualitative research is being used as a means to advocate for certain groups, and selectively choose participants who enhance the researcher’s agenda. Additionally, Hammersley argues that interviews, my chosen method of data collection, do not help researchers understand thought processes in a meaningful way. Instead, he argues, they ignore the context and possibility for change in the interview, by essentially reducing valuable, context-specific data down to variables.

On the practical side of this debate, Dearnley (2005) notes that there can be real limitations on collecting and analysing the data. For instance, transcribing a one hour interview
can take up to five hours (an underestimate in my opinion). In this research project, which has tight deadlines, I similarly struggled with time constraints.

Despite these real issues, and the preference of funding institutions for quantitative research (Corbin & Strauss, 2014), qualitative studies cannot be said to be of lesser quality than quantitative studies, nor do they represent data or ‘truth’ less fully (Peshkin, 1993). Peshkin states that “‘[r]eality’ a slippery notion at best, does not become clarified by any one person’s construction or approach to inquiry” (p. 28).

Qualitative studies can produce richly-descriptive, contextually-grounded research, with a deep understanding of individuals and their interpretation of the world and construction of reality (Merriam, 2002). Qualitative research understands that human experience is not generalizable, unlike quantitative research (Jones, 1995). Indeed it provides additional complexity and depth to data, which can augment and enhance quantitative studies (Jones, 1995). Qualitative studies recognize that “[d]ata do not provide a window on reality. Rather, the “discovered” reality arises from the interactive process and its temporal, cultural, and structural contexts” (Charmaz, 2000, p. 523-524).

3.7 Conclusion

This study used the qualitative research paradigm to analyse teachers’ construction of knowledge pertaining to use of epistemologically considerate (EC) texts in Ontario classrooms. Semi-structured interviews allowed the most richly accurate and reliable data collection, which was analysed through line-by-line coding of interview transcripts. Ontario College of Teachers-certified teachers with EC content experience were sought from the Greater Toronto Area to produce a grounded theory. Judgment and convenience sampling were used to find interview
participants. During this process I maintained ethical considerations stated by the University of Toronto ethical review board. In Chapter Four of this MTRP I report the research findings.
Chapter Four: Research Findings

4.0 Introduction

Scientific literacy is a vital 21st Century skill, and is the aim of the Ontario Ministry of Education (OME) 2008 Science curriculum. Epistemologically considerate (EC) texts are texts that display the history or reasoning behind their stated claims (Kloser, 2013), and may be used as tools to help achieve this aim. The central research question of this paper is: how are epistemologically considerate texts being used in Ontario classrooms? The use of EC texts has been reported, in some circumstances, to have generally positive effects on students’ academic performance, and understanding of science. In Chapter Two I reviewed research literature upon these putative effects, as well as some methods for implementation and how EC texts fit into general educational trends. In Chapter Three I discussed why I chose to use a qualitative research paradigm to create a grounded theory of EC text usage, as well as laying out my sampling criteria, which in this case were fairly broad – teachers only needed to be qualified in Ontario and to have experience using EC texts.

This chapter discusses the findings found through close analysis of interviews conducted with Raphael, Michelangelo and Donnatella, three high school teachers in the GTA. I aligned my research findings roughly with my subsidiary research questions, under the main question of ‘how are Ontario teachers using epistemologically considerate (EC) texts in their classrooms?’ This study attempts to create a grounded theory of how this is done.

I generated four themes from these interviews:

4.1 Characteristics of Teachers Using EC content

4.2 Instructional Strategies for EC content

4.3 Perceived Effects of EC Content on Students
4.4 Teacher Factors Affecting Uptake of EC Content

Each of these themes contains subsidiary themes, which I link to research findings from the Chapter Two literature review, where appropriate. In the conclusion I summarize my findings, then transition to Chapter Five where I share some implications and recommendations for further research.

4.1 Characteristics of Teachers Using EC Content

All the interview participants expressed deep care for their students, a high level of pedagogical content knowledge (PCK) and a strong desire to work in the field of education. I will first discuss their views on the link between science and society, then will discuss their understanding of the ‘nature of science’ (NOS) – the ‘how’ of science (Osborne, 2014) – which is informed largely by their experience in academia. I will then analyse their approach to teaching and classroom activities.

4.1.1 Perceptions of the relationship between science and society

In interviews with these teachers, the lack of scientific knowledge experienced by most of the population was mentioned on numerous occasions, with teachers noticing a divide in comprehension between scientists and laypeople. As teachers, they saw their role in narrowing this gap and increasing their students’ scientific literacy.

Raphael noted that many members of the population are unaware of how scientific knowledge is created. He believed that “the general population is not going to know that...probably more than half of the quote-unquote science that happens is not people with test tubes with coloured liquids.” He also commented on “clickbait” headlines and how difficult it would be for them “to say how valid a certain journal is,” due to media misrepresentation. This media-produced divide is often to the detriment of the wider community who need science to
make an ‘informed decision.’ Raphael argued that this was particularly relevant in cases involving homeopathy and “squalene adjuvants” in vaccines.

Donnatella added that “there’s so much richness in terms of innovation within the research community but...it stays within the community, right?” This, she added, was not due to the media but rather to “the scientific literacy barrier.” All of the participants understood increasing scientific literacy as one of their aims as science teachers (OME, 2008), to ultimately help students make a “safer, better” “right choice for their family and themselves.”

Interestingly, Donnatella did not necessarily believe that the process of science is intrinsically an academic or exclusionary process, as the other two participants seemed to. She stated:

Well...I feel that everything that we do tends to embed the nature of science, we just don't recognise that as a scientific process...[W]hat needs to be addressed is to bring it aloud, to help students see what, what nature of science is and how they have been doing it unconsciously.

This represents a change in pedagogy, from teachers giving knowledge to the students, to acting as a guide to their own self-discovery, which is more in line with the Ontario Ministry of Education (OME) curriculum (2008) and current teaching trends (DeBoer, 2000). Regardless of pedagogy, all teachers understood that students will be affected by science, and that their success in the 21st century could be dependent on scientific capability, which is line with present understanding (Laugksch, 2000; OME, 2008; Trefil & O’Brien-Trefil, 2007).
4.1.2 Understanding of the NOS

Through their direct involvement in academia and the creation of scientific knowledge (or familial affiliation for Raphael) these teachers have developed a deeply nuanced understanding of the NOS.

When prompted to define NOS, Donnatella described it as “how we conduct ourselves, or behave in the pursuit of finding knowledge.” While Michelangelo referred to it as “procedure… knowledge… application.” The broad definitions offered are commensurate with the OME definition which reads:

- what scientists, engineers, and technologists do as individuals and as a community
- how scientific knowledge is generated and validated, and what benefits, costs, and risks are involved in using this knowledge
- how science interacts with technology, society, and the environment (OME, 2008, p. 4)

Through descriptions of their work with EC texts however, the teachers demonstrated a deeper, more thorough comprehension of NOS. For instance, Raphael described an important aspect of science as:

The fact that I have something that's purely verifiable through intellectual means that deals with quantitative measurements, and qualitative measurements. Right? So I can verify what I'm looking at, and then someone else can verify that, so that again, these are just...those two things.

This demonstrates his understanding of science as an empirically-driven subject, requiring data analysis and replication.
When discussing why her class never uses textbooks, Donnatella stated: “I wanted to emphasize that science knowledge is continually changing. Using a textbook is a direct indication that knowledge is fixed in stone, it cannot be changed.” Here we see a clear understanding that scientific knowledge is tentative and constantly growing (Osborne et al., 2003), which she acknowledges certain classroom texts do not show this effectively (Chiapetta & Fillman, 2007; Kloser, 2013; Lumpe & Beck, 1996).

