THE USE OF WRITING STRATEGIES IN SCIENCE, TECHNOLOGY, SOCIETY AND ENVIRONMENT (STSE) EDUCATION

by

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Chapter 1

Introduction

The goals of science education are many and, some might argue, at odds with one another (Pedretti, 2005). However, all of these goals advocate a science education for all students—not simply those who will go on to become scientists and engineers. Given this premise, a much broader understanding of what it means to be scientifically literate emerges. This literacy includes acquiring and developing conceptual and theoretical knowledge, developing expertise in scientific inquiry and problem solving, and developing the complex interactions among science, technology, society, and environment (STSE) (Wellington, 2001). The goals of science education, then, become the backbone for the types of teaching strategies teachers are using in their classrooms.

It has been widely argued by science education researchers that the goals of scientific literacy are included in STSE education (Alsop & Pedretti, 2001; Hodson, 1998; Soloman & Aikenhead, 1994). In 1997, for example, the Pan Canadian framework recommended that scientific literacy would be best achieved through STSE education:

*The vision of scientific literacy included in this document sets out the need for students to acquire science-related skills, knowledge, and attitudes, and emphasizes that this is best done through the study and analysis of the interrelationships among science, technology, society, and the environment (STSE).* (Council of Ministers of Education, 1997, p. iii)

This recommendation to emphasize STSE is reflected to various degrees in different provinces. Reports from countries all over the world express similar sentiments – mainly that STSE perspectives should be a central component of science education and literacy. Examples can be
In broad terms, STSE is an umbrella term that explores the interplay between science and society (Pedretti, 2005). STSE is about helping students consider science in a larger social, cultural, and political context, which actually exists in the world outside the classroom. STSE equips students to make informed and responsible decisions and empowers them to take appropriate action (Pedretti, 2005). One of the goals of STSE education is to enable students to formulate a critical understanding of the interface between science, technology, society and environment. STSE promotes the development of a critical, scientifically, and technologically literate citizenry, one that is capable of understanding complex events arising from this interface.

The development of a literate citizenry stems from the careful design of teaching strategies by science teachers. Writing, as a teaching strategy, has been discussed for many years – no matter the discipline. Now, the focus is greater on the value of writing-to-learn strategies, especially in science education (Prain, 2006). There are two main research orientations to writing for learning in science. The epistemic orientation, more commonly known as the genrist approach, uses the scientific report as the key genre of scientific writing. Students learn about the traditional forms of scientific writing, such as a laboratory or research report. The idea is that knowing generic rules allows students to “process information deeply” as they “construct relationships among ideas” (Prain, 2006, p. 182). As such, learning happens as the student mimics the written work of professional scientists, reproducing literary functions found in these works in their own writing. The genrist researcher rejects anything in the non-scientific genre, such as narratives or poetry, as it is seen as having no contribution to obtaining scientific knowledge. The other orientation is called the diversified writing approach, and incorporates all non-traditional
forms of scientific writing, while also advocating the integration of traditional scientific writing. In this approach, students must write in “diverse forms for different purposes” in order to “clarify networks of concepts in science topics” (Prain, 2006, p. 184). The main idea is that students need to develop understanding of the social and economic consequences of scientific practices and so should write discourse in a non-science genre.

The literature on writing to learn in science, and specifically these two main research orientations, sheds some light on the advantages of using writing strategies within science – whether students learn by mimicking professional scientists, or by writing in diverse forms. By extension, these writing strategies can serve to meet the goals of STSE education by enabling students to formulate a critical understanding of the interface between science, technology, society and environment. Through this paper, I wish to report on which writing strategies science teachers are currently using, and what opportunities and challenges these strategies are creating for STSE education. The purpose of this project, therefore, was to analyze and describe how science teachers might meet the goals of STSE education through the use of writing strategies.
Chapter 2

Foundations of the study: Literature review and theoretical framework

“Only if we know why we want to include a certain piece of science in the curriculum can we decide how we ought to teach it.” (Millar, 1993, p. 370)

The past three decades has seen an abundance of research on rethinking science education and scientific literacy. As such, scientific literacy has become increasingly significant to the aims and purposes of school science education (Pedretti & Little, 2008). However, there is lack of clarity in the meaning of the term ‘scientific literacy’. The traditional meaning, which is that scientific literacy is the acquisition of knowledge achieved by testing student understanding of science content at different times throughout their education, is narrow. Pedretti and Little (2008) argue that this is a very simplistic and inadequate approach, as the legitimacy and validity of these tests can be challenged. Comparing test scores is problematic because it does not take into account variation in the science curricula across different jurisdictions, or the highly contextualized nature of teaching and learning. This brings attention to the fact that scientific literacy is not solely about content acquisition and we must be careful about how we measure literacy (Pedretti & Little, 2008). Beyond the scope of this project, how educators may measure scientific literacy warrants much further discussion.

