Implementing Ontario’s Science-Technology-Society-Environment Curriculum Expectations: Experiences of Senior Biology Teachers in Toronto

By

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A research paper submitted in conformity with the requirements

For the degree of Master of Teaching

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Abstract

Although some uncertainty persists regarding the precise definition of Science-Technology-Society-Environment (STSE), a significant body of literature has been amassed, demonstrating the measurable benefits of STSE and related pedagogical approaches for students, their learning, and, consequently, their enthusiasm for science. Interestingly, while science teachers appear to almost universally acknowledge the importance of presenting and engaging with STSE-based content in their classrooms, the research suggests that these same educators often remain reluctant to fully incorporate such material into their teaching practices. With that in mind, the purpose of this qualitative, interview-based study was to explore teachers’ experiences of implementing Ontario’s STSE curriculum expectations in their senior biology classes. From this investigation, it was found that, for senior biology teachers, the imperative to include STSE-related material in their lessons often went beyond the explicit expectations, and was, instead, influenced by values and experiences that were external to the curriculum documents. Further, while the participants in this study appeared to be personally invested in the value of STSE in the classroom, they, at the same time, perceived STSE-based lessons to be more time consuming and onerous to prepare than those based on more “canonical” scientific content. In light of these findings, possible implications for students, teachers, administrators, policy makers, and education researchers were discussed and recommendations for future practice were reported.

Key Words: Science-Technology-Society-Environment (STSE), socio-scientific issues (SSI), biology, secondary education, teacher attitudes, classroom practice
Acknowledgements

I owe no small measure of thanks to Dr. Lee Airton for their much-needed assistance and leadership in guiding me (and many of my fellow classmates in the Master of Teaching program) through this complex and onerous “MTRP” business. Your considerable efforts and positive words of encouragement have not gone unnoticed or underappreciated.

Thanks also to the numerous professors, teachers, and acquaintances who have provided valuable feedback on my written work and insight into my topic of study. Without your commitment and diligence, this project would not have been possible. In this regard, I would like to single out the contributions of my TA, Austen Koecher, in particular. Thank-you for taking the time to regularly review my work and for making your expertise available to me. My research has benefitted greatly from your generous support.

For my colleagues in the MT program, I highly value having had the privilege of working alongside you for these past two years. Thanks for being a part of my research and for letting me be a part of yours.

To my family and friends, thanks for not always asking me why I am not “done yet” and for, instead, seeing my education as something that can only be advantageous to you in the impending zombie apocalypse and/or the future colonization of Mars. That said, you will be happy to know that this is indeed my “last rodeo,” as it were.

I owe a special debt of gratitude to my wonderful mother, for allowing me to spend a large portion of my life pursuing higher education and, importantly, for not holding my apparent inability to settle on a particular profession against me. Without her absolutely unconditional love and support, I would not have had the freedom to explore those things that truly make me happiest.
And, lastly, I extend my utmost appreciation to my partner-in-crime of nearly twelve years, Stefan Ferraro. Thanks for agreeing to endure with me the crazy schedules, constant stress, and near-permanent poverty that often accompanies graduate education. Thanks for making me work when I’d really rather not, and for telling me that I can do it when I am pretty sure that I can’t. For all of your efforts – even the most subtle – I really cannot thank you enough.
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<th>Description</th>
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<tbody>
<tr>
<td>CEMC</td>
<td>Council of Ministers of Education, Canada</td>
</tr>
<tr>
<td>EMS</td>
<td>Emergency Medical Services</td>
</tr>
<tr>
<td>FNMI</td>
<td>First Nations, Métis, and Inuit</td>
</tr>
<tr>
<td>hBA</td>
<td>Honours Bachelor of Arts</td>
</tr>
<tr>
<td>hBSc</td>
<td>Honours Bachelor of Science</td>
</tr>
<tr>
<td>LD</td>
<td>Learning disability</td>
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<tr>
<td>MSc</td>
<td>Master of Science</td>
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<tr>
<td>MT</td>
<td>Master of Teaching</td>
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<tr>
<td>MTRP</td>
<td>Master of Teaching Research Project</td>
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<tr>
<td>NOS</td>
<td>Nature of Science</td>
</tr>
<tr>
<td>OISE</td>
<td>Ontario Institute for Studies in Education</td>
</tr>
<tr>
<td>PD</td>
<td>Personal development</td>
</tr>
<tr>
<td>PhD</td>
<td>Doctor of Philosophy</td>
</tr>
<tr>
<td>SSI</td>
<td>Socio-scientific issues</td>
</tr>
<tr>
<td>STS</td>
<td>Science-Technology-Society</td>
</tr>
<tr>
<td>STS(E)</td>
<td>Science-Technology-Society-Environment</td>
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<tr>
<td>TA</td>
<td>Teaching Assistant</td>
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Chapter One: Introduction

1.0 Research Context and Problem

Although some uncertainty persists regarding the precise definition of Science-Technology-Society-Environment (STSE) in practice, it has been generally described as a collection of approaches to science teaching that take into account the myriad cultural, social, political, and/or historical contexts in which scientific knowledge is constructed. Importantly, STS(E)\(^1\) also emphasizes the societal and environmental implications of scientific and technological investigation and discovery (Aikenhead, 1994; Pedretti & Nazir, 2011). Over the past several decades, a significant body of literature has emerged, demonstrating the measurable benefits of STS(E) and related pedagogical approaches (such as Science-Technology-Society, Future Studies, socio-scientific issues-, and context-based methods) for students, their learning, and, consequently, their enthusiasm for science (Bennett, Lubben, & Hogarth, 2007).

Interestingly, while science teachers appear to almost universally acknowledge the importance of presenting and engaging with socio-scientific issues in their classrooms, studies suggest that many of these educators remain reluctant to fully incorporate such material into their teaching practices (Aikenhead, 2006; McGinnis & Simmons, 199; Pedretti et al., 2008). Although several reasons for this have been reported, little progress has been made to remedy this apparent gap between classroom reality and the theoretical ideals that have been expressed by teachers and academics, alike (Aikenhead, 2006; McGinnis & Simmons, 1999; Pedretti et al., 2008).

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\(^1\) Here, the term STS(E) (as opposed to simply STSE or STS) is meant to symbolize the ambiguous distinction that exists in the literature between STS and STSE education. STSE is a uniquely Canadian construction (Canadian Council of Ministers of Education, 1997) of recent origin that is usually conflated with STS, a much older designation in the science education literature (Aikenhead, 2006). The only distinction between the two is that STSE explicitly emphasizes the link between science and environment; however, STS education does not preclude discussions of environmental issues, either. This ambiguity (along with several other STS(E)-like approaches to science education) will be discussed in more detail in section 2.2 of this paper, which is entitled “What is STS(E)?: “Currents” in STS(E) Education.”
Studies suggest that this general claim holds true in the context of science education in Ontario, Canada (Aikenhead, 2006; Pedretti et al., 2008; Steele, 2013), where the STS(E) ethos has more recently been embedded in elementary and high school science curricula in the form of explicit goals and curriculum expectations (Ontario Ministry of Education, 2007, 2008a, 2008b). Indeed, STS(E) is highlighted as the first of three discrete “Goals of the Science Program” that have been outlined for the province (Ontario Ministry of Education, 2007, 2008a, 2008b).

Although explicit STS(E) expectations are provided in the Ontario curriculum documents for each science course and unit (see Tables 1 & 2, pp. 4-5), there appears to be very few training and personal development (PD) opportunities available for teachers in areas relating to STS(E) education (Pedretti et al., 2008; Steele, 2013). As a result, the onus is generally on the teachers themselves to learn how to incorporate STS(E) into their lessons. Further, university-level science courses – where science teacher candidates obtain the majority of their subject-specific expertise – often do not cover STS(E) issues and, instead, focus on “content” (e.g. reactions, cycles, proteins, molecules, “the facts”, etc.) (Aikenhead, 2005). While a small number of online resources are available to help teachers better navigate STS(E)-related areas of instruction (e.g.: Bencze, 2011), and STS(E)-centered education is often an explicit feature of pre-service science teacher training in Ontario, many science teachers still report feelings of general unpreparedness and discomfort when it comes to teaching STS(E)-specific content (Pedretti et al., 2008; Steele, 2013). As indicated above, STS(E) approaches to science teaching have been shown to have positive effects on student learning and interest in science (Bennett, Hogarth, & Lubben 2006).

Thus, it follows that, should teachers feel unprepared to teach STS(E)-related subject matter and refrain from engaging with it in their classrooms, students may be underserved.
Unfortunately, the majority of recent studies undertaken in the area of STS(E)-based science education have focused on the European and American milieu, with comparatively little attention being focused on Canadian science education models. STS(E)-based biology education has been particularly under-represented in these discussions, with much more attention being devoted to the physical sciences, which are thought to be viewed more negatively by students (Bennett, Hogarth, & Lubben, 2006). Even so, by comparison, biology may still be considered more amenable to historical and social evaluations in the classroom than are other sciences. For instance, biology curricula often cover many more controversial and value-laden subjects than do the physical sciences. Indeed, these issues (e.g.: evolutionary theory, genetic modification, cloning, species extinction, stem cells, environmental degradation, etc.) often have increasingly obvious and pressing social implications (Khalil, Lazarowitz, & Hertz-Lazarowitz, 2014). In this way, the applications of STS(E)-based approaches to biology education may be at least as valuable as they are thought to be to chemistry and physics, in that they may be better able to aid students as they try to assess the plethora of important and on-going scientific debates that currently characterize modern society. Thus, in light of the reported benefits of STS(E) approaches to science education and the paucity of research in the area of STSE(E) and biology instruction, in particular, it is hoped that this research will fill an important gap in that exists in the current research literature.

1.1 Purpose of the Study

The purpose of this qualitative interview study is to elucidate Ontario secondary biology teachers’ experiences of integrating Ontario’s STS(E) curriculum expectations into their classroom practice. For the purposes of this study, I will explore the incorporation of STS(E) by these teachers by interviewing them about their own attitudes toward the STS(E) ethos and its
Table 1: Example STS(E) curriculum expectations from the Ontario Science Curriculum documents for grade 11. Only one STS(E) expectation for each of the units of study selected is shown, as an exemplar (Ontario Ministry of Education, 2008b). The expectations presented are also accompanied by the sample issue and suggested questions that they are paired with in the curriculum documents. Only STS(E) expectations for university preparation courses are displayed.

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>Unit of Study</th>
<th>STS(E) Expectations, Sample Issues, and Questions</th>
</tr>
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</table>
| 11          | Diversity of Living Things        | • B.1.2 analyse the impact that climate change might have on the diversity of living things.  
  o Sample issue: Some scientists believe that we are in the early stages of a human-made mass extinction partly caused by rapid climate change. Many species that cannot tolerate the change will become extinct. However, Earth’s history has shown that extinction of some species creates opportunities for surviving species to adapt, evolve, and flourish.  
  o Sample questions: Why do higher temperatures affect the survival of some species in freshwater environments? Why would an increase in ocean temperatures endanger many species that depend on coral as a home and food supply? In what ways have longer growing seasons, which may include a second harvest, affected the biodiversity of agricultural lands? How might species such as the Eastern Massasauga rattlesnake be affected by increased water levels in their habitats? |
| 11          | Plants: Anatomy, Growth, and Function | • F1.1 evaluate, on the basis of research, the importance of plants to the growth and development of Canadian society.  
  o Sample issue: The agricultural sector holds great economic potential as demand increases for products such as biofuels, biochemicals, and biopharmaceuticals. Bioresources could also support our efforts to produce renewable energy, improve health, and minimize environmental impact. However, critics are concerned about the impact of bioresources on the availability of food crops and the price of food.  
  o Sample questions: In what ways does the local food movement contribute to community development? How does the re-introduction of native plant species along river banks help to prevent land erosion? What plant species are considered important in sustaining Canada’s growth in the agricultural sector? How might the increasing demand for straw-bale housing materials support Canada’s agricultural sector and increase the sustainability of other natural resources? |
Table 2: Example STS(E) curriculum expectations from the Ontario Science Curriculum documents for grade 12. Only one STS(E) expectation for each of the units of study selected is shown, as an exemplar (Ontario Ministry of Education, 2008b). The expectations presented are also accompanied by the sample issue and suggested questions that they are paired with in the curriculum documents. Only STS(E) expectations for university preparation courses are displayed.

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>Unit of Study</th>
<th>STS(E) Expectations, Sample Issues, and Questions</th>
</tr>
</thead>
</table>
| 12          | Biochemistry           | • B.1.2 evaluate, on the basis of research, some advances in cellular biology and related technological applications.  
    o Sample issue: In nuclear medicine, radioactive compounds are injected into the body so that images of cells can be scanned to diagnose and treat medical conditions such as cancer and heart disease. Radioisotopes may now be used so routinely and effectively that we have come to rely on them despite concerns about production safety.  
    o Sample questions: How are drugs used to target tumour cells during chemotherapy? How are scientists using bacteria to create antibiotics that fight drug-resistant bacteria strains? What role might nanotechnologies play in replacing current diagnostic and treatment technologies? |
| 12          | Molecular Genetics     | • D1.1 analyse, on the basis of research, some of the social, ethical, and legal implications of biotechnology.  
    o Sample issue: Corporations that have patented genetically modified (GM) seeds legally require farmers to buy new seeds from them each planting season. Corporations that find GM crops on a farm that did not purchase their seed can take the farmer to court. However, natural processes such as cross-pollination can result in the migration of GM crops to neighbouring farms.  
    o Sample questions: Should private companies be able to patent life forms, including genetic material? Why or why not? Who owns and controls our personal genetic information? Who should have access to our personal genetic information and decide how it will be used? What are the ethical implications of reproductive technologies that allow postmenopausal women to conceive? |
efficacy as a teaching approach in senior biology classrooms, their perceptions of the outcomes of their efforts to include STS(E)-related topics in their lessons, as well as any barriers or supports that might influence their ability to adequately address the STS(E) curriculum expectations in their senior biology classes. Possible implications for students, teachers, administrators, policy makers, and academics will also be examined, with an aim to increase teacher commitment to fulfilling ministry mandated STS(E) expectations in Ontario classrooms.

1.2 Research Questions

The central question guiding my research is: what are Toronto-based educators’ experiences of integrating the STS(E) expectations that are embedded in the Ontario Science Curriculum into their senior biology classes? Additional sub-questions that guide my research include:

- How do teachers feel about the STS(E) curriculum expectations that have been designed for senior biology courses?
- What value do teachers place on teaching STS(E)-related content in their classrooms?
- What strategies do teachers generally use in order to integrate the STS(E) curriculum expectations in their classrooms?
- Do teachers feel that STS(E) is an effective approach to teaching in biology and how do they assess this?
- What barriers prevent teachers from addressing STS(E)-related content in their classes?
- What resources or supports do teachers feel that they require in order to better address required STS(E) content, as it is outlined in the Ontario Science Curriculum?
1.3 Reflexive Positioning Statement

The issue of Ontario’s STS(E) expectations is of particular interest to me for several reasons. In general, these reasons stem – at least in part – from my own academic background. In fact, long before entering my current teacher education program, I obtained an hBA (honours Bachelor of Arts) in Humanities, where my studies focused on the history and philosophy of science. During my time in this program, I was particularly interested in exploring the interactions that occur at the interface of biology and society, perhaps especially in the fields of genetics and evolution. After finishing my Arts degree, I went on to complete an hBSc (honours Bachelor of Science) and an MSc (Master of Science) in biology. Notably, my earlier interest in the history and philosophy of biology persisted throughout my two science degrees; however, I found that this sort of content was decidedly lacking from my undergraduate biology courses. Now that I am a prospective teacher and working alongside colleagues who do not have the benefit of my background in both the arts and the sciences, I feel that current biology education at the university level may be insufficient to prepare teachers to effectively engage with and teach STS(E)-related content, as is prescribed by the Ontario Science Curriculum. Further, as STS(E) approaches have been shown to increase student interest and engagement with science (Bennett, Hogarth, & Lubben, 2003, 2006), I am also concerned that students may be underserved by ineffective teacher training at the undergraduate level.

My academic background has also imbued me with a particular interest in science and how it relates to society. Indeed, I feel that understanding science as a socially imbedded process can help to provide students with a more accurate idea of what science “looks like” in practice. After all, scientific “facts” are not immutable things that simply emerge out of thin air; rather, they are complex historical and social entities that arise as a result of particular contexts. Understanding
this basic principle, I think, can only serve to reinforce scientific literacy, a skill that I believe is necessary for functioning in a society such as our own, which is rife with ongoing scientific controversies (e.g., genetic modification, evolutionary theory, stem cell research, gene editing, etc.). As a prospective high school biology teacher, I am committed to providing my students with ample opportunity to engage with issues surrounding the social implications and embeddedness of science. The STS(E) expectations that have now been firmly entrenched in the Ontario science curriculum are one vehicle through which to do this and are thus of particular importance to my own teaching philosophy.

On a personal level, the broader ethic of STS(E) is also reflective of my own political and philosophical leanings. STS(E) provides an avenue through which the structure of science and the power that it holds as an authoritative kind of knowledge can be questioned and problematized. For me, this is important because it gives those who might not see themselves reflected in scientific endeavours an avenue through which to interact with science in a way that may be less alienating and more empowering. This objective resonates with me, in particular, as I also come from a rural, low-income upbringing, where I did not always see science as a field that was open to me. I am now the first person in my family to have obtained a university degree, and, for the good of those who come after me, I want to use my knowledge and experience to help dispel some of the mythology of science that I once adhered to as a youth.