Michelangelo works with his students to define “hypotheses, predictions, developing a problem, how do you identify variables” and lots of additional laboratory investigation set-up requirements. His projects were additionally chosen by pupils upon personal observation, interest and experience, this models that science is founded upon curiosity and observation and that it generates hypotheses - elements of ‘the scientific method,’ which is part of the NOS.

In addition, the “innovation” that impacts populations discussed by Donnatella earlier clearly show her understanding of the link between science and technology, while Michelangelo used examples of: time spent “in hospital...talking to the doctor,” “degradation of the environment,” and “vegetables and fruits and fish and organisms that we consume that have these scientific processes embedded in them.” It is clear that these teachers understand how intimately science is related to society and the environment, which is heavily weighted in the OME definition of NOS (OME, 2008).

Finally, Donnatella demonstrated a complex understanding of the NOS, and spoke of her desire to share this with her students:

I told them that science isn't built in one generation; science definitely isn't built by one person right? There is continuous contribution over generations, and lots of sacrifices happening through that process, and what we gain is the information builds from
generation to the next. I told them that the experiments that we do in class sometimes take 3 days to find the results, but the questions, there are bigger questions that take generations, and you need...one person cannot live that long to find the answer from beginning to end, so you need collective pieces of effort and information to get there.

Interview participants demonstrated at every turn an advanced, multi-faceted NOS understanding, which go above and beyond the 2008 OME definition. Furthermore, the teachers’ understandings meet or exceed all the ‘fundamentals of NOS understanding’ from Osborne et al.’s 2003 study polling sociologists, historians, philosophers, instructors and practitioners of science (see Chapter Two for a full list of these criteria). The teachers’ comments demonstrate a constructivist and process-oriented understanding of NOS, which may be nested with a constructivist and process-oriented epistemology of learning and teaching science (Tsai, 2002).

These teachers’ clear understanding of the NOS does not necessarily translate directly into good classroom practice teaching it (Ahd-El-Khalick et al. 1998; Brickhouse, 1990; Lederman, 1999). Ahd-El-Khalick et al. (1998) show that many pre-service teachers planned and completed that lacked explicit connection to the NOS, or misrepresented what NOS really is. However, Lederman (1999) showed that teachers who believe NOS is important to teach, are better able to teach it. That these teachers value the teaching of NOS is clear from their interviews.

4.1.3 Pedagogy and classroom practice

All the teachers in this study displayed dedication, genuine care and interest in their students, and in their desire to help them understand and connect with material. They believed that the best way to do this was through student-driven activities.
Raphael describes how “basically everything I did from grade 8 was designed to kind of get me to be accepted into teachers' college.” When discussing what EC texts to use in her class, Donnatella frequently referred back to “‘knowing your students’,” especially relevant as this inner city school was the one she herself attended. When designing assignments she “puts [herself] in the shoes of a student who doesn’t know anything. I try. I try.” Here we see these teachers’ dedication to the profession and commitment toward their students.

Both Raphael and Michelangelo commented on alternate education systems and felt there was “a part missing”: leading them both to offer interactive inquiry projects “where the kids have to kind of develop their own procedure and perhaps develop their own hypothesis.” Michelangelo justifies this by approach saying “the best place to do research is right when they’re all eager and curious and enthusiastic.” From the interview data I collected, the enthusiasm and unbridled optimism of the teachers is clear to see. They all believe that students have the capacity to do ‘science’, read EC texts, and be engaged with the subject. They frequently discussed “scaffolding” and the numerous other supports they offer - these define student-centred learning.

The interview participants here reported at length, a science-inclusive, student-driven pedagogy with an atmosphere of care and commitment. This constructivist and process-oriented pedagogy aligns appears to be nested with their own NOS understanding (Tsai, 2002). I will discuss their actual teaching practices in the next section, but it is clear that these teachers think extensively about their students and their classroom. This is important, for Brickhouse (1990) noted that well established pedagogy and instructional practices are necessary to teach NOS effectively. These teachers’ dedication is especially apparent as the use of EC texts “cuts into a lot of your personal time”: evidently they are committed to using them.
4.2 Instructional Strategies for EC Content

Research literature on the topic of EC content integration into classrooms has numerous methods named (see Chapter Two or Yarden, Norris & Phillips, 2015 for a review). However, the teachers in this sample had not heard of any of these methods and instead used a wide variety of tools to maintain interest and engagement with often difficult subject matter. These strategies arose from the teachers’ strong PCK and content knowledge, which greatly affect students’ development of inquiry skills, enjoyment of, and engagement with the EC activity (Falk, Brill & Yarden, 2008).

4.2.1 EC content-augmented inquiry

Teachers in this study have been using large inquiry-based projects to introduce EC content into classrooms, to maintain students’ interest and connect them with the material. “Scientific inquiry… refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world (National Research Council (NRC), 1996, p. 23).” Open inquiry is the most independent form of classroom inquiry, and the one that mirrors academic science most closely. In this form students devise their own problem, hypothesis and procedure, with only the materials provided by the teacher (Colburn, 2000; NRC, 2000).

When describing his students’ choice of topic for the inquiry project Michelangelo said “that the more open you are, the more interesting the topic becomes, the more relevant the topic becomes and it helps kids because they find that ‘oh my gosh, this is something I always wanted to do and never did it.’” He stated further: “I don't say no to any topic.” Open inquiry requires this approach to teaching, shown by Michelangelo, where students are encouraged in their curiosity to explore new problems.
These larger research projects are open inquiry not just in the sense that the students can choose their own topic, but also that teachers act as “guides” only. Michelangelo described that process, and how he explains this to other teachers:

'I'm not the pro at everything. I don't know anything much about Einstein's theories, but I can tell you what it is, maybe read about it with you.' You know? And so, I've learned a lot and I tell my fellow teachers that I learn with my students.

In addition, open inquiry tasks require students to complete problem solving themselves: these teachers allowed this process in their inquiry projects. Donnatella describes a classroom dynamic facing unfamiliar concepts using EC papers:

I also provide them with iPads for translation and stuff like that. And they would read, and on one side, or a sheet of paper, they would have vocabulary and questions…[T]hey have that there, in front of them, they just follow: they have the technology. I walk around for them and make room for them to ask questions.

Donnatella used structured inquiry (Colburn, 2000; NRC, 2000) instead of open inquiry; choosing some topics for her students. When she did choose topics for groups she used culturally relevant examples e.g. analysis of spice - an attempt to increase student buy-in and interest. She described it as a journey of “continual discovery” for them.

Inquiry, and particularly, open inquiry like this has many positive effects (Anderson, 2002) most notably in the higher order thinking skills (Colburn, 2000; NRC, 2000) required by the OME (2008). But surprisingly, may not affect NOS comprehension without teacher intervention. Khishfe and Abd-El-Khalick (2002) found that doing inquiry alone cannot implicitly teach about the NOS - it is only by explicitly discussing it that NOS can be clarified. Most effective however are explicit teaching and a reflective approach to the exercise. Although
teachers in this sample did teach NOS explicitly, none mentioned reflection, although I would not be surprised if it were involved. It is theoretically possible that this ‘advanced inquiry’ using EC content may affect NOS understanding without explicit teaching and reflection, but, as Osborne (2009) noted, this requires students to learn the NOS by reading it, and without teacher intervention. In general, proponents of classroom use of EC content believe this to be so (Osborne, 2009; Yarden, Norris & Phillips, 2015).