For now, educators need to think more broadly about what it means to be scientifically literate and what this implies for science teaching and learning. Recently, scientific literacy proponents advocate a science education for all students—not just those who will go on to become scientists and engineers (Pedretti & Little, 2008). This emphasis broadens the understanding of what it means to be scientifically literate as described in the following:
acquiring and developing conceptual and theoretical knowledge, developing expertise in scientific inquiry and problem-solving, and developing understanding of the complex interactions among science, technology, society, and environment (STSE). This kind of scientific literacy enables growth, understanding, and an ability to make change in order to answer and address important questions pertaining to specific events and issues at hand within the realm of science (Pedretti & Little, 2008).

Since the current definition of scientific literacy calls for a science education that centers on the components of STSE education, a framework is required to understand why we need science education in the first place. Baird (1990) devised a framework that illustrates what science education is for, which has several practical uses. For one, it can be used for explaining the purposes of a lesson to students. Evidence suggests that if students know the ‘why’ of the lesson, they are more motivated to learn (Baird, 1990). Recognizing the purpose of a lesson is an important part of the metacognitive aspect of science education as learners think about what they are learning, and why, while learning it. Baird’s (1990) framework is as follows:

1. **Intrinsic value**: directions and justifications are used to improve students’ attitudes towards science.

   Science can actually be interesting and exciting. Not everything has to be relevant. Explanations of science can be interesting and stimulating to the minds of people just on their own. For example, why a needle floats on water may be interesting on its own. In addition, there is the culture and heritage argument that science is part of our past and contemporary culture. It is a global activity, no matter the culture, and knowing stories of science and scientists from our past is what it means to be a cultured and educated person.

2. **Citizenship argument**.
There is a need for scientific knowledge in the world. Past and current issues such as nuclear energy, drugs, animal testing, food consumption, etc. rely on participants (individuals and key decision makers) to make decisions based on scientific knowledge and understanding. Science impacts our individual decisions on these issues.

Additionally, there is a need for knowledge about scientists, their work, the evidence, the scientific enterprise and the nature of science (NOS). Citizens in a democracy need to understand science and how scientists work—that scientific evidence is not always conclusive or clear-cut. Now, risk, probability, and correlation is more important than certainty, proof, and simple causality. Students need to know science has limits, human activity calls for human error, that it is not always conclusive, and that decisions are not just made by scientific grounds. Science changes over time and across cultures and nations. Therefore, science proceeds in a social, moral, spiritual, and cultural context.

3. Utilitarian argument.

The vocational argument is that many students will not choose science careers but some will and almost all will use science in some form in their own work. This work may be in the form of scientific skills or scientific knowledge, but more often it is a scientific attitude. Another reason is for students to build generic skills. Science develops general, transferable skills in people that can be of direct value in life or in the workplace. These skills may include measuring accurately, recording results, tabulating and analyzing data, estimating, forming hypotheses, predicting, and evaluating what went wrong. Science education also helps develop scientific attitudes that are valuable to life and work. These attitudes may include developing an enquiring mind, curiosity and wonder, skepticism, and a critical analytical approach.
The following table is a summary of Baird’s (1990) justifications, and helps us envision a framework for the purposes of science education:

Table 1: What is science education for? A summary of justifications

<table>
<thead>
<tr>
<th></th>
<th>Intrinsic value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Making sense of natural phenomena; de-mystifying them</td>
</tr>
<tr>
<td></td>
<td>Understanding our own bodies, our own selves</td>
</tr>
<tr>
<td></td>
<td>Interesting, exciting, and intellectually stimulating</td>
</tr>
<tr>
<td></td>
<td>Part of our culture, our heritage</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Citizenship argument</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Science knowledge, and knowledge of scientists’ work, are needed for all citizens to make informed decisions in a democracy.</td>
</tr>
<tr>
<td></td>
<td>Key decision makers (e.g. civil servants, politicians) need knowledge of science, scientists’ work, and the limitations of scientific evidence to make key decisions, e.g., on foods, energy resources.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Utilitarian arguments</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Developing generic skills that are of value to all, e.g., measuring, estimating, evaluating</td>
</tr>
<tr>
<td></td>
<td>Preparing some for careers and jobs that involve some science</td>
</tr>
<tr>
<td></td>
<td>Preparing a small number for careers using science or as ‘scientists’</td>
</tr>
<tr>
<td></td>
<td>Developing important attitudes/dispositions: i.e., the ‘scientific attitude’: curiosity, wonder, healthy skepticism, an enquiring mind, a critical/analytical disposition</td>
</tr>
</tbody>
</table>


Baird’s framework is useful for putting aims into practice in the classroom. It outlines the ‘why’ of science education, and asks further what and how to teach to meet these aims. If one pursues the citizenship argument, teaching activities should involve newspaper and other media of science so that students can practice examining scientific issues critically and discussing controversial issues as well as the nature of science, the work of scientists, and the status of scientific evidence (Wellington, 2001). If the intrinsic argument is the aim, the ‘big issues’ of science must remain the focus rather than the smaller objectives of the curriculum. It becomes
difficult to pick all the topics, and the ones that are stimulating and motivating must be presented in interesting ways, such as multimedia (Wellington, 2001). Alternatively, the utilitarian argument calls for practical work to be done along with theory in order to develop transferable skills of value (Wellington, 2001). These three main arguments will be used in Chapter 3 of this paper in designing an STSE oriented curriculum through writing.