1.4 Overview

To respond to the research questions outlined in section 1.2, I will be conducting a qualitative research study using purposeful sampling to interview three high school biology teachers about their experiences of implementing Ontario’s STS(E) curriculum expectations in their senior biology classrooms, the instructional strategies that they employ in order to do so, as
well as their feelings of preparedness to engage with STS(E)-related content, and the perceived outcomes of their efforts.

In Chapter Two, I relate a brief history of the STS(E) movement in education, the shifting definitions of and approaches to STS(E) that exist in the literature, and how STS(E) has served to shape the current Ontario Science Curriculum. In Chapter Three, I review the research on the reported failures of orthodox science teaching, the benefits of STS(E) approaches to science education, the motivations of teachers to incorporate STS(E), and reported best practices for doing so. In addition, I examine some of the key gaps in the STS(E) literature related to biology instruction in the Canadian context. In Chapter Four, I elaborate on my research design. In Chapter Five, I report my research findings and discuss their significance in light of the existing research literature, and in Chapter Six, I identify the implications of the research findings for my own teacher practice, and for the educational research community more broadly, for which I propose a series of recommendations. I also articulate the questions raised by the research findings, and point to areas of future research.
Chapter Two: Conceptual Framework

2.0 Introduction to the Chapter

In this chapter, I examine the shifting definitions of Science-Technology-Society-Environment (STS(E)) and how these varied conceptions have allowed for a disparate array of front-line teaching practices, all operating under a larger Science-Technology-Society (STS) umbrella. I start by reviewing the literature in the area of STS(E) (and STS(E)-type approaches to science teaching), in general, where I consider the historical origins and present state of the STS(E) movement in science education. And, finally, I review how STS(E) approaches to science education have been integrated in North American schools, with particular emphasis on its implications for science education in Ontario, Canada.

2.1 STS(E): A Brief History

The goals we set for the science courses we teach are images of a future state, where we hope the student will be at some time. Yet we have not written science curricula this way. We review the past and leave out the future. – Hurd, 1975, p. 30

STS(E) has had a long history in Western models of education. Originating in the 1970’s, STS(E) eventually emerged out of the larger STS movement in secondary and post-secondary education (Aikenhead, 2006; Pedretti & Nazir, 2011). It could be argued that the STS(E) movement, itself, initially grew out of increasing social unease regarding the reciprocal influence of science on society and vice versa. In an age still reeling from the atomic bomb, nuclear fallout, Agent Orange, DDT, and Sputnik, concerns regarding the ethical, social, and political ramifications of science became central to the science education discourse (Aikenhead, 2003; Aikenhead, 2006; Cutcliffe, 1990; Hurd, 1975; Solomon, 2003). Moreover, at this time, science was coming to be viewed as a force that was mainly directed at the maintenance of the status quo.
(Aikenhead, 2003; Cutcliffe, 1990). That is, societal factors (such as funding for science by private and public industry) were seen to influence the determination of what scientific questions were deemed valid, while, at the same time, it was supposed that the internal, self-regulatory culture of science could also “inhibit the development of novel concepts and new areas of research” (Gallagher, 1971).

In 1971, James Gallagher, became one of the first proponents of STS(E) (though he did not then call it that) to propose changes to elementary and secondary science curricula. Specifically, he suggested that the model of science instruction be “broadened” to incorporate, not only the content and process of science, but also discussions of the complex interrelationships that occur between science, its application in technology, and other social factors (Gallagher, 1971, p. 329). The object of this expansion was explicitly to allow learners to explore “not just the knowledge we have, but how it was acquired” (p. 331), as well as to restore the “realism and relevance” of science courses that had been constructed in the image of so called “pure science” (p. 333). For Gallagher, the potential implications of adopting the more inclusive and holistic approach to science teaching that he had proposed were clear:

For future citizens in a democracy, understanding the interrelations of science, technology, and society may be as important as understanding the concepts and processes of science. An awareness of the interrelations between science, technology, and society may be a prerequisite to intelligent action on the part of a future electorate and their chosen leaders.

(p. 337)

That is, for Gallagher and other proponents of what would later come to be known as “STS”, the main function of science education would ideally be to produce scientifically literate citizens who could not only reiterate scientific facts, but could also critically consider them in context in
order to make informed personal and social decisions. For advocates of this new interdisciplinary view of science, science education was no longer to be exclusively directed at pre-professional apprentices (Aikenhead, 2003; Hurd, 1975). Rather, as would become somewhat of a slogan for the STS(E) movement in later years, science was truly meant “for all” (Fensham, 1985, p. 415; Malcolm, 2003, p.18-19).

Gallagher’s sentiments were later echoed and further developed by Hurd, in his seminal 1975 article, “Science, Technology, and Society: New Goals for Interdisciplinary Science Teaching”, where he outlined an explicit curriculum structure for the new school science (p. 27-30; Aikenhead, 2003). At the post-secondary level, undergraduate STS(E) programs were introduced in the United States as early as 1969 (Aikenhead, 2003; Cutcliffe, 1990). The early adoption of STS(E) by universities led to the formalization of the field through the creation of professional societies, organizations, and journals (Aikenhead, 2003, p. 61; Cutcliffe, 1990, p. 361). While the STS(E) movement in primary and secondary education was certainly influenced by these changes at the post-secondary level, the acronym, “STS”, would not come into popular use in these educational circles until somewhat later. The publication of Teaching and Learning about Science and Society by John Ziman in 1980, which referred to STS directly in relation to high school science, is often cited as the main impetus for its acceptance within these communities, particularly in the US2 (Aikenhead, 2003; Pedretti & Nazir, 2011). However, as Glen Aikenhead suggested in his 2003 historical account of the STS movement:

It seems clear that slogan STS came from different sources, from different people influenced by different circumstances and was embraced for different purposes. For almost

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2 However, it was in common use in the UK at this time, where the term and acronym were officially recognized by the Science, Technology, and Society Association (STSA). Importantly, Ziman acted as chairman of this association, as well (Aikenhead, 2003).
every writer there will be a different citation for the original source of STS. More importantly however, the slogan created networks of science educators dedicated to changing the status quo of school science. (p. 62)

In other words, while the base desire for change in orthodox science teaching was clear, the precise origins of STS are complex, as it appears to have had multiple interdependent origins. Indeed, this apparent complexity has been a persistent and longstanding issue for STS and both its proponents and its critics (Pedretti & Nazir, 2011; Zeidler et al., 2005; Pedretti & Hodson, 1995, p. 463; Cutcliffe, 1990, p. 362), as will be discussed in more detail in the next section.

2.2 What is STS(E)?: Currents in STS(E) Education

Today, STS and STS(E) are terms that are largely conflated in the literature. Indeed, the term “context-based” is also often used in place of STS(E) in other parts of the world, and perhaps particularly in the European science education literature (Bennett, Lubben, & Hogarth, 2006). Though some uncertainty persists regarding the precise definition of STS(E) in practice (Aikenhead, 2005; Pedretti & Nazir, 2011), it has been generally described as an approach to science teaching that recognizes science and technology

As complex socially embedded enterprises in which cultural, political, and economic values, as well as technical expertise, shape the directions of scientific research and technological innovation. In turn, of course, the products, and even the conduct, of science and technology affect cultural, political, and economic values and through them society and its institutions. (Cutcliffe, 1990, p. 362)

In addition to underscoring this reciprocal relationship between the values of science and society, STS(E) is also thought to emphasize the direct societal and environmental implications and
effects of scientific investigation and discovery (like environmental degradation, for instance) (Aikenhead, 1994; Hurd, 1975).

Importantly, this definition allows for a multiplicity of pedagogical approaches to STS(E) education. Indeed, as the complex history of STS(E) suggests, and as Pedretti and Hodson (1995) remind us,

It would be a mistake to assume that STS is a single, coherent and well-articulated approach to science education. Rather, it is a movement with a number of different strands, each with a distinct history, and it is a movement in which there are some significant tensions. Given these disparate origins and these various tensions, it would be surprising if there were not a wide variety of STS-oriented courses in existence. (p. 463)

To use the language of Pedretti and Nazir (2011), under the rather large umbrella of STS(E), several different – though not entirely distinct – “currents” or threads have been identified. Under the most recent schema, these currents include: 1) Application/Design, 2) Historical, 3) Logical Reasoning, 4) Value-centred, 5) Sociocultural, and 6) Socio-ecojustice. A brief description of each of these currents, their aims, and teaching approaches are given in Table 3 (Page 16). As there is much overlap between these threads within the larger STS(E) ethos, they are not thought to be mutually exclusive (Pedretti & Nazir, 2011). As is explained by Pedretti and Nazir (2011),

These currents must not be reified, nor should they be considered as some kind of hierarchy. Instead, each current has its own strengths and limitations. Some have a longer history than others, whereas others reflect more recent concerns. Some currents can also coexist, overlap, and be utilized in harmony. It is up to teachers to ultimately choose the
messages and methods that are appropriate to their educational context, the curriculum unit or topic, and to their particular worldviews. (p. 619)

This apparent permeability across the different strands of STS(E) has been, at once, the field’s greatest strength and its most common source of its criticism (Pedretti & Nazir, 2011). Indeed, its proponents largely revel in STS(E)’s defiance of strict definition (Fuglsang, 2001; Pedretti & Hodson, 1995; Pedretti & Nazir, 2011; Ziman, 1994). They claim that a certain amount of structural flexibility within STS(E) is prerequisite to its key role in education: helping students to adapt to a rapidly changing world (Pedretti & Hodson, 1995). According to its adherents, STS(E) is also thought to provide teachers with a “variety and richness” of approaches through which to “enhance, complement, and extend” traditional science content (Ziman, 1994, p. 22 & 31). In further defense of STS(E)’s pedagogical diversity, Ziman (1994) states that the particular benefits and shortcomings of any one approach to STS(E) education may be complimented by another, suggesting that one might think of STS(E) “as a gemstone, whose facets are less interesting than the edges and corners where they meet” (p. 31).

Others are perhaps less convinced of the virtues of STS(E)’s apparent eclecticism. As Zeidler et al. (2005) explain,

STS education, as typically envisioned and practiced, does not seem to be embedded in a coherent developmental or sociological framework that explicitly considers the psychological and epistemological growth of the child, nor the development of character or virtue. The lack of a theoretical framework with respect to STS materials has been noted by others, suggesting that STS may be an underdeveloped idea in search of a theory. (p. 358)
Table 3: Currents in STS(E) education, as identified and described by Pedretti and Nazir, 2011.

<table>
<thead>
<tr>
<th>Name of Current</th>
<th>Defining Characteristics</th>
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| Application/Design    | • Emphasizes the link between science and technology.  
• Focuses on problem-based learning, with application and design-based exercises.  
• Teaching approaches employed are generally utilitarian, pragmatic, and experiential.       |
| Historical            | • Emphasizes the historical roots of science and how knowledge is generated.  
• Focuses on historical case studies, role play, and simulations.  
• Teaching approaches employed are generally creative, reflexive, and affective.             |
| Logical Reasoning     | • Emphasizes understanding and making decisions about socio-scientific issues in light of empirical evidence.  
• Tends to be issues-based.  
• Teaching approaches employed are generally reflexive and cognitive.                         |
| Value-Centred         | • Emphasizes understanding and making decisions about socio-scientific issues in light of ethics and moral reasoning.  
• Tends to be issues-based.  
• Teaching approaches employed are generally affective, moral, logical, and critical.        |
| Sociocultural         | • Emphasizes that science as “one way of knowing” (p.615).  
• Promotes an understanding of science and technology as embedded in a sociocultural context.  
• Teaching approaches employed are generally holistic, reflexive, experiential, and affective. |
| Socio-ecojustice      | • Places emphasis on being critical of/solving social and ecological problems through human agency or action.  
• Aims to encourage feelings of citizenship and civic responsibility.  
• Teaching approaches employed are generally creative, affective, reflexive, critical, experiential, and place-based. |
For Zeidler et al. and others, the variety of disparate approaches to STS(E) only serves to undermine its intended role in science education. That is, STS(E) has become so diffuse since its inception that its content is usually isolated from – as opposed to fully integrated into – current science curricula (Zeider et al., 2005). Indeed, in universities and senior courses, STS(E) content is often taught separately from “pure science” in distinct programs of study (Aikenhead, 2005; Zeidler et al., 2005). Further, in high school texts, the prerequisite for STS(E) content is generally satisfied via the careful placement of supplementary text boxes containing tangential vignettes describing the various social and environmental effects and consequences of science (Calado et al., 2015; Pedretti & Hodson, 1995; Zeidler et al., 2005;). According to Zeidler et al. (2005), the problem here is that

Traditional STS(E) education (or perhaps STS(E) education as currently practiced by and large) only “points out” ethical dilemmas or controversies, but does not necessarily exploit the inherent pedagogical power of discourse, reasoned argumentation, explicit NOS [Nature of Science] considerations, emotive, developmental, cultural or epistemological connections within the issues themselves. (p. 359)

Indeed, due to longstanding disagreements about what STS(E) is and what it is not, for its critics, STS(E) remains as a mere “context for curriculum”, and not a proper and complete pedagogical strategy in and of itself (Yager, 1994, p. 13; Zeidler et al., 2005, p. 360).

2.3 STS(E) Alternatives: Future Studies and Socio-Scientific Issues

To contend with the inherent pluralism of STS(E), a few supposed “alternatives” to it have been put forward in the science education literature (e.g., Zeidler et al., 2005; Lloyd & Wallace, 2004). One such movement is Socio-Scientific Issues (SSI) education. According to Zeidler et al. (2005),
The SSI movement focuses specifically on empowering students to consider how science-based issues and the decisions made concerning them reflect, in part, the moral principles and qualities of virtue that encompass their own lives, as well as the physical and social world around them. Accordingly, SSI education is equated with the consideration of ethical issues and construction of moral judgments about scientific topics via social interaction and discourse. (p. 360)

According to this conceptualization, STS(E) is fully subsumed within SSI and includes additional considerations for the ethical implications of science as they relate to the moral and emotional development of the child (Zeidler et al., 2005, p. 361). Further, SSI is thought to adhere to a stricter theoretical framework than does STS(E). Under this framework, scientific literacy is directly promoted by encouraging the personal, cognitive, and moral development of the student. Cultural, case-based, nature of science, and classroom discourse-based issues all serve as entry points through which a science teacher may affect student development (Zeidler et al., 2005, p. 361). In terms of classroom practice, SSI explicitly employs controversial scientific topics in order to engage students in overt discussion and debate (Zeidler and Nichols, 2009, p. 49). Unlike STS(E), its opponents claim, SSI education directs teachers toward appropriate pedagogical strategies “that acknowledge the social development of children’s identity as part and parcel with the curriculum” (Zeidler & Nichols, 2009, p. 50).

Future Studies is another movement that seeks to divorce itself from the STS(E) moniker. As the name suggests, the field of Future Studies is explicitly concerned with exploring what are referred to as “alternative futures” (Lloyd & Wallace, 2004, p. 140). Broadly, “futurists”, as they are called “clarify goals and values, analyse and interpret the recent past and the present, explore projections of current trends, and carry out systematic studies of possible, probable, and
preferable futures.” Within the context of the sciences, a Future Studies orientation enables students to apply scientific concepts and skills to address social issues as well as to anticipate and predict the possible consequences of scientific interventions in human endeavours and the environment.

While their originators argue for their uniqueness, proponents of STS(E) suggest that the SSI and Future Studies education movements are simply extensions of the existing STS(E) ethic (Pedretti & Nazir, 2011). As argued by Pedretti and Nazir (2011):

Although it can be argued that these are different movements, we take the position that they all recognize the importance of broadly conceptualizing scientific literacy to include informed decision making; the ability to analyze, synthesize, and evaluate information; nature of science (NOS) perspectives; the coupling of science, ethics, and moral reasoning; and agency. (p. 604)

Indeed, this is also the position taken by this researcher. As a result, (and, surely, to the chagrin of their proponents) both Future Studies and SSI will be subsumed under the banner of STS(E) for the purposes of this study. However, this choice of definition should not affect the data collection or analysis processes in this investigation, as the teachers who participated did not make any intentional distinctions between STS(E), SSI, or Future Studies in their interviews.

2.4 Ontario’s Science Curriculum and the STS(E) Movement

Though changes to orthodox science teaching had been proposed by many sources by the late 1970’s, and comprehensive post-secondary programs specific to STS(E) had already existed in colleges and universities as early as 1969, STS(E) initiatives would not be integrated into elementary and secondary education policy and curricula until the mid-1980’s – particularly in the United States (Aikenhead, 2003; Kumar & Berlin, 1993). In Canada, on the other hand, STS
reforms were not formally prioritized by government until 1997, with the publication of the Canadian Council of Ministers of Education’s (CEMC) report, entitled *Common Framework of Science Learning Outcomes: Pan-Canadian Protocol for Collaboration on School Curriculum*, which presented STS(E) as the first of four foundations upon which subsequent science curriculum reform would be based. According to the CMEC document (1997), the STS(E) “foundation statement is the driving force of the framework”. Indeed, many of the learning outcomes presented in the document were intended to “flow directly or indirectly from the STS(E) domain,” thus further emphasizing the centrality of STS(E) to intended future curriculum reforms in Canada.