To my mind, the open inquiry approach was chosen not to illustrate part of the NOS (although it does do so), but rather to keep students involved and excited in the process. It may also be that, in the absence of specific techniques for EC content implementation, EC texts were wedged into existing inquiry projects to add authenticity to the project.

4.2.2 Explicit instruction on NOS

All three teachers in this sample talked about explicitly explaining the nature of science, and the nature of the EC content they were using. This is usually done as an introduction to the topic, and all the instructors were cautious not to overwhelm or shock their students.

For Raphael, his teaching on scientific journal articles “depends on the article, and it depends on the group and it depends on the kid. … It's hard for me to gauge because it's kind of dependent on the project that they're doing, right?” In his small groups he make talk about “statistical significance,” “validity” and “peer review” for instance, but both he and Michelangelo note these terms vary across journals.

For Donnatella, using structured inquiry, she takes one full period to talk about the articles and allow students to read them with her, talking time to talk about how committed scientists are to science, and how knowledge accumulates in science. Michelangelo discusses journal writing and academic protocols with his students in a half-period, in part of a larger week
long discussion of lab procedures and experimentation. Raphael and Michelangelo both mentioned working with each small group to discuss the article, and given these teachers’ approaches, it seems likely NOS would be mentioned directly there.

For this stage of their teaching using EC content, I have relatively little data, but this can be attributed to the nature of all these teachers’ classes, where there is relatively little traditional didactic teaching, and this approach is not favoured. These teachers did seem to model a teaching approach that is in line with their understanding of the NOS which may help students learn about the NOS indirectly, but this has been shown to have limited effectiveness (Abd-Ed-Khalick et al., 1998; Lederman, 1999). As previously stated, teaching to a class about the NOS while using inquiry, and scaffolding subsequent reflection seems to be the most effective method (Khishfe & Abd-El-Khalick, 2002; Schwartz, Lederman & Crawford, 2004). This is particularly so when reflecting on the scientific enterprise from a non-scientist standpoint - from the outside in, as it were (Schwartz et al., 2004).

4.2.3 Peer learning

The inquiry projects ran by these teachers were collaborative group projects, which may have helped increase students’ enjoyment of the project, and also allowed them to construct their own knowledge using other students. The first stage in Raphael’s inquiry project is looking “at really good examples of kids that are already doing them… and from those examples, they would then go and be able to better understand how to create their own.” “[T]hat's kind of like the whole constructivist model, way of doing it.” In Michelangelo’s school, the student-run scientific journal provides a wide array of successful articles to model from, and indeed Michelangelo “required [students] to put in ‘words of wisdom’” for the next student. Michelangelo explicitly encourages group idea exchange and presentation of ideas. He tells students “‘look, look at this!’
Look at the other students!...See what they have done for our school.” When presenting their research to the class, Michelangelo believes “sometimes the peer teaching is of value, more value than a teacher teaching in the same topic.”

I have found little in the way of research explicitly linking EC content to group work, or peer learning. These teachers noted a positive response to this approach, which as stated, does implicitly use a factor in the NOS (Osborne, 2003). This collaboration may however be an unintentional by-product of limited class and teacher resources, just as collaboration in science often is. This also allows for the constructivist exchange of ideas in peer learning (Anderson, 2002), which in itself emulates part of the cumulative, social nature of the scientific community (Osborne, 2003). Teachers using peer learning strengthen this process through the use of exemplars from across cohorts and across year groups.

4.2.4 Process over product

In these inquiry projects the teachers tended to value the action over the final product of the assignment. Understanding of the NOS can be hard to assess (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002), so determining the quality of a NOS-related product would be difficult. In addition, this lack of assessment is a common theme in inquiry projects which tend to value the process of inquiry (NRC, 2000).

Raphael offered students a variety of visual media end products for his inquiry project, allowing students who may not enjoy a written only environment to flourish, and enjoy the process without fear of the end product. Reducing student anxiety was also one of Donnatella’s primary foci, molded partly by her own experience as an ELL in rigorous science classes. She was very conscious of students’ anxiety over reports, stating that students “have a certain
perception of it and it’s not positive.” Reports don’t have to be “arduous” she argues; indeed, the three EC content assignments she uses require students to create only very short summaries.

Assessment was not discussed at any great length in my interviews in my interviews, however should these teachers choose to assess students’ NOS growth, they can use the VNOS questionnaire by Lederman et al. (2002). These authors note that although this questionnaire is useful, classroom-by-classroom assessment of NOS understanding is most preferable.

4.2.5 Modifications to primary scientific literature

One area that featured very heavily in research on EC content was the modification of PSL (primary scientific literature) for the classroom, creating adapted primary literature (APL) (Kloser, 2013; Norris, MacNab, Wonham & DeVries, 2009; Norris, Stelnicki & DeVries, 2012; Phillips & Norris, 2009; Yarden, 2009; Yarden, Brill & Falk, 2001, 2008; Yarden, Norris & Phillips, 2015). Only Donnatella had any experience with this, and modified articles frequently for her students.

She noted the importance of not overwhelming the students and tailoring articles to their achievement level. Her considerations when modifying the articles were: “students’ success, the goals, the function of the journal and the what, what I want the students to get out of it. So all of that is integral to how I not only choose the article, but also modify it to meet their needs, and to meet their level.”

Donnatella frequently mentioned scaffolding in her modification practice, stating “I don’t want them to feel like they can’t do it, because that would just demotivate them and the whole learning process.” Additionally, in a school with a high ELL population, Donnatella has to choose articles carefully, and scaffold students thoroughly, to ensure they can understand the material clearly.
Donnatella’s choice of articles generally aligns with Muench’s (2000) criteria, and her modifications generally align with how other researchers have been creating APL (Kloser, 2013; Norris, MacNab, Wonham & DeVries, 2009; Norris, Stelnicki & DeVries, 2012; Phillips & Norris, 2009; Yarden, 2009; Yarden, Brill & Falk, 2001, 2008; Yarden, Norris & Phillips, 2015).

4.3 Perceived Effects of EC Content on Students

The teachers interviewed reported mixed, although perceived-to-be generally positive, results from their practice with EC content. These focussed around academic improvements, but were not limited to the sciences, and indeed, in some cases expanded to non-academic areas. Advances were noted in vocabulary and precision in sciences, community building, interest in science, and transferable skills, while teachers reported that resultant stress in their students was a frequent occurrence. It can be assumed, however, from these teachers’ continued practice that they believe the positive academic aspects of using EC texts in their current format outweigh the potential negative aspects on students.

4.3.1 Improved comprehension of NOS

Whether students can learn NOS by reading EC content is a matter of great debate (see Norris, Phillips and Yarden, 2015 for a review). Teachers in this study believed that students did improve their NOS understanding, but this was not assessed directly - as far as my data implies.

Michelangelo stated that the repetition of his inquiry project year by year improves students’ NOS understanding year by year, “and by the time they get to my grade 11 or 12 classes they’re very familiar. They know how to conduct the research.”

Donnatella was more definite in her answer, believing that “with the reviews, [the students] understand how knowledge is being accumulated, how it's... how one knowledge piece
leads to the question for the next knowledge piece to fill in the gap. With the primary ones they see the process of science investigation.”

Since the teachers did not assess NOS improvements directly (e.g. using the VNOS questionnaire (Lederman et al., 2002), I have relatively little data on students improvement. However, the vast majority of research on EC texts implies NOS understanding is improved through reading (see Chapter Two, or Norris, Phillips & Yarden, 2015 for a review).

4.3.2 Improvement in students’ vocabulary, precision and scientific writing

Interview participants noted a distinct academic improvement by using EC texts in an inquiry framework. With regard to his inquiry-based project with high EC text usage, Michelangelo noted that students “see that it is much like what they are familiar with: lab writing skills. And they say 'woah, I can do this. I am familiar with this. Now I can incorporate a lot more scientific terms I have never used. Maybe I should drop pronouns.’” Due to the high frequency of subject specific vocabulary in scientific papers, students in this class were asked to frequently search new terms, which improved their vocabulary, and through the project design often managed to cover topics beyond classrooms e.g. GMO crops “[W]hy not do a project? Let them discover it for themselves.”

Donnatella noted that for her weaker students vocabulary was an initial point of confusion. She said:

[T]hey find it very difficult, like for me. And I understand that too because when I first came here English wasn't my thing. And the only homework I had was from English, right? And to have this on top of it I would have hated too, because it takes a lot of time for me read, it takes a lot of time for me to write.
However, she scaffolds these learners heavily, and noted that terms she had attempted to teach previously were greatly improved through the use of EC texts:

[F]or instance, if they were working in groups to design something, they have to tell group members what to do, and so they're very precise in... well more precise in allocating the task and communicating the instruction, using more of the vocabulary that I had hoped to instil in them.

As discussed in the research on EC texts (Kloser, 2013; Koeneman, Goedhart & Ossevoort, 2013), these resources may present additional initial difficulty for students in terms of vocabulary used, but do increase student comprehension of vocabulary in the long term. The use of precise, mutually-defined terminology is a part of doing school science, (Laugksch, 2000) belonging to the scientific community (Osborne et al., 2003; OME, 2008), and is part of the Ontario science curriculum (OME, 2008).

4.3.3 Transferable critical thinking skills

Participants mentioned the importance of critical thinking to scientific literacy, the students’ futures and the goals of the Ontario science curriculum. Teachers using EC content believed that asking students to read and analyse EC content helps embed critical thinking skills, often as part of a wider inquiry project.

Michelangelo believes “the benefit of [EC content] is: it allows you to build skills that you can apply in other courses. Doing research. Doing presentations. Being critical. And I find that those skills are something that you can carry for the rest of your life, to other courses.”

In her in-class discussions Donnatella found that students were more engaged “in a variety of different ways, and not just listening, but also asking questions, and I think participating in a science dialogue with me and with each other.”
The importance of critical thinking in the sciences is high, for as Raphael and Donnatella noted, ‘selecting reliable sources can be challenging’, but is also a mindset that students should apply to all aspects of their life. The ultimate end goal of critical thinking in science is, as Raphael states, that students can “make the positive judgement to navigate to the right choice for their family and for themselves.”

This improvement is in line with most findings on the use of EC content with high school students (Baram-Tsabari & Yarden, 2005; Brill & Yarden, 2003; Norris, Stelnicki & DeVries, 2011; Yarden, Brill & Falk, 2001). In this study, unlike these other works, teachers did not include facets of critical thinking that were improved, rather just that students were ‘thinking critically’. As such, further analysis is difficult.

4.3.4 Sense of community

Science teachers in this study believed that scientists constituted a special community, with a specific set of rules and bounds, in line with the research understanding of NOS (Osborne, 2014). Teachers noted that these real scientific texts may help students develop that sense of community with fellow scientists.

Through his work with scientific investigation, Michelangelo in particular, helped students foster a sense of community between science students within the school and extending outside of it. For instance, he encouraged the formation of a school journal, with students as its editing team. When describing the active nature of editor meetings he stated: “So there are a number of ways you can critique an article and one way is to become this, this group of authors, or this group of peer examiners if you like, by forming this small journal club.” It is clear that students, who are completing this voluntarily, enjoy the activity and feel like part of community of scientists within their school.
Through the peer learning stage of Raphael’s project, students see and acknowledge that other students have achieved ‘scientist’ status. By completing their own inquiry project they, like their peers, become ‘scientists’ in the school - becoming part of that community, which is especially important in grade 9 (the first year of high school). He said:

[L]ooking at other kids’ [investigative] projects that probably would have been one of the first times, especially if they're doing it in grade 9 they would have ever seen kind of like a bigger thing that kind of represents a, kind of like a big collection of, of different scientific steps almost, you could say.

In this case, EC content and a process involving it can be used to generate community in the high school, even with students who are not as interested in an extracurricular journal editing project.

Similarly, connections can be made to the outside community of science practitioners. Through the complexity of their papers, and their inquiry-based projects, students were encouraged by Michelangelo to reach out to mentors within the wider scientific community.

“[T]heir mentors could be from University of Toronto, could be from the hospital sites.”

Michelangelo explicitly states how that his students “feel that they can be in the same field as some of the researchers who’ve been in the field for 10, 15, 20 years, right? So I think that boosts your spirit of staying in sciences.” Michelangelo actively encourages this sense of community, with students believing “that they can do scientific research without being a so-called ‘scientist’ and I say "you are a scientist when you're doing this".” Here the acceptance by an esteemed science teacher into the school science community helps students build their belonging.

Finally, Donnatella talks about an extracurricular project she had run in previous years. In this project students were asked to communicate a new research finding from a modified Ph. D. thesis to the lay audience through animation. She states:
And I also wanted to bridge the scientific community with the lay people community to help share understanding and to show an appreciation, or have an appreciation of, of the what's being invented...So I wanted to sort of bridge it somehow and I felt that doing science animation would help because it's not really trained, the students who are participating, who are doing the animation because they're within the scientific training discipline so they have exposure to the scientific world, so they use that knowledge and while they're still connected to this group, the cohort, they are... and through the science animation they can sort of translate and deliver that message to this group.

Through this project, Donnatella conveys her expectation that these students act as a “cohort,” with power and knowledge that they will share with the lay community. This implies some sense of exclusivity. The belief that some people are scientists and some are not, is interesting to contrast with Donnatella’s earlier quotation that “everything we do tends to embed the nature of science” and that we just need to show students this. This seems to be an incongruity.

EC content is scientific by its very nature, and it feels scientific to read. From my anecdotal experience, it feels special to bring out EC content, and engaging kids in this, from these teachers’ experience, helps them become part of this scientific community. On the downside, this may be exclusionary to students who do not connect with EC content, or cannot get past the initial vocabulary hurdle we have mentioned.

While there has been relatively little research clearly linking EC content with the feeling of community, the work done at CCNY with undergraduate students (Hoskins, Lopatto & Stevens, 2011; Hoskins, Stevens & Nehm, 2007), has shown that students did increase their understanding of scientists as people. Similarly, they became more interested in the work of scientists, and science as a career. I believe this to be the start of community building.
4.3.5 Student interest in science as a discipline

From their experience, Donnatella and Michelangelo noted that some students were invigorated by the experience and the inquiry aspect of these projects - going beyond curriculum expectations to continue a personal journey with science. Some students felt that EC science was more real and enjoyable. Students who enjoy science and recognize it as more relevant to their lives are more likely to make scientifically-informed decisions later (OME, 2008; Trefil & O’Brien-Trefil, 2007).