However, it should be noted that, as this document was of federal origin, the provinces were not legally bound by it (Sammel & Zandvliet, 2003). As a result, these recommendations were not officially operationalized in any of the Canadian provinces until somewhat later. In Ontario, eventual curriculum reforms, taking place in two phases in the early and late-2000’s, placed a spotlight on STS(E) science education (Pedretti and Nazir, 2011; Sammel & Zandvliet, 2003). In the first incarnation of the Ontario Science Curriculum that was formulated after CEMC’s 1997 report, the STS(E) expectations were positioned at the end of each unit of study (Steele, 2013), contrary to the primacy of STS(E), which was implied in the original CEMC document. Later, in 2008, the Ontario science curriculum was revaluated, and the STS(E) expectations were repositioned at the beginning of each unit, largely because “nobody ever really pay[ed] attention to them” up until that point, given their somewhat concealed position at the end of each unit of study (Steele, 2013, p. 28).

According to the most current curriculum documents, STS(E) is highlighted in this way in order to “better align the curriculum with the optimal approach to teaching and learning science,
and to emphasize the importance of scientific, technological, and environmental literacy for all students” (Ontario Ministry of Education, 2008ab, p. 16). In these documents, the specific STS(E) expectations for each unit of study are even supplemented by sample issues and questions that science teachers’ may choose to investigate in their classes. Explicit examples of Ontario’s STS(E) expectations and some sample questions and issues for select high school biology courses are given in Tables 1 and 2 (p. 4-5).
Chapter Three: Literature Review

3.0 Introduction to the Chapter

In this chapter, I review the literature in the area of Science-Technology-Society-Environment (STS(E)). More specifically, I review research on the reported failures of traditional science teaching, the purported benefits of STS(E) approaches to science education, and examine how, when, and if these approaches to science instruction are put into practice by teachers. Finally, I focus my attention on some of the key gaps in the STS(E) literature – particularly as they relate to biology instruction in the Canadian context.

3.1 The Benefits of STS(E) and the Failures of Traditional Science Curricula

Regardless of its conceptual complexity, a significant body of literature has emerged that demonstrates the measurable benefits of STS(E) and related pedagogical approaches for students, their learning, and their enthusiasm for science (Akcay & Akcay, 2015; Akcay & Yager, 2010; Autieri, Amirshokoohi, & Kazemour, 2016; Bennett, Hogarth, & Lubben, 2006). Indeed, STS(E)-based approaches have been shown to improve student attitudes toward science at all levels of secondary education, without, at the same time, negatively affecting their understanding of more technical scientific concepts and principles (Akcay & Akcay, 2015; Akcay & Yager, 2010; Bennett, Hogarth, & Lubben, 2006; Lee & Erdogan, 2007). Indeed, in a systematic meta-analysis of the effects of STS(E) approaches on student attitudes toward science, 7 of the 9 research studies that were included showed evidence of significant improvement over conventional science teaching methods (Bennett, Hogarth, & Lubben, 2006). Of the other two studies considered, only one reported that students had acquired less positive attitudes toward science as a result of STS(E)-based interventions in the classroom. However, it is important to note that this study was focused on a particular physics-centred STS(E) program that had been
implemented in the Netherlands (Wierstra & Wubbles, 1994). Interestingly, as the authors of the original 1994 study clarify, this result might best be explained by the format of instruction that was employed by the program under study. Specifically, it allowed for what the authors referred to as especially “open learning environments,” which were sometimes “difficult for teachers to handle.” This, they claim, might have resulted in student perceptions of classroom disorganization and inadequate one-on-one time with teachers, thus worsening student attitudes toward physics and science, in general (Wierstra & Wubbles, 1994).

Remarkably, one of the main concerns related to implementing STS(E)-centred pedagogical approaches in the classroom is the perception that they may serve to undermine the successful learning of the core concepts of science (Pedretti et al., 2008). According to the evidence, however, the precise opposite appears to be true. For instance, in their seminal review the effects of STS(E)-based instruction on the quality of secondary science education, Bennett, Lubben, and Hogarth (2006) found that students who had been exposed to STS(E) teaching methods had also acquired a comparable understanding of scientific concepts to that which would have been attained using more traditional approaches. That being said, of the 12 original research studies that informed their conclusion, a third of them suggested that students had acquired a superior comprehension of scientific content when educated under an STS(E)-centred teaching regime. Further, none of the studies considered indicated that scientific understanding among students suffered as a result of STS(E)-based instruction. Indeed, an STS(E) focus has been adopted by many recent science education reform efforts in order to encourage increased levels of scientific literacy among citizens (e.g.: Ackay & Ackay, 2015; Akcay & Yager, 2010; Autieri, Amirshokooohi, & Kazemour, 2016; Malcolm & Doidge, 2012; Tal & Kedmi, 2006).
One of the major criticisms of traditional science education is that the decontextualized scientific content that it presents tends to alienate women, minorities, and those of low socio-economic status (Hughes, 2000). As a result, students who belong to these groups tend to be underrepresented in scientific fields of inquiry (Aikenhead, 2006). STS(E) education, on the other hand, may work to counter this apparent trend, and there is some preliminary evidence to suggest that context-based teaching methodologies may, in fact, serve to increase female participation and interest in science (Bennett, Hogarth, & Lubben, 2003, 2006; Cassseau, 1997; Tal & Kedmi, 2006). In particular, studies show that the use of STS(E) and related pedagogical approaches serves to reduce gender differences in attitudes toward science, and female students in STS(E) classrooms have been found to harbor more positive attitudes than their colleagues in more traditional educational settings (Bennett, Hogarth, & Lubben, 2003, 2006).

Similarly, it has also been proposed that STS(E) may be especially beneficial to students in special education classrooms. As is argued by Caseau (1997),

The STS approach starts with the students, with their interests, and with what is relevant to their lives. In STS investigations, students become decision makers regarding issues and questions, how to find and use information, and what actions to take. Students with learning disabilities in traditional special education and general educations classrooms have not been active decision makers. They have been passive recipients of information.

(p. 59)

That is, because STS(E) focuses, in part, on teaching science as it relates to human experiences, it encourages students with learning disabilities (LDs) to make more explicit connections between abstract science and the real world (Caseau, 1997). Further, because of STS(E)’s emphasis on ethical issues, it has been found this type of instruction may help students with LDs
to clarify their own morals and values. While these things may benefit all students, students with LDs are thought to benefit disproportionately from STS(E) education due to their perceived classroom status as “inactive learners” (Caseau, 1997, p. 57).

In order to respond to this proposed need for better science instruction in special education courses, Caseau then followed the development and implementation of an STS(E)-focused special education teacher training program and reported teacher perceptions of student responses to the adoption of new instructional approaches in the classroom. To this end, teachers noted students were more motivated to learn and presented fewer behavioral issues during STS(E)-focused lessons than in previous classes. In addition, the change in approach was perceived by teachers to have resulted in a more collaborative and participatory learning environment, whereby students became the co-creators of knowledge, and were no longer simply the passive recipients of it.

While it is almost universally acknowledged that creativity is foundational to the scientific enterprise (Hodson & Reid, 1988), orthodox approaches to science education seem to generally eschew student creativity in favour of strict memorization and teacher-centred learning (Lee & Erdogan, 2007). Interestingly, across a variety of student populations, creativity has been found to be positively affected by STS(E) instruction ((Hacieminoglu, et al., 2015; Lee & Erdogan, 2007). In a 2007 study of Korean middle and high school students, those who were taught using STS(E) approaches were found to perform better on creativity assessments than did students who were taught using conventional methods (Lee & Erdogan, 2007). In order to assess creativity, students were evaluated based on their abilities to ask questions, reason causes, and predict consequences in relation to situation statements. Students who took STS(E)-based science classes were able to complete these tasks significantly better than those who did not –
particularly with reference to reasoning causes and predicting consequences scales. Indeed, these results have been reproduced in the North American educational context, as well (Hacieminoglu, et al., 2015).

STS(E) approaches in the science classroom are also thought to be helpful in dispelling many of the common myths about science, how it is “done”, and by whom. In his defense of the role of the history and philosophy of science in science teaching, Sleznak (1994) argues that the Conventional goals of science teaching have been articulated in authoritative and influential policy documents as inductive generalization from data [...]. However, such pronouncements, like other methodological doctrines, are impossible to reconcile with the actual practice of scientists themselves as revealed by the historical record. (p. 23)

According to Aikenhead (2006), presenting “mythical” representations of science in the classroom has tangible consequences for student learning and interest in science (p. 27). For one, students who would otherwise do well in science may refrain from taking science courses based on these misrepresentations. Alternatively, students who remain interested in science despite its misrepresentation may do so for unfounded reasons. Either way, such inaccurate images of science may persist into adulthood, where these same students will be required to make decisions as citizens that are predicated on these myths – decisions that may have considerable societal effects. STS(E), on the other hand, may help to dispel these myths by smoothing “the path for students’ conceptual change” (Aikenhead, 2006, p. 96).

Relatedly, in a recent study on middle school students’ understandings of the nature of science (NOS), it was found that students who were exposed to STS(E) instruction had a better and more realistic understanding of the NOS than did their peers in more conventional science

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3 For the purposes of the above-described study, NOS referred to conceptions of how science changes over time, as well as the role of society, culture, creativity and imagination in the development of scientific knowledge.
classrooms (Akçay & Akçay, 2015). The authors explained their results by appealing to the nature of STS(E)-based instruction, stating that, unlike textbook-based approaches, STS(E) “encourages teachers to use more explicit methodologies” and gives students the “opportunity to chose a problem or issue from real life to investigate […] as well as to apply their concepts to new situations” (p. 43). Methodologically speaking, it is also important to note that Akçay and Akçay’s 2015 study followed a paired design, where each teacher who participated was responsible for instruction in both STS(E)-based and traditional educational settings. That is, for each teacher, only the method of instruction and the students in each class were allowed to vary across conditions, thus allowing pre- and post-test data for each class under each condition to be statistically analysed more reliably.

3.2 Barriers to Implementing STS(E): The Policy-Practice Divide

Interestingly, while science teachers appear to almost universally acknowledge the importance of presenting and engaging with socio-scientific issues in their classrooms, these same educators remain reluctant to fully incorporate such material into their teaching practices (Aikenhead, 2006; McGinnis & Simmons, 1999; Pedretti, et al., 2008). Although several reasons for this have been reported, little progress has been made to remedy the apparent gap between classroom reality and the theoretical ideals that have been expressed by teachers and academics, alike (Aikenhead, 2006; Bybee, 1991; McGinnis & Simmons, 1999; Pedretti, et al., 2008).

In a 2008 study of the attitudes of Ontario pre-service teachers toward STS(E) education, several perceived barriers to its implementation in the classroom were identified (Pedretti et al., 2008). These barriers related to: 1) the preservation of control and autonomy in the classroom, 2) feelings of intradisciplinary support and belonging, 3) concerns about teacher expertise and the necessity to address a more “content-driven” curriculum, 4) teacher preferences for “value-free”
science classes, and 5) wariness of political and ideological biases. To explain these apparent tensions, the researchers pointed to the influence of science teacher identities:

STSE education fundamentally represents a post-positivist vision of science and science teaching that emphasizes: transformation (through sociopolitical action); decision-making; interdisciplinary; uncertainty; multiple solutions; the coupling of science and ethics; and teacher as facilitator and guide. Given that this vision is not the norm for science teachers, it is not surprising that beginning teachers are reluctant to embrace STSE education. (Pedretti et al., 2008, p. 955)

That is, according to Pedretti et al. (2008), science teachers may be reluctant to completely embrace STS(E) education because it fundamentally conflicts with their own ideas of what science is and what good science teaching should entail.

Other more practical considerations have also been identified as barriers to the implementation of STS(E) in science classrooms. For instance, lessons related to STS(E) are often perceived to be excessively time-consuming when compared to traditional content-based coursework (Steele, 2013). The general feeling among teachers that has been identified in the literature is that the onus is on particular teachers to research and gather information on STS(E) content, to select case-studies, and make connections to student experiences, preferences, and interests. As a result of the considerable time commitment that is required to do this, in some instances, STS(E) may only receive shallow treatment in science classrooms (Steele, 2013, p. 27-28).

The Ontario Science Curriculum also often offers teachers little to no help with reference to determining what STS(E)-based lessons should look like, and minimal explicit instructional guidance for teachers is provided in the curriculum documents (Steele, 2013). Personal
development opportunities in the area of STS(E) education also appear to be wanting (Pedretti et al., 2008; Steele, 2013), though some online resources have been made available for Ontario teachers (e.g.: Bencze, 2011). STS(E) is usually an explicit feature of pre-service science teacher training in the province, as well. Even so, science teachers in Ontario still often report feeling insufficiently prepared to tackle STS(E) in the classroom (Pedretti et al., 2008; Steele, 2013).

Further, questions of where STS(E) should be situated within each unit – and within the science program, at large – is another formidable issue. Importantly, the positioning of STS(E) within the science curriculum sends tacit messages to students about the importance of the material being covered. If, for instance, STS(E) is to be covered last in a particular unit or course, it implies that the teacher only intended to address this information if there was sufficient time to do so. On the other hand, if STS(E) is covered first, this underscores the importance of STS(E)-related content. However, this consideration can conflict substantially with yet another issue; what information do the students need to know, particularly, in order to prepare them for university (Hoeg & Bencze, 2014)?

3.3 Why Teach STS(E)?: Teacher Motivations

Until more recently, most researchers who have inquired about educators’ perspectives on STS(E) have focused on teacher responses to science education reform and, more specifically, their inclinations to either “accept, reject, or modify” them in their own teacher practice (Czerniak & Lumpe, 1996; Mitchener & Anderson, 1989, p. 351). More recent literature, however, has given increasingly more attention to teacher motivations for incorporating STS(E), suggesting that STS(E)’s role in science education has taken on a more accepted role in science curricula. Importantly, these studies have proposed that the impetus for teaching STS(E) does not always come from state-authorized science curricula (Lee & Witz, 2009; Mansour, 2010).
Rather, teacher motivations for integrating STS(E) into their lessons may be entirely divorced from education mandates – as well as from the efforts of the larger STS(E) education movement, in its entirety. In these cases, teachers appear to be motivated by their own personal initiative, values, and concerns. Indeed, for teachers who are already keen to engage with STS(E) in their classrooms,

The values and concerns of such teachers pervade their teaching practise and often lead them to develop their own perspectives for science and science teaching. And they are teaching whatever they feel important without much contact with reform ideas. (Lee & Witz, 2009, p. 932)

Notably, this, in turn, points to a formidable “gap between what reformers and researchers assume about teachers’ teaching practises and illustrates what really motivates teachers to move toward reform ideas” (Lee & Witz, 2009, p. 933). However, the implication of this is that teachers of this variety often present STS(E)-based material to their students using their own individualized understandings of what teaching STS(E) constitutes. Further, the goals of individual teachers who are self-motivated to tackle STS(E) in their classes are often fundamentally disconnected from those of researchers and professional organizations in science education. Indeed, in their qualitative case study of American educators’ inspirations for teaching socio-scientific issues (SSI) in their science classrooms, Lee & Witz (2009) found that teaching goals and approaches to teaching SSI were often not uniform across classrooms.

3.4 Teaching STS(E): Approaches to STS(E) Instruction

Compared to the effort expended by academics on fleshing out the complex theoretical and conceptual nuances of STS(E), relatively little work has been completed with the aim of determining best practices for STSE(E) instruction in the classroom. However, the available
research in this area does seem to suggest that, in general, student-centred approaches to STS(E) are best suited. For instance, in a study comparing student- and teacher-centred approaches to STS(E) instruction, students who participated in student-centred classrooms were found to have obtained more positive science-related attitudes than did their counterparts in teacher-centred sections of the same course (Ackay & Yager, 2010). Indeed, student creativity and understanding of key scientific processes were also especially improved when nurtured in the context of a student-centred STS(E) classroom, without detrimentally affecting the acquisition of important scientific concepts. Student-centredness in STS(E) classrooms has also been reported as beneficial for “non-science” students (Tal & Kedmi, 2006). For instance, in an assessment of an elective high school-level STS(E)-based course that had been developed for the Israeli education system, it was found that students benefited especially from the small-group collaborative learning and whole class discussions that were often employed in the classroom – though, as the authors claimed, teachers often did not take advantage of this opportunity in practice. As they reasoned, these approaches allowed “students to experience science-as-culture praxis, and create scientific discourse in class,” thus enabling them to further develop critical argumentation and reasoning skills (Tal & Kedmi, 2006, p. 622).

While, in general, student-centred classrooms are widely reported to be more amenable to the goals of STS(E) than teacher-centred ones, some authors in the field of STS(E) education have also devised more particular instructional strategies. The research of Bencze and Sperling (2012) and Bencze, Sperling, and Carter (2012) have been particularly instructive in this regard. Specifically, these authors recommend the use of what they refer to as “student-led, research informed STSE Action Projects” (Bencze & Sperling, 2012, p. 69). More precisely, these projects allow students to perform independent research on a chosen STS(E) issue. In addition to
secondary research, students are enabled to perform independent primary research on their topic in the form of simple correlational studies. In the final stage of these projects, students are then empowered to use what they have learned from their research in order to take an informed action on their issue. These actions might include such things as educating others, lobbying people in positions of power, inventing alternatives to a problematic product, procedure, or behaviour, or changing one’s own personal habits.

Importantly, in their investigations into the implementation of these student-led projects with both student teachers and senior-level science students, it was found that the more control that students were given “over [the] generation of claims relating to SSIs, the more motivated they [were] to act to address them” (Bencze & Sperling, 2012, p. 67; Bencze, Sperling, & Carter, 2012). As Bencze and Sperling (2012) go on to explain, this finding reflects the notion that when students form “deep attachments to ideas and actions” they are often more engaged and motivated in their learning (p. 67).

While Bencze and Sperling (2012) and Bencze, Sperling, and Carter (2012) emphasize student-led projects as essential for securing student investment in learning about and acting on various SSIs, perhaps contrary to some of the earlier discussed studies, they also highlight the need for explicit teacher guidance (Bencze & Sperling, 2012; Bencze, Sperling, & Carter, 2012). In particular, they advocate for a student “apprenticeship” model, where teachers initially demonstrate effective primary and secondary research skills and engage in teacher-guided investigations into various SSIs in order to help “students develop expertise and confidence for directing their own research-informed socio-scientific activism projects” (Bencze, Sperling, & Carter, 2012, p. 137). Moreover, this fundamentally teacher-led “apprenticeship” step is thought
to be essential because “students left unsupported often flounder” and may thus fail to acquire the requisite skills and concepts (Bencze, 2000, p. 732).

3.5 Gaps in the Literature: STS(E) and Biology Instruction in the Canadian Context

Unfortunately, the majority of recent studies undertaken in the area of STS(E)-based science education have focused on European and American education systems, with comparatively little attention being focused on Canadian science education models. In this regard, STS(E)-based biology education has been particularly underserved by these discussions, with much more attention being devoted to the physical sciences, which are often thought to be viewed more negatively by students (Bennett, Hogarth, & Lubben, 2006, p. 352). Though few studies have been completed in this area, some important works can be identified. For example, in a qualitative, interview-based investigation of Portuguese grade 12 biology teachers in perceptions of implementing STS(E) in their classrooms, it was found that teachers were compelled to integrate STS(E) into their lessons, despite perceived difficulties in doing so (Bettencourt, Velho, & Almeida, 2011). In particular, students were motivated by the supposed benefits of STS(E), including increased student motivation and engagement with course material. The difficulties associated with the implementation of STS(E) that were identified by these teachers included: “(i) the need to have an in-depth knowledge of the curriculum in order to articulate the scientific content within the real context that was being studied, (ii) the framework of the learning activities in the STS approach, (iii) the synthesis of the collected information, and (iv) the time needed to plan and prepare the learning activities” (p. 3150). Indeed, as in other studies, time-constraints, in particular, were found to be the most pervasive barrier to STS(E) in senior biology classrooms. Further, though teachers chose to persist with STS(E) despite these
difficulties, they also acknowledged that traditional transmission-based approaches to science education were easier to implement.

3.6 Overview and Implications

In this literature review, I reviewed research in the areas of STS(E) and related pedagogical approaches to science teaching. More specifically, I reviewed research on the purported benefits of STS(E) approaches in science education and examined the barriers that exist for teachers in terms of its implementation. I further assessed the position of the literature on teacher motivations to incorporate STS(E) into their lessons, and discussed existing ideas about the best practices for doing so. This review clarifies the extent to which attention has been paid to the existing policy/practice gap between STS(E) education reforms and teacher efforts and commitment to incorporating STS(E)-related material into their lessons. However, this research also raises questions about how this policy/practice gap might be remedied, particularly in the Canadian context, and points to the need for further research in the areas of STS(E) in biology education, in particular.

In light of this, the purpose of my study is to investigate the experiences of senior biology teachers in Toronto, Ontario of integrating the STS(E) expectations that are embedded in the Ontario Science Curriculum into their senior biology classes. Possible implications for students, teachers, administrators, academics, and policy makers will also be examined, with an aim to increase teacher commitment to fulfilling ministry-mandated STS(E) expectations in Ontario classrooms.
Chapter Four: Methodology

4.0 Introduction to the Chapter

In this chapter, I describe and provide a rationalization for my chosen research methodology. In order to address the research questions detailed in Chapter One, several semi-structured interviews were completed with purposively sampled senior biology teachers who were employed in schools located in Toronto, Ontario. These interviews were directed at exploring teacher experiences of implementing Ontario’s Science-Technology-Society-Environment (STS(E)) curriculum expectations in their senior biology classes. The data obtained was subsequently coded and analyzed in accordance with qualitative, interview-based research methods.

In the following sections, I first discuss the methodological approach and precise procedures that I followed in the collection of data. I then describe the process by which participants were solicited and selected for involvement in this research project. Short biographies for each of the chosen participants will also be provided. Data analysis and ethical review procedures will then be reviewed before finally assessing the methodological strengths and weaknesses of the project described herein.

4.1 Research Approach and Procedures

This study followed a qualitative, interview-based research methodology. According to Morse (1991), a research problem that demands a primarily qualitative research design may be identified by the following characteristics:

(a) The concept is “immature,” due to a conspicuous lack of theory and previous research; (b) a notion that the available theory may be inaccurate, inappropriate, incorrect, or biased; (c) a need exists to explore and describe the phenomena and to
develop theory; or (d) the nature of the phenomenon may not be suited to quantitative measures. (p. 120)

Following this schema, theory is then developed inductively based on an analysis of the qualitative data (Carr, 1994). Quantitative research questions, on the other hand, are thought to be already bounded by established theory, and focus, instead, on testing them in a deductive fashion. As a result of these distinctions, qualitative research methods have historically been disparaged as being “soft”, “imprecise”, and, moreover, subsidiary to quantitative methods (Carr, 1994; Guba & Lincoln, 1994). However, claims such as these have since been vigorously contested and qualified by proponents of qualitative methodological approaches (e.g., see Guba & Lincoln, 1994). In response, it is claimed that the aims of qualitative and quantitative research are largely the same: “to discover the truth of the discipline” (Carr, 1994, p. 716). Further, it has been suggested that the two approaches merely differ with reference to what sorts of “truths” can be effectively accessed via data collection. To that end, qualitative research approaches are thought to best serve as a “vehicle for studying the empirical world from the perspective of the subject, not the researcher” (Carr, 1994, p. 716). Indeed, this is the aim of the present study, as well, and, as such, qualitative approaches were deemed by the researcher to be most appropriate to the elucidation of the research question at hand.

As may be more characteristic of an ethnographic study, this research also treated high school biology teachers as a distinct subculture within the larger science teacher population. However, unlike a typical ethnographic study, research subjects were not observed in a context that was relevant to the research question (Creswell, 2009); rather, individual participants were interviewed separately in a variety of neutral and mutually agreed upon locations. Though the level of analysis for the current research program was that of the individual, particular insights
that were gained from individual interviews by the researcher were understood to potentially represent more pervasive human conditions or experiences. As Witz et al. (2001) describe, “seeing something of the general nature of the person or of the essence of the phenomenon in a given case should involve seeing something universal, something the seeing of which by itself implies a sense of the ‘unity of mankind,’ or of the ‘unity of existence’” (p. 224).

4.2 Instruments of Data Collection

Semi-structured, face-to-face interviews served as the main data source for this project. A literature review was also completed in order to inform the fundamental research question and support the subsequent analysis and interpretation of the data collected. Interviews were completed in person and one-on-one; they were also audio-recorded, with participant permission, so that the researcher could easily revisit and transcribe the interview data for the purposes of later analysis.

According to Gill et al. (2008), the purpose of the research interview is to “explore the views, experiences, beliefs and/or motivations of individuals on specific matters” (p. 292). Indeed, interviews are particularly useful when participants cannot be directly observed in a relevant research context, as was the case for the current study (Creswell, 2009). Important to the current research question of interest, interviews also give research participants the opportunity to provide important historical and contextual information that may help to inform or direct data interpretation.

According to Creswell (2009), interviews also enable researchers to maintain control over the line of questioning. However, the degree of control that is exercised by the researcher in this regard depends significantly on the precise nature of the chosen interview design. For instance, interviews may either follow structured, unstructured, or semi-structured questioning formats
(DiCicco-Bloom & Crabtree, 2006; Gill et al., 2008). As Gill et al. (2008) describe, “structured interviews are, essentially, verbally administered questionnaires” (p. 291), in which all questions are predetermined beforehand. As a result, structured interviews are somewhat limited in terms of depth, as interviewers are not able to intentionally probe participant responses (DiCicco-Bloom & Crabtree, 2006; Gill et al., 2008; Qu & Dumay, 2011). Unstructured interviews, on the other hand, employ no or very few predetermined interview questions. These interviews, therefore, have the potential to be very time consuming and difficult to manage, as the course of the interview depends entirely on the nature of the participants’ initial responses and the ensuing whims of the researcher.

As a result of the above described limitations, semi-structured interview techniques were employed for the purposes of the current study. That is, several key questions were determined beforehand in order to frame the scope of the interview. Additional, subsidiary “probing” questions were also pre-emptively constructed in anticipation of potential interviewee responses. This interview format is thought to be beneficial in that it provides researchers with some guidance in terms of the intended direction of the interview, while also allowing them some flexibility to explore unanticipated participant insights as they come up throughout the interview process.

For the purposes of this study, interviews were also completed in-person and face-to-face, as opposed to over the phone or through the use of online, internet spaces. Historically, phone and internet interviews have largely been seen as impersonal and most well suited to short, structured interview formats (Curasi, 2001; Sturges, 2004). These claims have been more recently revisited, however, and it has since been suggested that these methods may serve to increase a participant’s perception of anonymity, which is particularly important when the topic
of research is sensitive in nature (Sturges, 2004). As the topic of the current research project is not considered to be exceptionally sensitive, and thus posed little risk of harm to interviewees, in-person interviews were determined to be appropriate. Interviews were also completed individually, as opposed to in a group setting. As the research question was directed at uncovering the views of individual biology teachers, as opposed to the collective perceptions of a group of such professionals, this was deemed to be a suitable research design (Gill et al., 2008).

A complete interview guide consisting of opening and closing scripts and protocols, as well as key questions, suggested segues, and supplementary prompts, is presented in Appendix B. The interview protocol is divided into 6 major, overarching sections, including: 1) Background Information; 2) Teacher Perspectives on and Feelings toward the STS(E) Ethos and Ontario’s Explicit STS(E) curriculum expectations; 3) Teacher Implementation and Integration of the STS(E) curriculum expectations into their Senior Biology Classes; 4) Teacher Perceptions of the Impact of STS(E) on Students and their Learning; 5) Perceived Supports and Challenges to Addressing the STS(E) curriculum expectations in Senior Biology Classrooms; and 6) An Invitation for Closing Remarks. Each of these sections is represented by key interview questions. When appropriate, these key questions are supported by optional prompts, intended to probe participant responses more deeply when initial answers are deemed to be insufficient or off-topic by the researcher. Example interview questions include:

- As a senior biology teacher, what do you feel is your main objective or purpose in the classroom?
- How would you define the general STS(E) ethos? What do you feel is its general object or purpose?
• How do you feel that the STS(E) curriculum expectations relate to your own personal objectives and aims as a senior biology teacher, if at all?

• Can you give me a specific, concrete example of how you’ve satisfied one or more of the STS(E) curriculum expectations in your senior biology classes in the past? In particular, can you think of the time in your career in which you felt you were most successful in meeting the expectations?

• How do you feel students respond to lessons/activities/assignments that are aimed at addressing the STS(E) curriculum expectations, in general?

• In your experience, what do you feel are the most significant barrier(s) and/or challenge(s) to addressing the STS(E) curriculum expectations in senior biology classrooms, if any?

4.3 Participants

In this section, I outline the sampling criteria and recruitment procedures that were employed in the selection of 3 appropriate interviewees for this qualitative, interview-based research study. Each criterion and procedure is then fully justified in light of the established literature and the purpose of the current study. Short biographies of each participant are also provided.

4.3.1 Sampling criteria. In the context of interview-based qualitative research, participant selection procedures have an important function in establishing the boundaries or scope of a project. In other words, sampling criteria give an indication of what will and what will not be the focus of study (Baxter & Jack, 2008). In the current study, several sampling criteria were applied in the selection of appropriate interviewees. Firstly, participants were required to be current teachers, practicing within the city of Toronto, Ontario. This criterion was primarily
implemented in order to ensure that interview participants were located within a feasible travel distance from the researcher. However, this condition also functioned to limit the geographical scope of the study and establish some curricular homogeneity across the sample, thus lending to the potential comparability of the data obtained from each participant (Marshall, 1996), and, subsequently, the possible generalizability of the findings across the larger geographical context (Carr, 1994).

Secondly, teacher participants were chosen who had experience teaching senior high school (i.e., grade 11 and 12) biology classes, in particular. This sampling criterion was applied in order to ensure that participants were able to adequately address the main research question, which focuses on teacher attitudes toward and practices surrounding the implementation of aspects of the current Ontario senior high school biology curriculum.

Thirdly, interviewees were chosen who had at least 10 years of teaching experience. This criterion was specifically intended to target teachers who had acquired significant teaching experience both before and after the official inclusion of the explicit STS(E) curriculum expectations in the Ontario Science Curriculum, which occurred in 2008. In the literature, some authors have suggested that teachers with increased seniority are more comfortable implementing and addressing the STS(E) curriculum expectations in their science classrooms than are prospective and novice educators (e.g., Steele, 2013). However, still other studies suggest that the overall school or departmental cultures established by experienced teachers are often perceived to be inhospitable to the general ethos of STS(E) that is being disseminated to prospective teachers via more contemporary teacher training programs (e.g.: Hoeg & Bencze, 2014; Marbach-Ad & McGinnis 2008; McGinnis & Simmons, 1999; Pedretti et al., 2008). Thus,
this sampling criterion was intended to allow the researcher to potentially elaborate on these apparently conflicting claims after the data analysis process had been completed.

**4.3.2 Sampling procedures.** Any one of several sampling strategies may be employed in order to obtain a representative study sample. However, the precise strategy selected depends largely on the object of the study at hand (Marshall, 1996). In the context of quantitative research studies, random sampling is often employed in order to ensure generalizability across the population from which the sample was drawn (Carr, 1994; Marshall, 1996). That being said, random sampling is considered to be inappropriate for qualitative studies, like the interview-based study described here, which are often characterized by more in-depth explorations of small sample sizes (Crouch & McKenzie, 2006; Jackson, Drummond, & Camara, 2007; Marshall, 1996).

Oftentimes, qualitative research employs either convenience or purposeful sampling schemes in order to select research participants (Marshall, 1996; theoretical sampling is also used by qualitative researchers, though it will not be discussed here). As the name suggests, convenience sampling is the least rigorous approach and involves the selection of only the most accessible research subjects. Purposeful (or judgement) sampling, on the other hand, involves the selection of participants who are deemed to have particular experiences or other attributes that are relevant to the aim of the study, as is determined by the researcher based on the published research. For the purposes of the current study, the researcher employed a combined purposive and convenience sampling strategy in the selection of appropriate research participants. The sample was purposive in so far as each interviewee was required to meet all three of the sampling criteria outlined above before being permitted to take part in the study. However, these teachers were selected by first exploiting the researchers’ current personal and professional
contacts within the city of Toronto in order identify and solicit interested and appropriate teacher participants. Further, individual participants were asked to recommend additional potential interview candidates to the researcher, a process that is referred to as “snowball sampling” (Marshall, 1996).

4.3.3 Participant biographies. In total, in-person, one-on-one interviews were completed with 3 Toronto-based high school biology teachers. In order to preserve their anonymity, each participant was assigned a pseudonym. For the purposes of this study, the research subjects are known as Celia, Gabby, and Paul.

4.3.3.1 Celia. Celia is a veteran teacher with nearly 24 years of experience. She has taught at a variety of high schools in Ontario and has instructed classes at all intermediate and senior grade levels. Outside of the classroom, Celia has also engaged with younger learners in informal science education settings. While her teaching specialties are biology and environmental science, she has also taught courses in chemistry and general science. Most recently, she was responsible for teaching grade 10 academic science, grade 11 college and university biology, and grade 12 university biology courses.

Since becoming a teacher, Celia has obtained additional qualifications in physical education and math, and has gained her biology specialist certification. She has also participated in a teacher education course at the Huntsman Marine Science Centre located in St. Andrew’s, N.B. Prior to acquiring her certification as a classroom teacher, Celia also completed an MSc in exercise physiology and a PhD in physiology.

4.3.3.2 Gabby. Gabby has been teaching high school for nearly 16 years and has spent the vast majority of her career at a private school in Toronto. In addition, she spent a short time as a public and Catholic school supply teacher in Peterborough. Like Celia, Gabby has also taught all
grades at the intermediate and senior levels, with biology and environmental science as her main teachable subjects. Besides teaching intermediate and senior biology and general science classes, she has also delivered careers courses at her school.

Since obtaining her teacher certification, Gabby has obtained additional qualifications in math, giftedness education, religious education, and guidance and careers, and has acquired her special education and biology specialist certification. She has also previously worked for the Canadian Ministry of Natural Resources, the Commonwealth Scientific and Industrial Research Organisation in Australia, and had obtained employment as a lab technician and research associate in an academic research setting. She has taught additional qualifications courses for fellow teachers and has acted as a teaching assistant for undergraduate biology courses, as well. Prior to becoming a high school teacher, Gabby also completed an MSc in biology.