To drive this interest in the field of science and fit with the theme of open inquiry, all of the interview participants gave students choice in terms of the topics they were viewing. Michelangelo stated that students were “[a]bsolutely” interested in EC texts, but that the element of choice may have helped “them understand better their curiosity about that topic.” Raphael, similarly allowed students to “pick a project based on their own interest,” which he described as a form of differentiation.

In Michelangelo’s school the reputation of his investigative project as a fun and interesting way to spend time has led to students voluntarily completing extra work with EC content. Here he discusses students who return to voluntarily complete the assignment:

And there's always one or two students who come back and say 'Sir, I'm not in any of your classes, but I want to do a [EC-based inquiry project].' And I say 'Sure.' And I said "You sure about doing it with no marks?" 'No, no. It's because I love it.' And a number of students who have done that is phenomenal.

When discussing how students feel about EC texts in his classroom Michelangelo believes students “feel confident. They feel that science is relevant.” I believe these students are strongly modelling their teachers’ enthusiasm and expertise.
This improvement in students’ connection to the actions of science are in line with previous research findings on the use of EC literature (Gottesman & Hoskins, 2013; Hoskins, Lopatto & Stevens, 2011; Hoskins, Stevens & Nehm, 2007; Kloser, 2013; Schinske et al., 2008; Yarden, Brill & Falk, 2001).

4.3.6 Student stress and confusion

Using EC texts is not without its difficulties for students. Many students do not have the requisite skills, do not enjoy the assignment or understand the vocabulary, according to the interviews that I have completed.

Michelangelo mentioned that students are not used to this non-traditional style of teaching, and his focus on analysis, claiming “some of them do not like critical understanding, critical views of issues, they do not like discussing - they just want to memorise and regurgitate it.” He noted that these projects do “stress them initially,” and that parents often complain their children are not understanding the material.

Donnatella informs her pedagogy from past personal experience as an ELL, and pointed out that “depending on the nativity of the language that you have, if you initially don't understand the topic to jump into something more detailed could be confusing.” She does “understand the frustration” of not understanding the language, but believes it can be overcome. She hoped that by “giv[ing] them this exposure, in the long run it would help.” She noted that her university was a difficult time in her language learning, and wanted “to give these students a head start, on that brick wall that they might face.”

This frustration and stress associated with deciphering the EC text was also found in studies from around the world (Baram-Tsabari & Yarden, 2005; Brill, Falk & Yarden, 2004; Norris, Stelnicki & DeVries, 2012). These teachers’ continued use of EC texts indicates that they
believe the positive academic aspects of using EC texts are more important than the potential negative emotional aspects. This is likely due to these teachers’ own success in the subject, and perhaps an inability to acknowledge that some students are not naturally inclined to science.

Michelangelo tracked student difficulty: “Is it laziness? Is it...you know, not being able to understand certain concepts? Not being able to find time to do it? Cause you'd rather be working, and get paid than doing this project for a mark?” This demonstrates that perhaps these teachers are primarily focussed on the academics of their students, and not on their whole well being.

4.4 Teacher Factors Affecting Uptake of EC Content

From the literature we have seen wide-ranging potential benefits of using EC content, some of which my interview participants echoed. With such putative effects, the question arises: why aren’t more teachers doing this? What teacher factors are limiting EC usage? Teachers in this study knew of very few other teachers completing this work. They mentioned internal and external factors for why this might be so. Internal skills are the high-level skills required and fear. The primary external factors are lack of time, accessibility to resources and lack of community support.

4.4.1 Lack of time

Teachers have tight timetables, with numerous competing demands for time and attention. As such, finding the time to institute EC implementation, with its high entry cost, may be difficult for many teachers.

Raphael describes his multi-stage open inquiry project’s time commitment as “really, really daunting,” which would be made additionally worse if this were the first time a teacher were working with EC content. Michelangelo described that the extra work of EC content in an inquiry context means “you’ve got to go research it, you’ve got to support the kids, so it actually
causes teachers to become experts in their project, and therefore we run into problems.” These are common complaints of using inquiry projects (NRC, 2000), which may be made worse by the knowledge requirements of using EC content.

As the only teacher using structured inquiry to introduce EC content, Donnatella provides an additional interesting point. She also noted that often there is not enough time “in the whole semester to fit [EC content] in,” especially since “the whole view of how you plan or design your instruction has to be changed...it has to be an integration of everything in order for you to make the time.” Here we can see that both incorporating EC content through and inquiry, and through a top down approach requires a large time commitment that perhaps only the most dedicated teachers will enact.

There is scant research on teacher time commitments and EC content, but it seems obvious that under time pressure, teachers may not have time to create an EC content-focussed curriculum. Additionally, most research has focussed upon the theoretical use of EC texts, and whether it has any effects, not on the practicality of its usage. Similarly the context of EC texts in inquiry has not been researched at all.

4.4.2 Teacher access to EC content

School boards often provide very limited access to EC content for teachers and students. Although there are school-based search engines, these are often toward younger readers and do not necessarily contain the components that make EC content epistemologically considerate. Also, despite the increasing presence of open access journals (e.g. PLoS), there are limited resources available for teachers searching for this content.

Donnatella notes that her searches are possible only through her brother’s wide university database access, and yet still, finding access to a “good selection of articles can be a challenge.”
Raphael did not explicitly believe that this would be an issue, but noted we “unfortunately, we're actually kind of counting on the validity of this board-approved search engine product” which may not always be high.

While finding articles can be tough barrier to overcome, finding appropriate articles can be even trickier. Importantly, while all teachers felt that EC content could be read by every student, even English Language Learners (ELLs), there were reservations about finding appropriate texts. Raphael for instance noted “one of the realities you’re going to have in the GTA… is that you’ll have an increasingly large number of students who will be ESL [English as a Second Language], right? So it’s really hard to find a journal article that will be written in a form that will be age-appropriate.” In her work, Donnatella discussed article selection for classes with a lot of ELLs:

[E]very class has a diverse group of students in strength of language and my class would be no different, especially my basic, but the articles doesn't necessarily have to be different, because when I chose those I already have factored all of this, right? It's more of whether they're interested in reading them.

Donnatella frequently chooses older articles that “write a lot simpler,” and may also be easier to find online. These may however adversely affect students’ understanding of the relevance. She noted the importance of scaffolding her students to the point where they can read these articles. We can see from these interviews that finding articles can be difficult, and especially finding articles that work for your class can be even more challenging for teachers.

Much of the research on EC texts comes out of university campuses, where access to resources is not such an issue - this explains the lack of research on resource limitation.
4.4.3 Teacher subject matter knowledge

The three teachers in this study have a large amount of experience with academia, which most Ontario teachers do not have. Accordingly, other teachers may not have the skills required to teach using EC content. Donnatella thanked her “very fortunate, fortunate position” that she gained through her graduate years “training third year students how to read and write scientific articles.” She noted that “accessibility is not just resources, it’s also the skills.”

These skills might be in terms of ability to find articles: “as a teacher, you’re not going to know what all the best journals are” claimed Raphael. Thus teachers may lack the requisite skills to find and use EC content, or may attempt to do so, and in the process find things that are not as epistemically sound as other articles - misrepresenting the NOS to their students. Teachers may also lack the ability to read and understand these articles themselves. Donnatella explained that her use of chemistry articles required her “to understand the niche, the language niche within the article, within that sub-sub-disciplinary topic.” Of course, no science teacher can know everything, but the ability to search and ‘translate’ articles requires a growth mindset, curiosity and courage, as shown by Michelangelo, when he tells students: “I’m not a pro at this… I need to learn some stuff with you, so come up and we’ll learn it together.”