4.3.3.3 Paul. Like Gabby, Paul has also been teaching high school for almost 16 years and has been employed at a number of Toronto-area high schools. He has taught grades 9 through 12, and most recently delivered grade 9 applied and academic science and grade 12 university biology courses. In the past, Paul has also taught chemistry. Indeed, biology and chemistry are his main teachable subjects.

Since beginning his career as a high school educator, Paul has obtained his biology specialist certification, as well, and has completed parts 1 and 2 of the principal’s qualification program. Prior to becoming a classroom teacher, Paul was gainfully employed as an emergency medical services (EMS) worker. He went on to acquire Master-level training in college-level course instruction, and taught classes in the EMS field for 5 years. During his time with the EMS, Paul also worked as a field training officer, providing additional training to fellow EMS workers in response to changes in provincial standards.
4.4 Data Analysis.

For most qualitative research, data collection and analysis occur concurrently “so that investigators can generate an emerging understanding about [the] research questions, which in turn informs both the sampling and the questions being asked” (Creswell, 2009; DiCicco-Bloom & Crabtree, 2006, p. 317). Indeed, this conception of data collection and analysis as an iterative process is also common in the literature focused specifically on interview-based research (Baxter & Jack, 2008).

According to Creswell (2009), the qualitative data analysis process may be understood and visualized as a series of linear steps. However, in practice, Creswell (2009) suggests that these supposed stages of analysis are often demonstrated to be intricately interrelated, and generally occur out of the intended sequence, as would be expected given the iterative nature of qualitative research. In the case of the present study, audio recorded interview data was first transcribed in preparation for analysis. The interviews were then reviewed in order to gain a general sense of the information being presented and to reflect, holistically, on their possible meanings. The data was then coded by organizing segments of the text into relevant categories representing recurrent, novel, and/or expected topics that were identified in the interview transcripts. The identified codes were then used to generate a smaller number of important themes or findings that emerged from the data. Specifically, major themes were identified for each case, independently, and then again across cases. These findings were subsequently evaluated and interpreted in light of the published research.

4.5 Ethical Review Procedures

The current study adheres to the strict ethical review protocols that have been outlined for the Master of Teaching Research Project (MTRP) and accepted by the Ontario Institute for
Studies in Education (OISE) ethical review board. The ethics approval that was obtained limited the scope of the study method to informal, audio-taped semi-structured interviews with educators, only. Classroom observations and interviews on school grounds were also prohibited and were not included under the current ethics approval scheme.

Beyond institutional ethics approval, several other ethical concerns were also considered and addressed in the design and completion of the current research. Firstly, all participants were required to read and sign an informed consent form prior to participating in the study (Appendix A). In general, the consent form acts to acknowledge the various aspects of a participants’ rights that will be respected and protected throughout the data collection and analysis processes (Creswell, 2009). Among other things, the consent form specifies that any volunteered data will be kept confidential and anonymous. In the context of the current study, anonymity was ensured by using pseudonyms in order to protect the identities of the study’s participants. In order to further safeguard the security of the participants’ personal data, interview transcripts and recordings were also maintained on a password protected computer that was only accessed by the researcher. Assurances that the interview data obtained would only be used for academic purposes were also provided on the consent form. To that end, within 5 years of the completion of data analysis and the submission of the final study report, all records and transcripts will be destroyed so as to prevent them from being obtained by other researchers or those who could otherwise misappropriate it (Creswell, 2009).

The consent form also stipulates that participants are entitled to withdraw from the interview process at any time, should their involvement become too stressful, uncomfortable, inconvenient, or in any way undesirable (Creswell, 2009). In order to ensure that inequities in the power dynamic between the researcher and the interviewee did not become a barrier to their
comfortable participation (Creswell, 2009; DiCicco-Bloom & Crabtree, 2006), participants were able to review final interview transcripts in order to modify, retract, justify, or otherwise embellish their initial responses. In addition, when requested, interviewees were also sent a copy of the final manuscript prior to its submission in order to provide them with an opportunity to review the final product and assess their own representation in it.

In general, interview data should not be collected or interpreted in a way that causes intentional or unintentional harm to a participant (DiCicco-Bloom & Crabtree, 2006; Dickson-Swift, 2007; Qu & Dumay, 2011). In the context of the current study, the main research question of interest necessitated discussions of the personal beliefs and professional practices of the study’s participants. As a result, and out of respect for the participants, interview questions were framed, as much as possible, in a non-judgemental manner so that interviewees felt safe to freely share their views and experiences. Throughout the data analysis process, the researcher was also careful not to appraise teacher beliefs, perspectives, and practices, but rather, to disinterestedly assess how these beliefs and perspectives informed their professional practices, whatever they happened to be.

4.6 Methodological Limitations and Strengths

In the published literature, several methodological strengths have been attributed to qualitative interview research. As was earlier discussed, according to Creswell (2009), interviews are particularly advantageous when participants cannot be observed directly, as was the case for the current research project. Further, during interviews, participants are able (and often invited) to share important historical or contextual information that may have significant implications for data analysis and cannot be readily accessed by participant observation, alone. Similarly, interviews allow the researcher to better control the direction and scope of data collection, as
they are able to construct relevant questions and prompts beforehand, as opposed to relying on the whims of the research participant.

That being said, qualitative interviews are also associated with a variety of methodological limitations. Oftentimes, the results of qualitative studies are not thought to be generalizable beyond the small sample context from which they were drawn (Carr, 1994). With reference to semi-structured interviews, in particular, this issue may be further exacerbated by minute differences between interviews across participants. As a result, data comparability across participants (and, therefore, generalizability across the larger sample population) may be reduced (DiCicco-Bloom & Crabtree, 2006; Qu & Dumay, 2011). That being said, generalizability is often not the primary goal of qualitative research (Marshall, 1996). Rather, increased data richness and depth are prioritized when employing qualitative research measures (Byrne, 2001; Carr, 1994; Crouch & McKenzie, 2006; Jackson, Drummond, & Camara, 2007; Marshall, 1996). This goal is supported by semi-structured interviews, which allow the researcher the flexibility necessary to modify the course of questioning in order to address and delve deeper into previously unanticipated aspects of participant responses as the come up (DiCicco-Bloom & Crabtree, 2006; Gill et al., 2008; Qu & Dumay, 2011). Further, the generalizability of results obtained by qualitative means can be improved when a sample is well defined (Carr, 1994).

Under qualitative research schemes, the researcher is the main instrument of data collection (Creswell, 2009). As a result, the researcher has the potential to introduce their own biases into the data and its interpretation. Further, in the context of a qualitative interview, specifically, the researcher’s presence alone may serve to bias participant responses (Carr, 1994; Creswell, 2009; DiCicco-Bloom & Crabtree, 2006). However, as is atypical of quantitative work, the qualitative researcher is often overtly and reflexively positioned within the research, itself, so that the
influence of their perspective and experiences on the production of results can be more effectively monitored (Daly, 2007).

As earlier discussed, due to particular constraints imposed by the predetermined ethical review process that was employed in the completion of this research, the current study was also limited by sample size, allowable methods, and available time.

4.7 Conclusion

In this chapter, I have described and justified the research methodology employed in the current study, including the specific methodological approach, sampling strategies, data collection and analysis techniques, as well as ethical review procedures that were followed. Short biographies of each participant were provided and the methodological strengths and weaknesses of the project were also detailed. In the following chapter, I will report the results of the completed research program.
Chapter Five: Research Findings

5.0 Introduction to the Chapter

In this chapter, I discuss the findings of the qualitative interview research described in the previous chapter. Importantly, this analysis was performed with the study’s main research question in mind: What are Toronto-based educators’ experiences of integrating the Science-Technology-Society-Environment (STS(E)) expectations that are embedded in the Ontario Science Curriculum into their senior biology classes? The findings are organized into the following five themes:

1) For senior biology teachers, the imperative to incorporate STS(E) into their lessons often goes beyond the explicit curriculum expectations.

2) Senior biology teachers recognize that STS(E) is inextricably linked to technical science content.

3) Senior biology teachers acknowledge that STS(E) makes technical science content more relevant to the lives of their students.

4) Senior biology teachers feel that STS(E) content is best integrated into their lessons through student-led summative assignments and in-class activities.

5) Senior biology teachers perceive that STS(E) takes more effort and time to implement successfully than other types of content.

Within each themed section, I provide supporting evidence that was gathered from the interviews of 3 Toronto-based high school biology teachers. The significance of these findings is then further discussed within the context of the current published STS(E) literature, which was thoroughly reviewed in Chapters Two and Three. Finally, I conclude the chapter with a summary of the research findings.
5.1 The Imperative to Incorporate STS(E) Often Goes Beyond the Explicit Curriculum Expectations

For the teachers who participated in this study, the drive to incorporate STS(E) into their teaching practice often went well beyond the imperative placed upon them by explicit curriculum expectations. Rather, for them, much of the desire to do so seemed to emerge from distinctly extra-curricular sources. In particular, insights gained from previous education and employment, personal interest, as well as the notion that the STS(E) curriculum expectations reflect current and pressing social and environmental concerns were all fundamental influences on participant teachers’ choices to incorporate STS(E) into their senior biology classes.

As was earlier noted, in 2008, the Ontario science curriculum was revised and, as part of those revisions, STS(E) was resituated as the first of three goals for the curriculum (Ontario Ministry of Education, 2008ab). Further, following these revisions, the STS(E) expectations were presented first within the prescribed curriculum for each unit of each course, suggesting their intended primacy over more canonical science content-knowledge. Despite these radical changes to the curriculum, however, the teachers who participated in this study noted no significant changes to their practice, as a result. For instance, when asked about the effect that the new STS(E) curriculum emphasis had on her teaching, Celia replied that, “Biology is a subject that relates itself to relating to society. We always did that, even before [the STS(E) expectations] were front and centre […] I would say we haven’t really added or done things a whole lot different because we did try before, to just try and make the connections [between science, technology, society, and the environment].” This suggests that, for teachers like Celia, the drive to integrate STS(E) or STS(E)-type materials into their biology classes was not the result of curriculum reforms, but rather, existed long before the reforms were put into place.
In some cases, the explicit STS(E) curriculum expectations were understood by the participants only to be a guideline; a vehicle through which they could express their own interests, experience, and expertise. When asked how she would describe the grade 11 and 12 biology STS(E) curriculum expectations, Gabby commented on the malleability of the sample STS(E)-related questions and problems that are provided in the curriculum documents (see Tables 1 and 2 for examples):

I think those can be good for the people that might not be as familiar, [or] have as much of a background in being a biologist and living with a biologist [as] I have. So, they can be an aid […] But I think they can also distract people. Sometimes I'm concerned that new teachers will see these curriculum expectations and think ‘Oh god, I have to do this one and this one and this one’ and it’s, like, no. It's a sample question. You don't have to do all of those questions. You don't have to do any of those questions. But what you do need to do is [...] have a good question.

Gabby later went on to explain that there are a number of specific questions or example scenarios that are presented in the curriculum documents that she would “never in a million years use” because they were not “as engaging an example as one that I can think of” or, alternatively, they were “so old-hat that you can’t use [them] anymore.” That is, while they were contained within the curriculum and presented a clear STS(E) connection, they did not always suit the personal preferences, expertise, and aims of the teacher.

Notably, both Gabby and Celia had obtained advanced degrees in biology prior to becoming classroom teachers and, in their interviews, they both drew a connection between their prior education and their interest in pursuing STS(E) in their biology classes. In their interviews, both Gabby and Celia related that, because of their backgrounds as working scientists and
graduate students, they had come to the realization that making connections between science, technology, society, and the environment was really “what science is all about” (Celia). That is, as Gabby explained, science “is a tool we use. It's a way of knowing and learning things that we use to cure cancer, improve traffic flow, clothe ourselves, feed ourselves, you know, all of these things” rather than what Celia referred to as a simple collection of “isolated facts.”

For Paul, who had previously worked for several years as an Emergency Medical Technician (EMT), the connections between science, society, and the environment had also existed in his mind before he became a biology teacher in 2001. However, for him, the drive to incorporate STS(E) appeared to originate from a deeper concern for society and the health of the environment:

Whether it's natural disasters or human made disasters, there seems to be so much damage to our planet and I think all biologists and naturalists, environmentalists who care about this planet and its future would say that we all need to be educated […] We have to teach others, and as a teacher, […] it's natural to include that in your lessons.

Indeed, there was a pervasive emphasis across all three interviews on the environmental and social imperatives for including STS(E) in biology courses. The need to make students “aware” of their own personal impacts on the environment and, in turn, how “what’s happening to the environment is then going to have an impact on people” (Celia) was a common thread. More generally, STS(E) seemed to be understood as a way “broaden” student’s horizons by “opening up opportunities for them to realize, like, ‘Whoa! My world is bigger than it was before!’” (Gabby), thereby making each student a “better consumer, voter, [and] citizen.”

Regardless of its specific source, it appears that motivation to incorporate STS(E) is derived from something personal and specific to a given teacher’s experience – and not the
explicit curriculum expectations, themselves. However, it could be claimed that general curiosity
and the need to “stay current” (Paul) is, perhaps, something that teachers hold in common,
regardless of their personal experiences. For instance, when asked about what prepared him to
tackle the STS(E) aspect of the senior biology curriculum, Paul suggested that,

There’s always got to be, I think, something internal about that and maybe teachers have
that in common because, I would say teachers are lifelong learners, right? So, if you’re a
life-long learner, it should already be inside you to want to know more, and stay on top of
things, right? […] So, that's one thing that's part of our nature, is wanting to learn
constantly.

Indeed, references to the idea that teachers are innately curious “life-long learners” appeared in
all three interviews in one form or another. Further, this perceived quintessential teacher
characteristic was often framed as a positive influence on an educator’s motivation to teach
STS(E)-related content, in that it allowed teachers to respond to the larger societal developments,
changes, and needs that are reflected by the STS(E) curriculum expectations.

The finding that teachers’ motivations to incorporate STS(E) are not always aligned with
explicit curriculum reform efforts is also reflected in the work of Lee and Witz (2009). In their
interviews with STS(E) reform-oriented science teachers in the United States, these researchers
also found that the impetus for teaching STS(E) was often entirely divorced from explicit
education mandates – as well as the efforts of the larger STS(E) education movement, altogether.
In these cases, the authors found that teachers were motivated by their own personal initiative,
values, and personal concerns “without much contact with reform ideas.” (p. 932)

However, the implication of this is that the teachers of this variety often present STS(E)-
based material to their students using their own individualized understandings of what teaching
STS(E) constitutes. Further, the goals of individual teachers who are self-motivated to tackle STS(E) in their classes are often fundamentally disconnected from those of researchers and professional organizations in science education. As a result, teaching goals and approaches to teaching STS(E) were not found to be uniform in the classrooms studied by Lee and Witz (2009).

The lack of adherence to uniform standards of STS(E)-informed teaching by science educators was also pointed out on several occasions by participants in the present study. For instance, when asked about the main weaknesses of Ontario’s STS(E) expectations, Paul suggested that the inherent interpretational flexibility of the curriculum expectations was a potential stumbling block in terms of board-wide “consistency in what [teachers are] delivering.” However, as was discussed above, for participants like Gabby, the apparent flexibility of the specific STS(E) expectations represents one of the core strengths of the senior biology curriculum. Indeed, this alternative perspective is reflected well in the work of several prominent researchers and defenders of STS(E) education (Fuglsang, 2001; Pedretti & Hodson, 1995; Pedretti & Nazir, 2011; Ziman, 1994). For these authors, STS(E)’s defiance of strict definition is prerequisite to its key role in education: helping students to adapt to a rapidly changing world (Pedretti & Hodson, 1995). In this way, STS(E) is also thought to provide teachers with a “variety and richness” of approaches through which to “enhance, complement, and extend” traditional science content (Ziman, 1994, p. 22 & 31). That said, more research is required in order to more fully assess the potential implications that the apparently diverse motivations that guide teacher practice in the area of STS(E) may have on the quality of education that students receive in science classrooms.
5.2 Senior Biology Teachers Recognize that STS(E) is Inextricably Linked to Technical Science Content

In addition to finding personal significance in the STS(E) expectations, participating teachers also unanimously recognized that STS(E) was inseparable from, and imperative to the teaching of, the more technical, content-driven aspects of the Ontario senior biology curriculum. For Paul, making the distinction between STS(E) and specialist biology content was seemingly unnecessary. For instance, when asked about his general familiarity with STS(E), he noted that,

It’s no longer something you have to maybe separate and have a class lesson just on that topic. When we think about ecology and population growth, [we] always think about what the repercussions of urbanization [are] or what’s the technology that’s going to allow for sustainability and, you know, clean kind of energy ideas. Things like that, they all creep into the conversation. They’re ingrained, I suppose.

In other words, the inclusion of STS(E) into his biology classes had become something “common sense” and “automatic”; something that was “a natural fit” for the biology classroom and “the thread that weaves through all of the content.” Moreover, for Paul, STS(E) connections could easily be made to virtually any topic in biology. Indeed, when asked about what units in grade 11 and 12 biology were more amenable to the inclusion of STS(E), he remarked that “it’s harder to think of where it can’t kind of fit into it.”

Very similar sentiments were expressed by Celia. When asked to articulate the specific characteristics of a unit of study that would make it more amenable to the integration of the STS(E) expectations, she said, “[P]artially, [the STS(E) expectations] are just are part of the unit. Like, you can’t talk about biotechnology and not talk about [STS(E)], you know? […] I mean it literally. When you are doing the biotechnology, you’re doing the STS(E) expectations.
[...] It’s just there.” This notion that, in addressing biology content knowledge, a teacher must also necessarily address STS(E) was echoed by Gabby, who described STS(E) as defining the “raison d’être” of any biology course, and the individual expectations as “part and parcel” of the more technical content. “By hitting those STS(E) expectations,” she described, “you are going to be able to hit a lot of the content, right?” In other words, as with Paul, for both Celia and Gabby, the STS(E) expectations were perceived to simply be “embedded” (Celia), naturally, within the more technical biology content.

Importantly, even though the factors that influence the motivation to address STS(E) appeared to be unique to each teacher, and divorced from the overall aims of curriculum and science education reform movements, teachers and reformers do seem to share in common the perspective that science and technology are “complex socially embedded enterprises” that cannot be readily separated from their societal influences (or, alternatively, their influences on society) (Cutcliffe, 1990, p. 362). To be sure, the educational benefits of this perspective on science teaching are well supported by the published research, as well. As discussed in Chapter Three, the integration of STS(E) into science classrooms has been shown to improve student attitudes toward science at all levels of secondary education, without at the same time negatively affecting their understanding of more technical scientific concepts and principles (Akcay & Akcay, 2015; Akcay & Yager, 2010; Bennett, Hogarth, & Lubben, 2006; Lee & Erdogan, 2007). Interestingly, one of the main concerns related to implementing STS(E)-related pedagogical approaches in the classroom is that they may serve to undermine the successful learning of the core concepts of science (Pedretti et al., 2008). According to the evidence presented here and elsewhere, however, the precise opposite appears to be true. Indeed, as will be discussed in the next section, it is often claimed that STS(E) approaches to science education actually encourage students to make
personal connections to the subject matter, and as a result of these connections, students are thought to be better able to retain science content (Bennet et al., 2007).

5.3 Senior Biology Teachers Acknowledge that STS(E) Makes Technical Science Content More Relevant to the Lives of Their Students

As a result of the apparent seamlessness of the distinction between STS(E) and technical biology content, when STS(E) is well integrated into a lesson, according to Celia, students “don’t even notice we’re doing it. It’s just there.” In fact, for her, it is only when the connections between STS(E) and the technical content of biology are “fit in artificially” that problems may arise. In particular, she suggests that, when the relationship between STS(E) and content is not made explicit, or is not thoughtfully integrated into a lesson, the “‘Why does this matter?’ and ‘Why are we doing this?’ and ‘Why do [we] need to know this?’ piece” is largely left unanswered for students.

The importance of STS(E) in providing the context for learning in senior biology classrooms was repeatedly emphasized by Gabby, as well. “It provides the context for anything that we do,” she explained:

If you’re not doing any STS(E), then you’re losing a lot. You’re going to be answering that same question over and again, ‘Why are we studying this? Why are we studying this?’ And you deserve to. If you can’t give them a good scenario, a good thing to chew on, a good thing to bite into, then you deserve to get that question 20 times a day. ‘Why are we learning this?’ Good question. I have no idea.

For Gabby, STS(E) also serves as a “fabulous source of authentic problems” that, perhaps, more accurately reflect the anticipated real-life experiences of students. As she explained, “their lives are not going to be full of questions out of the textbook. That’s not what life is. Life is messy
problems. Life is confusing problems.” And, for her, it is through encountering these “messy problems” that students get “a chance to practice [...] what science really means in their lives.”

Indeed, the role of STS(E) in emphasizing the broad applicability of science to the lives of students was a pervasive focus across all three interviews. Paul and Celia each referred to the “authentic contexts” for learning that can be provided by the STS(E) expectations as “the applications of science” or “the applications of content,” respectively. Notably, for them, including discussions of these applications in their lessons was perceived to have the power to positively influence student engagement in senior biology classrooms. When describing how his students responded to the integration of STS(E) expectations into his biology lessons, Paul noted that,

If you present it in a way that they see a relevancy to it, I think they're interested and they're interested in learning because it's not so theoretical as applicable. They now see how the science connects to our situation and case. So, I think it heightens their level of interest in the learning if you do it right with relevant topics and at the right part of the curriculum.

In other words, STS(E) was perceived by teachers to reveal the connections between science content and real-life to their students, and in funneling what Gabby referred to as “really juicy, valuable, context-setting [...] STSE ideas” into “rich” and relatable lessons, the material, in turn, became more “exciting and motivating for the kids.”

Importantly, for Gabby, the acknowledgement of the broader application of canonical biology content to the lives of individuals was perceived to extend to all students, and not just to those who were interested in eventually pursuing biology at the post-secondary level. As she explained, even for students who have no intention of becoming “a scientist in their real life, […]
it's going to enter into [their] decisions […] as a parent, as a consumer of health care or food or cars or any kind of product that's engineered or manufactured or even the ones that aren't manufactured. You know, ‘What plant am I going to put in my garden?’ All of those things.”

That is, by building transferable skills, like “research skills or presentation skills or the ability to solve problems” (Paul), STS(E) was thought to help equip students with whatever knowledge would “in the end, serve them best” in the future, irrespective of post-secondary destination.

Celia expressed it likewise, stating that, regardless of whether or not they’re going into science later on in their academic careers, students who have encountered STS(E) content in their senior biology classes would at least be “going out into the world as better citizens” as a result.

The notion that STSE education produces a more informed citizenry is well represented in the science education reform literature. Indeed, this has been a central claim to the STS(E) movement in education since its inception. As was discussed in Chapter Two, in 1971 James Gallagher, who became one of the first to propose that the model of science instruction be “broadened” to incorporate the complex interrelationships that occur between science, technology, and society, suggested that, “[a]n awareness of the interrelations between science, technology, and society may be a prerequisite to intelligent action on the part of a future electorate and their chosen leaders” (Gallagher, 1971, p. 337). Indeed, for Gallagher and other proponents of STS(E) education, the main function of science education should be to produce a scientifically literate society, in which individuals were not only familiar with scientific concepts, but also with those interactions that occur at the interface of science and society.

Remarkably, this perspective is also clearly echoed in the teacher interviews presented here.

According to Bennet et al. (2007), the central “aspiration” of STS(E) teaching lies in its ability to stimulate students’ “affective responses to science” or to speak to “how they feel about
their experiences of science” (p. 348). In particular, as the authors explain, by providing authentic contexts in which to cultivate new scientific ideas and concepts, STS(E) helps students to be better able to “see the importance of what they are studying” because they are encouraged to make personal connections to it (p. 348). This perception was similarly reflected in the interviews performed here. The particularities of how individual teachers go about effectively engaging their students in STS(E)-related content in senior biology classrooms will be discussed in greater detail in the next section.

5.4 Senior Biology Teachers Feel that STS(E) Content is Best Integrated Through Student-Led Summative Assignments and In-Class Activities

Unsurprisingly, the teachers who participated in this study employed a variety of strategies in order to incorporate STS(E) into their senior biology lessons. However, a few general trends in terms of the methods of implementation of the STS(E) curriculum expectations could easily be discerned from the data. In particular, it appeared that STS(E) content was most often integrated by the study participants through the use of student-led summative assignments and in-class activities. While the precise nature of these activities and assignments varied from teacher to teacher (largely as a result of personal preference or expertise), the interview participants did indicate that STS(E)-related content could not easily be disseminated via a teacher-centred lecture format.

For the participants in this study, projects were perhaps the most commonly discussed method of addressing STS(E) in the senior biology classroom. Indeed, when asked about a time when they felt that they had met the STS(E) expectations most successfully, all three interviewees pointed to a particular project that they had designed with STS(E) in mind. While the overall formats and objectives of these projects varied from teacher to teacher, in all cases,
they emphasized the need for students to make a “personal connection” (Celia) to the subject matter. For example, for the major summative assignment in the Population Dynamics unit of the grade 12 university biology course, Celia requires her students to choose an endangered species to research and present on. As part of this project, students must discuss “how humans are contributing to the endangerment of the species” of choice, as well as generate a “personal action plan” that describes the measures that each student intends to take in order to either bring awareness to or otherwise help to address the issue. According to Celia, in the past, students have taken a wide variety of approaches to fulfilling the personal action plan requirement of the assignment, including participating in letter-writing campaigns to the Canadian Prime Minister, Ministers of the Environment, and even representatives of foreign governments, as well as starting petitions, starting blogs, and contributing to relevant charities. Indeed, she explains that, as a result of their personal action plan,

There is a commitment [among the students] to their particular species and they definitely make a personal connection by doing the research and finding out all about that species and what’s going on with it and I would say that that’s something that’s going to last forever, […] this consciousness of what we are doing to the environment and this desire to help.

Paul described a very similar scenario when he discussed his version of an exemplary application of the STS(E) expectations in his own practice:

They have to come up with maybe a solution in their mind of what can be done to change, you know, people's attitudes, whether it's ‘don't buy this product’ because it's, you know, damaging to our environment […] They come up with their own conclusions, rather than
[me] telling them what they should be saying or thinking. Their attitude, they come up with their own. I think that's what makes it that much more of a higher caliber [assignment].

It is important to note that, in both examples, the ability of students to determine and take control of their own directions and approaches to a prescribed STS(E) problem dictated the teacher’s perception of the success of that project in meeting the STS(E) curriculum expectations.

Because of the apparent emphasis of the interview participants on the importance of student-led projects in the successful application of the STS(E) expectations, they also expressed a reciprocal reluctance to support teacher-led pedagogical approaches in the presentation of STS(E)-related content. For example, Gabby suggested that it was not appropriate to “do STS(E) in a lecture” as it was not considered to be “a doable format for it.” Rather, teacher-centred lectures were spoken of by the participants as a method for presenting “definitions” (Gabby), “terminology” (Paul), or any of the technical “content” that a teacher may have to “plough through” (Paul) in senior biology courses in order to even be able to broach more complex, STS(E)-related content. When it came to the presentation of STS(E) content, on the other hand, the role of the teacher was not to play, as Gabby put it, “the sage on the stage” but, rather, to facilitate student learning as a “guide on the side” – or better yet – as what she referred to as a “sage on the side” or an expert facilitator of largely student-led activities and projects. Even during informal in-class discussions of STS(E) topics, as Paul highlighted in his interview, a teacher’s ability to “facilitate the discussion amongst other students” was perceived to be of paramount importance.

In the current STS(E) education literature, very little work has been done in order to elucidate the methods that teachers use in order to meet the STS(E) curriculum expectations in senior biology classes, or even in science classes, more generally. However, some authors in the
field have recommended or devised particular instructional strategies that they feel might be best suited to the particular aims and ideologies that are represented by the greater STS(E) education movement. In particular, the “student-led, research informed STSE Action Projects” explained by Bencze and Sperling (2012, p. 69) and Bencze, Sperling, and Carter (2012) show exceptional similarity to the approaches described by the teachers who participated in this research. In particular, these projects involve students performing independent secondary and primary research (in the form of simple correlational studies) on a chosen topic that is of some personal significance. Informed by this research, students are then empowered to take personal actions in response to a perceived STS(E) problem. These actions might include such things as educating others, lobbying people in positions of power, inventing alternatives to a problematic product, procedure, or behaviour, or changing one’s own personal habits. In line with what was communicated by the teachers who participated in this research, Bencze and Sperling (2012) found that the more control that students are given “over [the]generation of claims relating to SSIs [socio-scientific issues], the more motivated they will be to act to address them” (p. 67; Bencze, Sperling, & Carter, 2012). As Bencze and Sperling (2012) go on to explain, this finding reflects the notion that when students form “deep attachments to ideas and actions” and are encouraged to personally connect to them, they are more motivated in their learning, a factor that was discussed in more detail in the previous section (p. 67).

While these authors support the notion that student-led projects as essential for securing student investment in these STS(E) projects, they also emphasize an overarching need for teacher leadership. Indeed, prior to completing student-led projects, teachers and students are encouraged to engage in “apprenticeship” model, where educators initially demonstrate the necessary research skills required to complete such projects, and generate co-created exemplars for student
reference (Bencze, Sperling, & Carter, 2012). Without this active and explicit teacher guidance, it is thought that, having failed to gain the prerequisite skills and concepts independently, some students may be left unsupported once they are released to complete their projects on their own (Bencze, 2000). Though the teachers involved in this study largely resisted teacher-centered approaches to STS(E)-based instruction in their senior biology classrooms, the work of Bencze and others suggests that there may still be role for such methods in modern science teaching at the secondary level. Even so, it is important to note that very little research exists on the precise strategies that teachers adopt in order to integrate STS(E) into their classrooms, and still less research is focused on comparing the efficacy of different approaches in this regard. As a result, more research may be required in order to adequately assess the potential value of teacher-led and student-led approaches to the implementation of STS(E) in science classrooms.

5.5 Senior Biology Teachers Perceive that STS(E) Takes More Effort and Time to Implement Successfully than Other Types of Content

While all teachers who were interviewed for the purposes of this study expressed a clear commitment to STS(E)-inspired instruction, they all also acknowledged that STS(E) content is often not as easily integrated into senior biology lessons as more technical scientific content. In particular, STS(E)-driven lessons were generally perceived to be more time-consuming, especially onerous for teachers, and more likely to be unsuccessfully executed than typical content-driven lessons.

All three teachers who participated in this research indicated that STS(E)-based lessons, though more rewarding, often took more in-class time to implement than did more orthodox content-based lessons. When recounting their experiences of a time in which they felt they had most successfully met the STS(E) expectations in a senior biology class, both Celia and Gabby
indicated that the process took anywhere from three to six classes, and for Celia, the project that she related accounted for “every bit of [the students’] biology homework” during that time. Gabby further suggested that, because of the time that it takes to successfully execute a good STS(E)-driven lesson or project, it is not always possible to include such activities in all units of study:

> [U]ltimately, you want [STS(E)-based activities] to have FNMI [First Nations, Métis, and Inuit], environmental ed., all of the bells and whistles and policies all in one beautiful little package, but sometimes, in reality, that just doesn't happen because you run out of time. Or, you know, there's a snow day or, you know, a million other things that go on. […] In terms of time, when you create something that's rich and exciting and motivating for the kids, sometimes it ends up spinning out longer and you want to do it and you do do it, which means it sucks time away from the next unit and whatever you've planned there is going to suffer somehow. But I'd rather take that extra class, make it a 4-class thing instead of a 3-class thing or even make it a 5-class thing instead of a 2-class thing, if it's motivating, if there's a lot of really active learning going on, if they're developing skills…

For Gabby, a good STS(E) lesson can be incredibly “rich” and motivating for students but, at the same time, “it’s not trivial.” That is, it appears that for the participants of this study, STS(E)-centred lessons take time to do well and to ensure that the students are getting all that they can out of the experience.

Time was also the main obstacle that Paul and Celia pointed to when asked what might prevent teachers from successfully implementing the STS(E) expectations in their senior biology classrooms. “You're juggling time with a lot of what you want to cover,” Paul said in his interview: “There's assemblies, there's different things that come up and shorten your teaching
schedule and maybe [teachers] want to get through [material] to not be behind and, you know, you have to meet all the curriculum for the exam or the unit test.” In addition to the various time demands that teachers are constantly negotiating during their careers, Celia and Gabby also discussed the difficulties associated with the time it takes simply to design STS(E)-based lessons. As Gabby indicated in her interview,

I think the biggest trouble, I knew it certainly is with us here, is the time. The time to take […] to sit down and actually do a source search. The time to actually print those out and read through them and think about, would this work with my kids? […] Could I put a local perspective on this? Is this too hard or too easy for them? Is it a moot point because they know this already? To be able to sit down with other teachers, to go to, you know, whatever PD [professional development] session, either within the school or a course outside of the school, or some sort of summer workshop or whatever. To be able to sit down and say ‘Hey, I've got this cool resource and it worked this way’ or ‘I need to develop a new resource that does X, Y, and Z and has good STSE’ […] To be able to take the time to…to really deeply think about rather than just print something out […] and not really think about how it fits with the rest of your program.

In addition, Celia also indicated that appropriate teacher resources on STS(E) instruction were sometimes difficult to locate, and further stated that “when you’re teaching, you don’t have time to find this sort of stuff.”

In general, the participants in this study seemed to concur with the notion that STS(E)-related instruction in senior biology classes (relative to more content-based lessons) relied more heavily on the personal motivations and will of a particular teacher than on any universal training or wider faculty influence. As a result, STS(E)-type content, while often perceived by the
participants in this study to be more satisfying to teach than technical content, was largely thought to be more onerous for the teacher to pursue in practice. While time was clearly thought to be a major factor that impinged upon a teacher’s ability to incorporate STS(E), Paul also pointed to a lack of emphasis on STS(E) within departments. As he related in his interview,

> Being in three different schools, [I have found that] you don't just sit in your departments and have a meeting and say, ‘What STSE topics are we going to cover?’ We never have that kind of conversation. It's more like, ‘What content have you covered or are you going to cover first?’ and then that is left to, really, the individual teacher, [to determine] how much time they really want to spend on [STSE]. So, that's something that I would say isn't consistent, right? […] But I think, if time permits, and departmental time permits, that’s something that needs to be addressed a little bit more in meetings so that [STSE] doesn't get kind of left in the back of your classroom lesson, right? So, you [can] kind of make sure it's there.