It seems likely that teachers who have the requisite skills to find and use EC texts also already have a well developed understanding of the NOS. Teachers without the experience and skills necessary to find and understand articles likely have a more basic understanding of the NOS, and through this inability are prohibited from furthering it. Whether they would choose to use it is an altogether different matter, given demands on their time, planned teaching practice and interest. Research confirms that many teachers do not have a deep understanding of NOS.
and do not have clear PCK to provide effective teaching for it (Abd-El-Khalick & Lederman, 2000; Osborne, 2009).

One issue that may arise from this lack of skills is the teacher’s own perception of their skill level – perhaps underestimating it, or not acknowledging their expertise in the scientific area. This may lead to fear of EC content, and teachers afraid of EC content are less likely to use it. Interestingly, Michelangelo noted additional fear in terms of teaching practice. He stated:

Many [teachers] are afraid. Because they are afraid that they don’t know the answer. And I say to them, ‘don’t worry, we are learning with them’. They’re not comfortable. They want to be in charge. And many teachers want to be in charge in class, and they find that by losing that control, they become less of a teacher.

Fear of incorrect PCK is not necessarily limited to use of EC content, however these fears are more frequently confirmed in any inquiry-based classroom (NRC, 2000). This fear is based on a didactic style of teaching that we have moved away from in the past 50 years (DeBoer, 2000; OME, 2008).

4.4.4 School community

Positive school community can have positive effects on teacher practice and inventiveness. Participants noticed a lack of administrative support, and a very weak community of science teachers using these types of texts.

For example, Donnatella told me that her administration don’t even know she’s been using EC content in her classes, particularly because of other pressing issues at her inner city school. This, however, is at least preferable to the parent-focussed attitude of principals at Michelangelo’s school where “[students] complain to their parents, parents complain to the principal, principals come up to me saying ‘what are you doing?! Why are the kids not
understanding this?’ I say, ‘it’s a hard project, but that’s why I’m here’.” Without adequate support and protection from principals teachers will be apprehensive to attempt new practices.

With a strong community network of other teachers using EC texts to rely upon, teachers may withstand low administrative support (Brady, 1985). However, Donnatella knew of no other teachers using these tools, while Michelangelo knew of only people he had helped himself. He works frequently to promote EC content and inquiry approaches. Here we can see ‘what could be’, and the support offered by his community network: “I keep encouraging them. I say 'no, it's not necessary'. I think it depends on how you approach the kids, how you present to the kids.

And you say 'I'm a teacher, I'm just a regular person.” He added that he tells teachers:

‘If you have issues, come and I will support you in any way I can.’ And I've been doing that, I've been creating support groups among our teachers....there was a teacher who left just this year, and she's now ready to start her own SIP, in her own school.

From experience in classrooms, I believe that the main reason why other teachers are not reaching out to for EC content connections is not that they don’t exist; it’s that very few name it as a specific exercise, or as a specific tool. Since completing these interviews I have met many other teachers who use EC content, but clearly network building has not occurred yet.

Michelangelo is perhaps right that Science Teachers’ Association of Ontario (STAO) could coordinate this networking, although whether many additional teachers would want to use these tools is again up for debate.

4.5 Conclusion

Through this research I have answered my research subsidiary questions and gained insight into how EC texts are being used in Ontario classrooms. Four themes have emerged, and additional research questions have arisen.
Firstly, EC texts tend to be used by very dedicated science teachers, who are driven by a student-centred attitude and sophisticated NOS understanding. They are highly experienced in their field, which likely gives them the skills to read EC content and teach it to their class. It would be interesting to know how teachers’ education affects their choice of pedagogy, and which teachers in Ontario are most likely to use EC content.

Secondly, we saw that these teachers reportedly used a variety of methods to keep students interested in the content, most notably, the use of inquiry and project work. Research (Khishfe & Abd-El-Khalick, 2002) has shown that explicit NOS teaching and reflection is the key determinant of NOS improvement. I am curious how teachers in Ontario implement this reflective approach in their inquiry classrooms. In their classrooms, the research participants additionally used explicit NOS instruction (although minimally), peer learning, favouring process over product and some modifications to research articles. Of course, this is a sample of three teachers; it would be beneficial to know what other teachers in Ontario are doing with EC content.

The third theme was ‘effects’ - are these EC texts really living up to the reputation from the literature? Generally we saw that these teachers believe EC texts do have positive effects on students’ academics, namely that vocabulary, precision, and critical thinking skills were all reportedly improved. In accordance with the research literature, NOS understanding was also reportedly improved, but teachers did not quantify this, and we did not discuss their assessment of these EC content-inclusive projects. They also reported improvements were also noted in students’ perception of science, and feeling like part of the scientific community. Unfortunately, for some students, use of EC content meant confusion and stress, but teachers felt that the pros of EC texts outweighed the cons. Most of these effects were corroborated by other research, while
some research findings were not reported by participants in this study. See Chapter Two for a full description of reported effects. A wider sample of teachers would indicate whether any of these additional effects are noted in Ontario. In addition, a quantification of the noted effects may lend quantitative, ‘scientific credence’ to the teachers’ claims.

Finally, a discussion of factors limiting implementation was completed. Teachers named many factors, but most prominent was a lack of time. EC content requires a large time commitment, which many Ontario teachers may not be able to dedicate. A lack of community, skills and resources for most teachers was also reported, which may in turn lead to fear, and maintenance of teachers’ present NOS understanding. This was confirmed by other researchers. Further research could probe how the OME and professional organizations can affect change in teachers’ understanding of NOS and NOS-related PCK.

This study was planned primarily to discuss implementation of these EC ‘tools’, but teachers had very little experience with these tools, and so the focus of the investigation shifted mostly toward demographics of teachers using them and a wider discussion of the nature of science, and how this can be communicated.

Overall, my findings show that some dedicated Ontario teachers, with a high NOS understanding, use EC texts in their classroom. They use a variety of tools, most notably using EC texts as part of an inquiry project, and note varying results, which they consider generally positive. These teachers posited that a lack of time, skills and resources (both material and intangible) may be limiting EC uptake by teachers. In Chapter Five, I will discuss the implications of these findings, specifically with regard to teachers and community, including a discussion on factors affecting the future implementation of EC texts. I will also discuss the
narrow implications of this study for my practice as a teacher. Finally, I give recommendations for future implementation of EC texts, and areas for future research.
Chapter Five: Conclusion

5.0 Introduction

In this chapter I briefly characterise the findings of this research, and then will discuss the implications of these findings on a systemic scale and also on a personal level. My recommendations based on these implications are also disclosed, as well as areas for possible future research on epistemologically considerate (EC) texts in the classroom.

5.1 Overview of Key Findings and their Significance

Through interviews with in-service science teachers who use EC texts, a few commonalities between their background and approaches were discovered. Of these three teachers, all had a long-standing desire for a career in science teaching, and carried an associated dedication to the profession. All the teachers also had a strong student-centred attitude into the classroom - designing and choosing activities they think students will enjoy and learn from - this is a typical response to modern teacher education. In addition, all the teachers had intimate experience working in scientific knowledge creation, giving them a unique and sophisticated nature of science (NOS) understanding.

These teachers’ dedication to the profession and high pedagogical content knowledge (PCK) is evidenced through their approach to instruction using EC texts. Teachers all used an inquiry project-based approach with some amount of direct instruction on NOS. As part of the open inquiry approach used, teachers employed peer learning, in and across year groups. Similarly, teachers favoured the action of inquiry over the end results: the process of doing science, over the products. Finally, Donnatella only implemented modifications to primary scientific literature to enable students to understand more of and connect with the material.