So, in addition to the personal time investment of individual teachers on the pursuit of STS(E), teachers also perceive there to be a deficit in the time available for discussing the STS(E) curriculum expectations on the part of at least some high school biology departments. This suggests that, while clearly valued by the participants in this study, STS(E) does not represent the main thrust of biology teaching for some educators and departments. Rather, it appears that, for them, STS(E) might be more accurately conceived of as a vehicle for teaching specialist biology content. As was discussed in section 5.3, this notion fits well with the finding that, for some teachers, STS(E) often provides an “authentic context” for learning in senior biology classes.
Lastly, some teachers who participated in this study also indicated that teachers might perceive an increased degree of “risk” when pursuing STS(E) content in their senior biology classrooms, relative to instances when they are simply teaching heavily content-driven lessons. Some of this, it appears, stems from the perception that it is not always certain that students will end up in what Gabby referred to as “the right place”, particularly following an open-ended STS(E) lesson or project. As she explained,

The destination is always the same, right? The curriculum expectations or a certain level of understanding. If you get there by lecture, it's a pretty straight line. If you get there by doing sort of an STSE authentic scenario, [...] you set it up and then the kids carry you. But you're hoping that it's going to end [at a particular point]. You might be off tangent and you might have to do a little bit of lecture to bring them back to where they need to be. If you're doing it completely open-ended and the kids are establishing the question, the scenario, like, and they may be individually coming up with how am I going to learn about biodiversity, or how am I going to learn about DNA, [...] you have to be really flexible with how much of that destination they reach [...] Not all of [the students] are going to have all of the expectations. So, that's an awkward place to be if you are doing a common exam with three other sections, with two other instructors. That's a hard place to be [...] So, I think, probably the biggest thing is probably comfort with risk.

In addition, with open-ended, student-led STS(E) projects and activities, a teacher may not always have familiarity with the particular topic or concern that a given student has chosen. As a result, teachers have to be comfortable with not necessarily being the expert in the room. As Gabby goes on to explain,
So, [teachers are] not going to feel comfortable going off-menu with a messy problem if they really don't know their stuff really well. [...] There's sage on the stage and there's guide on the side and somewhere in between that there's sage on the side. And I think a lot of teachers may be okay with giving the kids a somewhat open-ended question but not too open ended because god knows what might happen, whereas being a sage on the stage is very comfortable. ‘I know therefore I am going to talk at you.’ Being a guide on the side is a really risky, dangerous place to be because you really don't know what's going to happen. You cross your fingers and really hope that you're going to meet curriculum expectations. But it really is a risky place to be. [...] You really need to think on your feet to be able to do it well.

The notion that a teacher’s level of expertise or comfort with the content of the curriculum is directly proportional to their willingness to take these sorts of professional risks was also echoed by Paul. When asked about what sort of teacher might experience barriers to teaching STS(E) most acutely, he suggested that both new and experienced teachers are equally susceptible. However, because of this perceived risk, for him, a newer, less experienced teacher may be less likely to

Want to take risks because of failure. The fear of failure might be why they want to, kind of, stick to the plan, right? [...] It is something in the profession of teaching where you have to kind of be able to be comfortable to, you know, take risks. And, as a result of risk, maybe fail, too, and learn from it. So, if you have that experience and you have that open-mindedness, the teacher who wants to be effective, will be.

Further, as a result of the perceived risk involved, teachers might have a limited capacity to valuably integrate STS(E) into their lessons. As Gabby explained,
It's a huge amount of work and a huge amount of risk. Like, there's a certain amount of risk that everybody feels comfortable with [...] But doing more than a certain amount of risk is sort of like, I'm sorry, that's exhausting. And I'm not going to be on my game for even the activities that I do know and I am comfortable with and if there's too many changes in that course, I'm not going to be at my best to be able to react when something does go south.

And it will, right? You have to expect that.

That is, for Gabby, after a certain point, risk appears to act as a deterrent to the integration of STS(E) in senior biology classrooms – at least in terms of the open-ended, student-led format that the participants in this study seemed to favour.

So, while especially rewarding, the teachers who participated in this research largely found that integrating STS(E)-related content into their senior biology courses was an exceedingly time-consuming and onerous endeavour; and moreover, for these teachers, it appears that doing so did not always lead to feelings of guaranteed success. As a result, the participants suggested that, when a teacher is less comfortable with the course material, they may be less likely to take these sort of risks, regardless of the potential payoff. Importantly, many of these practical considerations have also been identified as barriers to the implementation of STS(E) in science classrooms in the published literature. In particular, lessons related to STS(E) have been shown to be perceived by teachers to be overly time-consuming when compared to traditional content-based coursework (Steele, 2013). In agreement with the findings reported here, the general feeling among teachers that has been identified in the literature is that the onus is on particular teachers to research and gather information on STS(E) content, to select case-studies, and to make connections to student experiences, preferences, and interests. As a result of the
considerable time commitment that is required to do this, in some instances, STS(E) may only receive shallow treatment in science classrooms (Steele, 2013, p. 27-28).

A deficit of training and personal development (PD) opportunities for teachers in areas relating to STS(E) education has also been reported in the published literature (Pedretti et al., 2008; Steele, 2013). Though STS(E) is now often included in most science teacher education programs, and some useful internet resources have been made available for teachers (e.g., Bencze, 2011), feelings of uneasiness and under-preparedness still persist among Ontario science educators when it comes to integrating STS(E) in the classroom (Pedretti et al., 2008; Steele, 2013). As a result of these feelings, as expressed in the interviews reported here, teachers may be less likely to incorporate STS(E) into their lessons in practice. Indeed, this might be especially true if teachers perceive the practice to be inherently more “risky” than other alternative approaches to science education, as seemed to be widely expressed by the participants in this study.

5.6. Conclusion

In this chapter, I presented the findings of this qualitative interview research study on the experiences of three high school biology teachers with the implementation of the STS(E) curriculum expectations that are embedded in the Ontario science curriculum. From the interview data, five prominent themes emerged, including:

1) For senior biology teachers, the imperative to incorporate STS(E) into their lessons often goes beyond the explicit curriculum expectations.

2) Senior biology teachers recognize that STS(E) is inextricably linked to technical science content.
3) Senior biology teachers acknowledge that STS(E) makes technical science content more relevant to the lives of their students.

4) Senior biology teachers feel that STS(E) content is best integrated into their lessons through student-led summative assignments and in-class activities.

5) Senior biology teachers perceive that STS(E) takes more effort and time to implement successfully than other types of content.

Taken together, these findings suggest that, though some teachers may be independently instilled with a proclivity for incorporating STS(E) into their senior biology courses and recognize the pedagogical value of doing so, significant barriers remain, even in these seemingly ideal circumstances. Indeed, to the researcher’s knowledge, the findings presented here represent the first academic inquiry into the experiences of seasoned biology teachers with STS(E)-based science education in the Ontario education context. In the following chapter, the implications of these findings for students, teachers, administrators, policy makers, teacher education programs, and education researchers will be discussed, and subsequent recommendations for how additional needed support might be provided for teachers as they begin or continue to implement STS(E) in their classrooms will be presented.
Chapter Six: Conclusion

6.0 Introduction to Chapter

The purpose of this study was to explore teachers’ experiences of implementing Ontario’s Science-Technology-Society-Environment (STS(E)) curriculum expectations in their senior biology classes. In this chapter, I further discuss the findings of this research. To do this, I first provide an overview of the key findings that were presented in Chapter Five, as well as their significance in light of the published literature, which was reviewed in Chapters Two and Three. I then describe the broad implications of these findings for various stakeholders, including students, high school biology and science teachers, department heads, policy makers, and STS(E) researchers. Narrow implications for my own personal teaching practice will also be elaborated upon. Subsequently, several recommendations for how to contend with these implications will be enumerated before, finally, pointing to particular areas of inquiry that are in need of further research.

6.1 Overview of Key Findings and Their Significance

Five major themes emerged as a result of this research. Firstly, for the senior biology teachers who participated, it appeared that the imperative to incorporate STS(E) into their lessons often went well beyond the explicit curriculum expectations for their courses. In particular, personal interest, previous employment and education, and the perception that STS(E) reflects current and pressing social and environmental concerns were found to be more important determinants of a teacher’s choice to incorporate STS(E) into their senior biology classes than were the curriculum requirements or pre-existing science education reform movements. Importantly, this finding is reflected in the published research, as well (Lee & Witz, 2009). However, as a result of the disparate motivations of teachers, some participants noted that
STS(E) is not generally implemented in a consistent manner from classroom to classroom and, thus, students may not be receiving the same quality product from their educators. While this inconsistency has also been noted in the literature, no consensus exists in terms of its potential effects on science education. While some suggest that this lack of consistency might be harmful in terms of the maintenance of educational standards (Zeidler et al., 2005), still others propose that the variety of approaches taken by teachers in the implementation of the STS(E) expectations might actually better serve students in an ever-changing world (Fuglsang, 2001; Pedretti & Hodson, 1995; Pedretti & Nazir, 2011; Ziman, 1994).

Secondly, all research participants appeared to view STS(E) as inextricably linked to the technical science content that is also presented in senior biology classes. Indeed, interviewees often spoke of the connection between STS(E) and more orthodox biology content as “automatic”, “common sense”, and “natural,” suggesting that participants did not necessarily see a true distinction between these two different types of content. Interestingly, while teacher motivations for integrating STS(E) were largely found to be divorced from larger science education reform efforts, they did, at the same time, appear to share this perspective in common with reformers (Cutcliffe, 1990). This implies that, though reform-minded teachers might adopt different approaches to STS(E) in practice, they may still share in common their conceptions of science and its relationship to society and the environment.

Thirdly, all interviewees acknowledged that STS(E) makes technical science content more relevant to the lives of their students. In particular, STS(E) was largely mobilized by teacher participants for the purposes of drawing connections between specialized science content and real-life contexts. Indeed, teachers also perceived that these efforts had a positive impact on student learning and engagement in the classroom, regardless of their academic goals.
Importantly, the notion that STS(E) is intended to underscore the relevance of science to real life has been well-emphasized in the literature, virtually since the inception of the STS(E) education reform movement (Gallagher, 1971). Since then, ample evidence has also been garnered in support of the role of STS(E) education in enhancing student engagement in science classrooms (Bennet et al., 2007).

Fourthly, the senior biology teachers interviewed for the purposes of this research tended to integrate STS(E) content into their lessons through student-led summative assignments and in-class activities. In general, this finding agrees well with the existing literature, which clearly favours the use of student-led projects in the successful implementation of STS(E) in classrooms (Akcay & Yager, 2010; Bencze, 2000; Bencze & Sperling, 2012; Bencze, Sperling, & Carter, 2012; Tal & Kedmi, 2006). That said, the published research still suggests that an important role may remain for teacher-led STS(E) activities, particularly when it comes to the presentation of new skills and concepts. In the case of the interview data presented here, however, many teachers expressed resistance to the idea of implementing STS(E) via lecture. Importantly, very little research exists on the precise strategies that teachers adopt in order to integrate STS(E) into their classrooms, and still less research is focused on comparing the efficacy of different approaches in this regard (See, for example, Akcay & Yager, 2010). As a result, more information is required in order to adequately assess the relative value of teacher-led and student-led approaches to the implementation of STS(E) in science classrooms.

And lastly, despite its value, the teachers who participated in this research seemed to perceive that STS(E) takes more effort and time to implement successfully than other types of biology content. Moreover, the interviewees suggested that the integration of STS(E) in senior biology classrooms presented more risk than did more canonical content. Notably, many of these
practical considerations have also been identified as barriers to the implementation of STS(E) in science classrooms in the published literature. In particular, lessons related to STS(E) have been shown to be perceived by teachers to be overly time-consuming when compared to traditional content-based coursework (Steele, 2013). Further, as a result of the considerable time commitment that is required to do this, in some instances, STS(E) may only receive shallow treatment in science classrooms (Steele, 2013). A lack of professional development (PD) and pre-service learning opportunities for teachers in areas relating to STS(E) education were also pointed to in the literature, which were purported to further exacerbate feelings of unpreparedness and general risk-avoidance among science educators who are tasked with implementing STS(E)-related content (Pedretti et al., 2008; Steele, 2013).

6.2 Implications

This section will be composed of two subsections. The first subsection will broadly detail the potential implications of the results of this research for various stakeholders, including students, high school biology teachers, department heads, policy makers, and STS(E) researchers. This will then be followed by a discussion of the narrow implications of the results for my own teaching practice.

6.2.1 Broad: Implications for the educational community

Though they differed in many respects, the teachers who participated in this study all emphatically stressed the important role of STS(E) in the education of senior biology students. However, much of the published literature has suggested that, in many science classrooms, STS(E) connections to content are still often understated by teachers (Hughes, 2000; Nashon, et al., 2008; Pedretti et al. 2008; Pedretti, 2003; Steele, 2003). As a result, in many cases, students may not be experiencing some of the benefits of STS(E)-centred science education that were
perceived by the teachers who participated in this and other studies. Indeed, if these perceptions are accurate, this suggests a need to more strongly emphasize and support the teaching of STS(E)-content in science classrooms in order to better serve students. The particulars of how this might be achieved will be discussed further in section 6.3.

Similarly, the varying and personal motivations that teachers offered as key to their commitment to implementing the STS(E) curriculum expectations also suggests that students may have vastly different experiences of STS(E) education, depending on who is educating them. This lack of standardization across classrooms likely has important effects on the quality of different students’ education in the sciences, and in biology in particular. However, whether these effects are beneficial, detrimental, or neutral remains to be seen.

For senior biology teachers (and, perhaps, science teachers more broadly), it appears that, while many may have a very personal drive to integrate STS(E) into their lessons, they may not always feel well-supported to do so. In particular, a lack of time, collaboration between teachers, PD, and sufficient prior education on STS(E)-related topics might lead to feelings of unpreparedness among senior biology educators as they take on the personal burden of implementing the STS(E) curriculum expectations. For teachers who, perhaps, do not share the same personal connection to STS(E), this lack of support may be even more important, as the risks associated with pursuing a heavily STS(E)-centred lesson might be perceived to be excessive and of little reward. In light of this insufficient support, there is a distinct possibility that senior biology teachers are not or are only very shallowly addressing STS(E) in their classrooms.

High school science departments may also play an important role in the valuation of STS(E)-related content in senior biology classrooms. From the evidence gathered here, it seems
possible that STS(E) may not occupy the same amount of departmental time as canonical content. That is, less care may be taken in ensuring that all biology staff are covering the STS(E) curriculum expectations than is taken when discussing the coverage of technical biology-content. Further, the relative isolation of science departments from other academic departments might be limiting important opportunities for interdisciplinary collaboration, which may serve to support the formation of curricular connections between science, technology, society, and the environment.

The notion that teachers may be harbouring their own, personalized motivations for incorporating STS(E) into their lessons also has important implications for policy makers and education researchers. In particular, teachers may be operating under very individualized definitions of what STS(E) education entails, and thus their conceptions of STS(E) may not be continuous with those employed by policy-makers or reform-minded researchers.

6.2.2 Implications for the researcher’s teaching practice

My dual academic background in both the socio-historical and practical aspects of science have coalesced to form the foundation of my interest and commitment to STS(E)-education. Though my familiarity with STS(E) predates this research, the findings presented here have highlighted several important implications for my own teaching practice, as well. In particular, it emphasizes an imperative for me to move beyond the scope of my own teaching practice and to consider the ways in which I might positively affect the practices of other science teachers through advocacy and collaboration. To this end, as a newly-trained educator, I aspire to collaborate with my teacher colleagues and facilitate interdisciplinary partnerships in order to support the development of useful teacher resources and lesson plans.
This research has also suggested to me the importance of looking to one’s community as an important resource and vehicle for STS(E) content. With that in mind, I am committed to exploring local STS(E) issues in my future science classes in order to make solid and familiar connections between content and the lives of my students.

This research has also served to reemphasize to me that the role of the teacher is not simply to introduce students to facts, but to enable students to formulate connections between content and real life. Further, it re-solidifies the claim that schools are not designed for the role of rote memorization and regurgitation, but instead must provide students with tools that they can use in order to better operate within society. That is, the aim is to prepare students for life after schooling, and in the context of a science classroom, STS(E) education is one way to effectively support this goal.

6.3 Recommendations

Several recommendations naturally follow from the implications outlined in section 6.2. In particular, the recommendations laid out here may be enacted at the level of individual teachers, school administrators, policy makers, or teacher education programs.

While teachers are required to incorporate STS(E) curriculum expectations in their science classes, this may not occur in practice for a variety of reasons. Further, while those who participated in the research described here emphasized the importance of STS(E) in their own practice, some teachers may not share this commitment. As a result, it may be necessary for some senior biology teachers to take the time to critically and explicitly reflect on their own connections to STS(E): to ask themselves what it is that they feel are the most important aspects of their senior biology courses, how these choices and preferences are reflective of their own identities as educators, and, in turn, what that might mean for how they approach STS(E)-related
content. Perhaps, if teachers were to consider these connections more explicitly, they may be able to more easily find avenues to authentically integrate STS(E) into their lessons.