Participants reported that the effects of these teaching strategies and use of EC texts in
the classroom was generally positive. Teachers noted that vocabulary, scientific precision and critical thinking skills were improved through use of EC texts, which is partly corroborated by research in this area. One major theme from the research literature is an improvement in students’ understanding of the nature of science, which was also found by teachers in this study, although no formal measurements were made. Along with understanding of the NOS, teachers also felt that students felt connected to part of the scientific community. On the downside however, stress and confusion were reported in some students.

The final theme from this study related to barriers towards EC text implementation: time commitment, lack of community, and a paucity of resources (physical and skill-based) were all noted. Teachers mentioned that skills necessary to find and analyse scientific texts were low in many teachers (as far as they could tell), and that this may lead to fear of using these texts.

5.2 Implications

In this section I will first discuss broad implications of the study and next, narrow implications on my growth as a teacher, and upcoming teaching practice. Broad implications are: that only teachers with contact with academic science may be using EC text; that there is a lack of EC-specific professional community between teachers using EC texts; that NOS can be taught through inquiry; and that most teachers may lack the resources to effectively implement EC texts. Narrow implications of the study are that, to me, it appears these tools may not be relevant to every classroom, and that as a teacher, being innovative and trying new things, is a must.

5.2.1 Broad implications: the education community

One implication from the participants’ biographies is that it seems teachers who have a background in scientific knowledge creation may be the ones most likely to end up teaching about it. Through my personal experience I have seen a varying dedication to NOS instruction
and NOS comprehension activities; many teachers I have interacted with did not even know the term, despite its Ministry of Education mandated importance. I think that it is indicative that only teachers who have been intimate knowledge of high level academic science activities (academic research) are the ones who choose to use EC texts. It seems commonsensical that teachers may care most about topics that they have been involved in, thus teachers who have been involved in scientific research may be the ones best suited and most interested in teaching about NOS; for other teachers, other issues, both academic and extra-curricular, may be prioritized.

When asked about other teachers using these resources, participants knew few other teachers who were using them. In addition, their administration did not know they were using EC texts either. The implication is thus that publicity regarding these teaching tools could be very low. Teacher community and resource sharing are minimal, with administrative oversight and support also low. For other educational movements there have been wide community building efforts; it is therefore surprising that community building in this NOS-understanding movement appears to be so slow. This community building may be facilitated by administrators but these teachers ‘administrators seem to have little involvement in their teachers’ practices, and are thus unable to do so. From these limited findings, publicity regarding EC text usage appears to be minimal for parents, not just for teachers, possibly leading to surprise and indignation when they hear of EC-based projects.

I believe that this study adds to the body of evidence that nature of science can be taught through students’ involvement in inquiry activities. The success reported by these teachers after using EC texts, and ubiquity of their approach, implied to me that EC texts add a special element to inquiry activities that may go above and beyond what can be learned through inquiry alone.
From these teachers’ reports, teachers believe students can learn NOS particularly well through this method.

The final implication from my findings is that many teachers out there may not have the resources to complete work with EC texts. These resources are threefold: time resources, physical resources and mental resources. All interview participants noted that using EC texts, especially in an inquiry environment, requires a large time commitment, one that many teachers may not be able to provide. Additionally, teachers also mentioned an inability to find appropriate research literature to use in their classrooms, which from my personal experience, is a real difficulty. Finally, other teachers may feel anxiety or fear in the face of EC texts which they have little experience with. In-service teachers may lack the skills to read EC texts, and there is a strong implication that teachers do not receive any additional training on how to teach using these texts - which is perhaps unsurprising given their limited usage.

5.2.2 Narrow implications: professional identity and practice

After discussing these topics at length with my research participants I have come to realise the very intense commitment required to use these texts in the classroom. Not only must teacher have great subject matter knowledge for the topic in question in order to read these texts, they must also be able to translate difficult language almost instantaneously for students, which when using an inquiry model means knowing many student-chosen topics in great detail. In addition, knowing your students’ reading ability and adapting EC text usage to this is a concern.

For my professional practice, it is my view that perhaps EC texts should only be used on a class-by-class basis for the most dedicated and academically-oriented students. For these academically-oriented students, EC texts can add value and insight into their understanding of science, which I have seen can also help them enjoy the subject. In most classrooms, these may
not suit the population. At the start of this project I was astonished that more teachers were not using EC texts; I see now that these teachers were likely doing this because it was not a good fit for their classroom, or not feasible for their teaching practice.

One thing not necessarily mentioned in the findings of this study, but that came up in the interviews nevertheless, was the value in trying new things, and being reflexive about your teaching. Each of the teachers in this study uses a variety of tools in their teaching practice, and is adventurous in the projects and assignments they choose for students. After reflection, the teachers refine their practice, and select the best practices to reach students; however, frequent innovation seems to be ‘the name of the game’. One valuable pedagogical theme I have noticed is the value of inquiry, not just in enhancing student understanding of NOS, but also in promoting student engagement and connection to the material.

5.3 Recommendations

My first recommendation based on this study is related to teacher community: greater effort should be exerted to help build a collaborative teacher community by which teachers can share pedagogy and resources to better their practice. Through the research findings in Chapter Four, I noted a disconnect between administration and teacher practitioners, as well as a lack of communication between teachers struggling while using the same tools. Teacher communities could build resources for all teachers and provide opportunities to develop professionally. This is better for the teacher, and may lead to more effective classroom practice. In this case, teachers could share implementation practices, easy-to-read papers, glossaries or worksheets, and how best to improve students’ NOS understanding. These communities and banks of resources already exist for other educational movements, with more publicity and community building the EC text-using teacher community could develop and grow also. This community building is
particularly relevant to the high school science classrooms, which I believe to be changing at an unprecedented rate. For the EC text users, community building, and resource building could perhaps be facilitated by a professional organisation like Science Teachers’ Association of Ontario, an academic institution like OISE, or the school boards themselves.

I would also recommend greater use of inquiry-based learning in classrooms. It thoroughly engages students and promotes learning that can encompass many other facets (e.g. NOS and EC texts). I believe that initial teacher education programs should do more to promote inquiry pedagogy, while the school boards should provide professional development on inquiry. For teachers who would value teaching nature of science to their students, there is certainly worth in EC texts. Professional development for these teachers should focus on pedagogical content knowledge (PCK) for EC texts, as well as approaches to developing EC-based inquiry activities.

For teachers who are not interested in using EC texts, especially for reasons that I have described, I would highly recommend bringing local scientists into the school. These scientists can make science accessible for the students - and may be able to provide the positive aspects of EC texts, without the negative effects of such an approach. Having been part of science outreach efforts before, I have seen the positive impact bringing an interesting and relevant scientist to the school can have.

My final recommendation comes directly from Donnatella, who noted that to really increase your students’ understanding of the NOS you need to implement a whole class, or whole department approach. Individual efforts like an EC-based inquiry project might have short term positive effects, but a wider scale project is by far the best way to increase your students’
understanding. For this important aspect of scientific literacy, I would thus recommend that departments have clear expectations for NOS inclusion.

5.4 Areas for Further Research

Educational literature does an excellent job of addressing most aspects of working with EC texts, but there are still knowledge gaps. Mostly, I would like to hear more teacher testimony on the process, and discern the true extent of its usage, especially in Ontario. It would add quantitative verifiability to this rich qualitative data.

While teacher understanding of NOS has been thoroughly addressed by many authors, I believe future work could be completed on the impact of Professional Development exercises on teachers’ understanding of the NOS, and on their PCK for NOS knowledge-building activities. It would also be interesting to see the impact of educational literature on teachers’ actual teaching practice.

One interesting finding from this study is quite how irrelevant the Ontario Ministry of Education curriculum documents seem to classroom teachers. This may also explain why few teachers work to actively address NOS in their teaching. Discovering the effect of OME documents on teacher practice would be valuable for all Ministry documents and initiatives.

While I still value EC texts as classroom tools, I have recognized that these are not tools meant for every classroom, and require highly dedicated and particularly-oriented teachers. A greater understanding of tools that increase NOS understanding for students who are perhaps not academically-oriented, and are more accessible for all teachers is a necessary area of research. Is there an easier way to embed NOS understanding in all science classroom activities? It would also be valuable to know whether the EC-augmented inquiry used by my participants can teach NOS implicitly, or whether this still needs to be explicitly taught.
Finally, for teachers querying EC text usage, research on the quantifiable effects of their classroom implementation may be a helpful tool. Very little is known about the Canadian (especially Ontarian) context, and figures stating its importance may be therefore be important to some teachers.

5.5 Concluding Comments

The Ontario Ministry of Education believes (and I agree) that students should understand NOS by the time they leave grade 10, but with an ever increasing load on teacher’s plates, how to do this and keep students entertained is very hard to know. As a means to help students learn about the nature of science, and how science is done, the use of EC texts may be a useful tool. Teachers here noted that an inquiry approach might be effective in promoting student interest and understanding, and found generally positive results. Understanding how teachers in Ontario use EC texts may affect their future implementation, which might ultimately lead to better teaching practice. I hope that teachers keep working with these resources to improve and adapt their teaching for their future students.

I have learned a great deal about science teaching through this research project, and the value of innovation and inquiry (for students and teacher) has been reaffirmed to me. I hope that as I continue to grow as a teacher, potentially using EC in my classroom, and that I can reach all students, not just the ones who align with my own history and scientific experience. The ability to analyse sources is a vital component of scientific literacy, which now more than ever will play an important role in students’ lives.
References


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evaluative criteria. *Qualitative Sociology, 13*(1), 3-21.


Appendix A: Letter of Signed Consent

Date:

Dear _______________________________

My name is Alistair Eggo 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 and why epistemologically considerate texts are used in Ontario classrooms. Epistemologically considerate texts are ones that give a history or justification for their claims, e.g. a primary scientific article. I am interested in interviewing teachers who have experience working with these tools in Ontario classrooms. I think that your knowledge and know how will provide valuable insights into this topic.

Your participation in this research will involve one approximately 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. I may also present my research findings via conference presentations and/or through 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. Any information that identifies your school or students will also be excluded. The interview data will be stored on my password-protected computer and the only person who will have access to the research data will be my course instructor.

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 during the interview. 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 to participation, and I will share a copy of the transcript with you shortly after the interview 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,

Alistair Eggo
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 Alistair Eggo 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
NOTE: Potential prompts, and sub-prompts, are given as indented lists for the overarching questions which are numbered.

Hello there. My name is Al Eggo. I am an OISE student studying for a Master of Teaching degree, hoping to become a science teacher. This research project forms one of my MT degree requirements.

I completed my Bachelor of Science at the University of British Columbia in 2015. While there I spent most of my degree focussed on fisheries science, spending a large amount of time working with primary scientific articles – which is one of the reasons I chose this research project.

We’re here to talk about the use and inclusion of epistemologically considerate science texts in Ontario science classrooms, something I believe you know a lot about. Based on your responses to the following interview I will create a qualitative research project on how and why these texts are being used in Ontario.

This interview is split into 4 sections and I have prepared questions to help guide our conversation. That being said, I may at times go off course to ask your thoughts on certain tangents, or related topics. I am recording this conversation, but please feel free to speak candidly about your thoughts and experiences. Thank you very much for volunteering for this study. Do you have any questions before we start?
Section A – Personal Information

1) Could you please guide me through the path that led to you becoming a teacher?
   a. What qualifications did you pursue academically?
   b. Did any members of your family have jobs that inspired you to study science or become a teacher?
   c. How long have you been teaching for?
      i. How long have you been teaching at this current school?

2) What grades and courses do you teach currently?

3) How has your understanding of science as a discipline has changed over time?
   a. In university? In your regular life? In your professional capacities?
      i. Did you do much practical work in science at university?
      ii. Were most of your instructors at university actively involved in research, to your knowledge?
   b. Do you feel like you thoroughly understand what it means to do science and be a scientist?
      i. (if yes) Did you feel that there was a moment in your life when you had that revelation?
      ii. (if no) Why do you think so?

Section B – ‘Defining Terms’

4) What do you think the Ontario Science curriculum means when it talks about scientific literacy?
   a. Could you elaborate on how you would define that term?
   b. Have you heard other definitions for what scientific literacy means?
5) What does the term ‘nature of science’ mean to you? Have you heard this term before?

6) Is there anything that you think all students leaving grade 10 should know about the nature of science (‘how science is done’)?

7) What springs to mind when you think of epistemologically considerate (EC) content? Please give some examples.
   a. What makes it epistemologically considerate content?
   b. What in your view is the aim of epistemologically considerate content?

Section C – Experiences with EC content

Kloser (2013) describes epistemologically considerate texts as “texts that make explicit at least some aspect of the history behind or the justification for its stated claims” (p. 1233). This is what I mean by EC content from here on out.

8) How did you learn or hear about epistemologically considerate content?
   a. Can you describe your level of experience with using epistemologically considerate content in your classroom?
   b. How long have you been using EC content?

9) What type of EC content have you been using so far?
   a. Have you changed the type of EC content you’re using over time?

10) How do you decide which EC texts to use in the classroom?

11) Do you ever modify EC content for your class? If so, how? If not, why not?

12) Could you walk me through a typical class where you incorporated EC content?
a. What was the classroom set up like? What have students done ahead of schedule? How do you assess them? Is the class noisy or quiet? What resources do you need

b. Have you tried using other instructional techniques for the implementation of EC content?

13) How did you decide to try this approach to implementing EC content?

a. Did you hear about it from literature, or colleagues/friends?

b. What makes this a good technique?

14) In your experience, how has EC content impacted students in your class?

a. What are the positive aspects of using EC texts?
   i. Comprehension
   ii. Interest
   iii. Trust
   iv. Confidence
   v. Understanding of NOS
   vi. Scientific reading skills
   vii. Scientific practical skills

b. What negative aspects have you noted?
   i. See above.

c. Do you think students can learn subject content effectively from EC texts than from traditional textbooks?

15) What has been the response of your fellow teachers and administrators to your use of EC content?
Section D – Thoughts on implementation

16) What challenges and barriers to the use of EC content have you experienced?
   a. How did you overcome these barriers?
   b. Which barriers have you not managed to overcome?

17) What supports to the use of EC content have you experienced?
   a. What could administration do to help teachers with the implementation of EC content?

18) What advice would you give to teachers new to teaching with EC content?

19) Do you feel like EC content is accessible to every Ontario science teacher?
   a. Do you feel like EC content is accessible to every Ontario science classroom?

20) Do you think the classroom is a good place to teach about the NOS?
   a. Do you think the classroom is a good place to learn about the NOS?

21) Do you have any final thoughts?