STS(E) is also innately interdisciplinary in nature. That is, it interrelates with disciplines beyond science, including history, philosophy, and the social sciences. In order to better highlight these connections in their classrooms, teachers should also make efforts to collaborate with educators in other relevant disciplines, in addition to facilitating partnerships with educators in their own departments. Furthermore, efforts can also be made to determine areas of content overlap between disciplines in order to facilitate cross-curricular projects and activities that students can then engage in, thus making the interrelations of science, technology, society, and the environment even more unambiguous.

Of course, teachers require ample time to complete such tasks. As a result, school administrators might be called upon to ensure that such time exists. For instance, administrators can take the necessary steps to foster an atmosphere of collaboration within their schools. They might also be tasked with connecting science teachers with relevant PD opportunities. In addition, high school science department heads should be encouraged to devote time to a more thoughtful and thorough consideration of the STS(E) curriculum expectations among staff. This would help to ensure that all teachers are actively engaging with these expectations in their classrooms, and would give teachers and opportunity to discuss and appraise the different approaches that they have adopted for doing so.

Policy makers and reform-minded researchers also have an important role to play. As teachers appear to have very diverse motivations for integrating STS(E) into their senior biology lessons, it is possible that the goals of educators do not align well with the goals of the curriculum or the ideals put forth by academics. This state of affairs may be somewhat
worrisome, considering that teachers are often the main enactors of education policy and policy is frequently informed by ideas put forth by academics. As a result, policy makers and researchers alike may have to embark upon a more thoughtful assessment of the intentions of STS(E) theory and policy in education. In this case, the question for consideration might be less about what teachers should be teaching and more focused on how or whether it is necessary to ensure that teachers share a common understanding of the merits of that material.

Lastly, some responsibility for the effective implementation of the STS(E) curriculum expectations in science classrooms might also be expected to lie with teacher education programs. At present, in Ontario, teacher candidates in the sciences require no explicit STS(E)-related training prior to their acceptance into teacher education programs. A standard Bachelor of Science is sufficient, and these programs often do not include an assessment of the relationships between science, technology, society, and the environment. In order to ensure that prospective science teachers enter teacher education programs prepared to teach STS(E)-related content, these programs might consider changing the admission requirements to include STS(E)-related courses as well as the typical content-based science classes. These additional required courses might include those related to the history or philosophy of science, for instance. Alternatively, teacher education programs might have to be prepared to introduce STS(E) content as part of the program, itself. However, this would require programs to mobilize more resources in order to do so, which may not be desirable, particularly for those programs that are already course-intensive.

6.4 Areas for Future Research

The research performed here points toward several areas of potential future research. As was earlier noted, the level of commitment of the teachers who participated in this research to implementing the STS(E) curriculum expectations in their senior biology classrooms appeared to
be somewhat exceptional vis-à-vis the published literature (Hughes, 2000; Nashon, et al., 2008; Pedretti et al. 2008; Pedretti, 2003; Steele, 2003). Indeed, this disparity between the literature and the results presented here may point to a need to move beyond an appraisal of teachers’ perceptions of their own actions and practices in the classroom in relation to STS(E). That is, teachers likely perceive themselves, their motivations, and the effects of their teaching practices somewhat differently from how an outsider, another teacher, or even a student might interpret them. In this way, it would be interesting to look at the relationship between science teachers’ perceptions of their own practice and that of the students who are on the receiving end of that practice. Further, in this regard, more research is also required in order to better assess the potential implications that the apparently diverse motivations that guide teacher practice in this area may have on the quality of education that students receive in science classrooms.

In addition, this study represents only a very cursory look at the relationship between STS(E) and the practices of actual teachers. While some research has been done on what classroom strategies are perhaps most amenable to STS(E) content (Akcay & Akcay, 2015; Bencze, 2000; Bencze, 2011; Bencze & Sperling, 2012; Bencze, Sperling, & Carter, 2012; Tal & Kedmi, 2012), very little has been done in the way of determining what teachers actually do in order to implement the STS(E) expectations in their classrooms. Further research into this area might take several forms. For instance, exploring the relationship between teachers’ personal motives for integrating STS(E) and their choice of instructional strategies might reveal further information about their commitment to and alignment with the ideals presented by science education reformers and policy makers. Additionally, different methods of accessing STS(E) content in the classroom might be compared and appraised in order to determine best practices for teachers (as in Akcay & Akcay, 2015).
Questions still remain about the relative value educators place on STS(E) when teaching, as well. For instance, from this research, it is clear that the participants highly valued STS(E). However, the relative value that teachers placed on STS(E) content when compared to more canonical senior biology content was only very subtly hinted at by participants, and was not explicitly stated. Indeed, this question might best be answered using larger-scale quantitative or mixed-method survey-based research methods, rather than the strictly qualitative approach that was employed here.

This research was also performed at a very local level (three teachers from three different schools in downtown Toronto). While there is a paucity of Ontario-specific research on teachers’ experiences of implementing the STS(E) curriculum expectations, very little research appears to exist exploring how STS(E)-content is approached by educators in other jurisdictions, as well. Thus, further investigations into how biology teachers go about implementing STS(E), in general are also needed.

6.5 Concluding Statements

The research findings presented here were novel in several respects. Although some literature exists exploring best-practices in STS(E) education, very little research has explored the actual practices of teachers in relation to STS(E) in their classrooms. Further, the findings presented here also appear to counter many of the claims made in the published literature, which state that science teachers often shy away from STS(E) in their own practice. Indeed, the educators who participated in this research all emphasized a very clear personal commitment to STS(E) in their senior biology classrooms. And, lastly, this research also focuses specifically on STS(E) education in the Toronto context, upon which there is a notable deficit of research (even less still being focused exclusively on senior biology education).
As other authors (e.g., Pedretti & Nazir, 2011; Ziedler et al., 2005) have suggested, STS(E) is a very complex field, which may thus appear unapproachable or vague. Indeed, while STS(E) education has been shown to produce tangible academic benefits for students, the precise definition of what STS(E) actually is in practice remains somewhat elusive. In this way, it is hoped that this research has done some work to demystify STS(E), not only for educators but for researchers, as well. Though its characterization remains imprecise, the reasons for why this might be the case are becoming somewhat clearer and, importantly, the steps that might be taken in order to clarify its role and intent in education are steadily being illuminated.
References


Appendix A: Letter of Consent

Date:

Dear [participant],

My name is Deanna Harris and I am a student in the Master of Teaching (MT) 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 senior (grade 11 and 12) biology teacher perspectives and practices in relation to Ontario’s Science-Technology-Society-Environment curriculum expectations. I am particularly interested in interviewing teachers who were instructing senior biology classes prior to the official inclusion of these expectations in Ontario’s science curriculum and have experience implementing them in their biology classrooms. To that end, I feel that your knowledge and experience will provide valuable insights into this topic.

Your participation in this research will involve one roughly 60-75-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 and 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.

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,

Deanna Harris, hBA, hBSc., MSc., MT Candidate
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 Deanna Harris and agree to participate in an interview for the purposes described. I agree to have the interview audio-recorded.

Signature: ________________________________

Name (Please Print): ________________________________

Date: ________________________________
Appendix B: Interview Protocol and Questions

A. Introductory Script

Thank you for agreeing to participate in this research study, and for making time to be interviewed today. My name is Deanna Harris and I am second-year Master of Teaching Student at the Ontario Institute for Studies in Education at the University of Toronto. My research study aims to investigate how experienced, senior (grade 11 and 12) biology teachers feel about and implement the Ministry-mandated Science-Technology-Society-Environment (or STSE) curriculum expectations that are embedded in the Ontario science curriculum. My aim is to elucidate the conditions under which teachers are most likely to address the STSE expectations and what supports teachers feel that they require in order to meet the expectations (if any).

This interview will last approximately 60 minutes, and I will ask you a series of questions about your own personal feelings about the STSE curriculum expectations and how and when you typically address them in your senior biology classes. I will also inquire about what types of resources you have used to do so and what other supports you might feel are lacking in this area (if any). While I want to emphasize the importance of your participation in this interview, I also want to remind you that you may refrain from answering any question, and you have the right to withdraw your participation from the study at any time.

As was explained in the consent letter, this interview will be audio-recorded.

Do you have any questions before we begin?

B. Pre-Interview Protocol

1. Discuss the consent form with the participant and have them sign and date it prior to the interview. The researcher will retain one copy and another copy will be made available to the participant for their records.
2. Ask if the participant has any further questions about the research project.
3. Test the audio recorder and begin recording.
4. State date and time of interview.
5. Start interview

C. Interview

Part I: Teacher Background Information

Segue: To begin the interview, I would first like to ask you a few questions about your teaching experience, training, and prior education.

1. Could you tell me a little bit about your previous teaching experience?

   Prompts for question 1:
   a) What classes and grade levels have you taught?
b) What classes do you currently teach?
c) What school do you currently teach at?
d) How long have you been a teacher in Ontario?
e) Do you have experience teaching biology in any other province or country?

2. Could you tell me a little bit about your own teacher training and prior education?

Prompts for question 2:
   a) When did you obtain your teacher training? In what year?
   b) What are your other teachables, if any?
   c) Other than your teacher training, have you obtained or are you in the process of obtaining any other university degrees or certificates? In what field(s)?

Part II: Teacher Perspectives on and Feelings toward the STS(E) Ethos and Ontario’s Explicit STS(E) curriculum expectations

Segue: Now that I have obtained some general information about your teaching experience and educational background, I would like to ask you some specific questions regarding your personal perspectives on your practice as a senior biology teacher, in general, as well as your feelings about the STS(E) curriculum expectations, specifically. I will also be drawing particular attention to your experiences with STS(E) and STS(E)-related material before and after the official integration of the STS(E) curriculum expectations into the provincial science curriculum in 2008.

3. As a senior biology teacher, what do you feel is your main objective or purpose in the classroom?

4. Are you familiar with the term, Science-Technology-Society-Environment (STS(E))? In what context(s)?

Prompts for question 4:
   a) Have you heard this term used outside of the context of Ministry of Education science education mandates in Ontario? If so, in what context(s)? Explain.

5. How would you define the general philosophy of STS(E)? What do you feel is its general object or purpose?

6. How do you feel that the objectives of the general STS(E) ethos relate to your own objectives and aims as a senior biology teacher, if at all?

7. Based on your experience as a senior biology teacher, how would you describe the explicit STS(E) curriculum expectations that are presented in the biology curriculum for grades 11 and 12?

Prompts for question 4:
   a) What do you feel is their general object or purpose?
8. How do you feel that the STS(E) curriculum expectations relate to your own personal objectives and aims as a senior biology teacher, if at all?

9. As a teacher with more than 20 years of experience in Ontario, you were instructing biology classes prior to the official integration of STS(E) as explicit expectations in the provincial science curriculum. How did the inclusion of these expectations change or alter your practice, if at all?

Prompts for question 9:
   a) What were your feelings about these changes to your practice at the time? What are your feelings about these changes now?

10. Overall, would you say your feelings toward the STS(E) curriculum expectations are more positive or negative in nature? Why do you feel that this is the case?

11. What are the main strengths and/or weakness of the STS(E) curriculum expectations for senior biology classes, in your view?

12. The STS(E) curriculum expectations often address concerns about the social and environmental implications of science and human actions. With this in mind, are there any aspects of the STS(E) curriculum expectations that you are uncomfortable addressing in your biology classes? Why/Why not?

Part III: Teacher Implementation and Integration of the STS(E) curriculum expectations into their Senior Biology Classes

Segue: The next few questions are intended to address your personal practices and experiences with reference to addressing the STS(E) curriculum expectations in your senior biology classrooms. More specifically, you will be invited to describe and evaluate particular aspects of your own teacher practice in this area.

13. Using general terms, can you describe for me how you would typically implement, integrate, or address the STS(E) curriculum expectations in your senior biology classes?

Prompts for question 13:
   a) What types of activities and assignments do you use?
   b) What types of teacher inputs do you employ (e.g.: lectures, films, guest speakers, field trips...etc.)?
   c) How much in-class time would you say that you devote to addressing the STS(E) curriculum expectations? Per year? Per unit of study?
   d) How often would you say that you address the STS(E) curriculum expectations? Every class? At the beginning or end of a unit? Somewhere in between?
   e) What topics do you tend to cover with respect to the STS(E) curriculum expectations? Are they generally history-based? Issue-based?
14. Can you give me a specific, concrete example of how you’ve satisfied one or more of the STS(E) curriculum expectations in your senior biology classes in the past? In particular, can you think of the time in your career in which you felt you were most successful in meeting the expectations?

Prompts for question 14:

   a) Is this an example of an STS(E) lesson, activity, or assignment?
   b) What was the topic?
   c) What were the students doing? What were you doing as the teacher?
   d) How long did it take to implement?
   e) How were the STS(E) expectation(s) satisfied by the lesson/activity/assignment that you describe? Which expectation(s) were satisfied, specifically?
   f) What grade/unit was this lesson/activity/assignment intended for?
   g) How was it assessed?
   h) What do you think makes this an exemplary illustration of your ability to meet the STS(E) curriculum expectations? (e.g.: Met explicit expectations? Increased student engagement? Meets perceived needs of society?...etc.)

15. Are there some units of study in the senior biology curriculum that you feel are more amenable to the STS(E) curriculum expectations than others?

Prompts for question 15:

   a) What are these units?
   b) What makes the STS(E) curriculum expectations for these units easier to meet? (e.g.: Personal interest? Student interest? Available resources? Time?...etc.).

16. Conversely, in which units of study do you feel that the STS(E) curriculum expectations are more difficult to address?

Prompts for question 16:

   a) What are these units of study?
   b) What makes the STS(E) curriculum expectations for these units more difficult to meet? (e.g.: Lack of personal interest? Lack of student interest? Lack of available resources? Lack of time?...etc.).

Part IV: Teacher Perceptions of the Impact of STS(E) on Students and their Learning

Segue: I have asked you about your personal feelings toward Ontario’s STS(E) curriculum expectations and their implementation in classroom practice. The next set of questions will require you to consider the perceived reactions and responses of your students to your efforts to address the STS(E) curriculum expectations in-class. I will then ask you to consider the ways in which these responses inform your practice.

17. How do you feel students respond to lessons/activities/assignments that are aimed at addressing the STS(E) curriculum expectations, in general?
Prompts for question 17:
  a) How would you rate student engagement in these lessons/activities/assignments relative to lessons/activities/assignments on other aspects of the senior biology curriculum that are unrelated to the STS(E) curriculum expectations?
  b) Why do you think engagement was increased/decreased relative to these other lessons/activities/assignments?

18. Do you feel that addressing the STS(E) curriculum expectations in your classes has served to support or undermine specialist biology content knowledge among your students? Why/Why not?

19. How does your knowledge of your student’s preferences and past responses to your efforts inform how you continue to address the STS(E) curriculum expectations in your classroom, if at all?

Part V: Supports and Challenges to Addressing the STS(E) curriculum expectations in Senior Biology Classrooms

Segue: We have discussed several aspects of your practice with regards to addressing the STS(E) curriculum expectations in senior biology classrooms. To that end, I am also interested in your feelings of preparedness to address and integrate the STS(E) expectations into your biology classes. In the next section of the interview, I will be asking you questions related to these feelings as well as the types of resources that you have used or would like to use in your classes in order to help you to address the STS(E) curriculum expectations.

20. On the whole, do you feel well prepared and comfortable addressing the STS(E) curriculum expectations in your senior biology classrooms at this stage in your career?

Prompts for question 20:
  a) If so, what has prepared you for it?
  b) If not, why not?

21. Think back to a time before the STS(E) curriculum expectations were introduced. Would you say that you addressed STS(E)-type issues and topics in your classes even at this time?

Prompts for question 21:
  a) If so, what were your motivations for doing so?
     i) Why do you feel that your teaching at this time addressed STS(E)-related topics and issues?
  b) If not, why not?
     i) Why do you feel that your teaching at this time did not address STS(E)-related topics and issues?
     c) Was STS(E) addressed in your teacher training at all?

22. What sorts of resources have you employed in order to assist you in addressing the STS(E) curriculum expectations in your senior biology classes, if any?
23. Do you feel that any additional resources should be made available to teachers, such as yourself, in order to assist you in addressing the STS(E) curriculum expectations in your senior biology classes?

_Prompts for question 23:_
- a) If so, what types of resources do you think would be helpful?
  - i) How would the availability of these resource(s) serve to reinforce or support your practice and/or student learning?
- b) If not, why not?

24. In your experience, what do you feel are the most significant barrier(s) or challenge(s) to addressing the STS(E) curriculum expectations in senior biology classrooms, if any?

_Prompts for question 24:_
- a) Do you feel that these challenges are greater for experienced or beginning teachers?

Part VI: An Invitation for Closing Remarks

_Segue:_ The interview is now complete. However, before officially closing the interview, I would like to invite you to make any concluding remarks that you deem to be of significance.

25. Is there anything else that you would like to add on the topic of addressing the STS(E) curriculum expectations in senior biology classes in Ontario?

D. Closing Script

Thank you for your participation in this research study. Your contribution to my research is invaluable.

E. End of Interview Protocol

1. Turn off audio recorder.
2. Re-address the consent form and inform participant that they will be sent a draft of the final research paper for their review prior to its final submission.
3. Thank participant and direct their attention to the researchers contact information if they have any further questions.