Each argument for the purpose of science education calls for educators to think more broadly about what it means to be scientifically literate. Scientific literacy is not a new term, but is being increasingly used as a substitute term for the goals of science education (Hodson, 1998). The meaning is still unclear in literature, and there are different meanings for different researchers. Pella et al. (1966) describe scientific literacy as the basic concepts of science, the nature of science, ethics that control the scientist in his or her work, interrelationships of science and society, interrelationships of science and humanities, and the differences between science and technology (Hodson, 1998). Science for all Americans (from pp. 4 of the Am. Association for the advancement of science, 1989) defines a scientifically literate person as: “…one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; uses scientific knowledge and scientific ways of thinking for individual and social purposes” (Hodson, 1998). Another document, Benchmarks for Scientific Literacy (1993, from pp. 322), defines scientifically literate people as ones “who are literate in science…are able to use the habits of mind and knowledge of science, mathematics, and technology they have acquired to think about and make sense of many of the ideas, claims, and events that they encounter in everyday life” (Hodson, 1998). However, all of these definitions do not include a capacity and willingness to act in environmentally responsible and socially just
ways, which is a hallmark of STSE education. In 1996 the SCCC addressed this problem with its definition of scientific literacy: “a person who is scientifically capable is not only knowledgeable and skilled but is also able to draw together and apply her/his resources of knowledge and skill, creatively and with sensitivity, in response to an issue, problem or phenomenon” (Hodson, 1998, p. 5). This definition is far more oriented towards STSE education, and is the one that resonates with the goals of STSE education described further in this paper.

In order to obtain a cohesive picture of STSE education so that we may design good teaching strategies, we must first understand the nature of science. By definition, the concept of Nature of Science (NOS) is “the sum of the total of the ‘rules of the game’ leading to knowledge production and the evaluation of truth claims in the natural sciences” (McComas, 2000, p. 22). There are nine core NOS ideas outlined by McComas (2000) that are worth summarizing, as they help science educators develop engaging curriculum models:

1) Science demands and relies on empirical evidence. Data needs to be provided to justify all final conclusions—this is a hallmark of science, but not all evidence is gained through experiments. It also relies on basic observations.

2) Knowledge production in science includes many common features and shared habits of mind. This does not mean that there is a single step-by-step scientific method by which all science is done. A stepwise method, starting with the problem, hypothesis, then tests, conclusions and reports are useful research tools but not all scientists use any single method routinely.

3) Scientific knowledge is tentative but durable. Science cannot prove anything because the problem of induction makes “proof” impossible, but scientific conclusions are still valuable and long lasting because of the way that knowledge eventually comes to be accepted in science.
Induction and deduction are hallmarks of logic, but they are not perfect as there is no way to confirm accuracy.

4) Laws and theories are related but distinct kinds of scientific knowledge. Both are valuable products of the scientific endeavor. It is a misconception that laws are mature theories and which makes them more valuable.

5) Science is a highly creative endeavor. The scientific knowledge generation process is just as creative as in the arts. So often bright science students reject careers in science because they fail to see the creativity involved.

6) Science has a subjective element because of its status as a human activity—just because two scientists may see different things, does not make it less rigorous or useful.

7) There are historical, cultural and social influences on science. Research performed and research that is prohibited is determined by or discouraged by human forces like history, religion, culture, and social priorities. An example of this is the debate over stem cell research and therapeutics.

8) Science and technology impact each other, but they are not the same. There are two kinds of problems investigated by modern science. Technology comes about from a particular human need, but “pure” science aims at understanding the fundamental nature of reality: “knowledge for knowledge sake.” For example, the laser was a pure discovery that showed utility later.

9) Science and its methods cannot answer all questions, such as questions of morality, ethics, and faith. It is a common but false premise that science and religion are at war.

These nine core NOS notions are challenging to feature all at once in a science classroom. However, they help educators develop engaging curriculum models as they weave NOS lessons throughout the scientific content instead of just in an introduction. In Chapter 3, these NOS ideas
will be the central instructional purposes that in turn help educators teach to STSE education through writing.

In STSE education, it is important to first note the variation of the acronym in literature. In certain literature, the environment aspect of STSE education has been bunched with the science aspect, rendering STS education. These two acronyms are interchangeable. As mentioned in the introduction, STS education interprets science and technology to be socially embedded, as shown in Figure 1 below, taken from Alsop and Pedretti (2001):

![Figure 1: Alsop and Pedretti’s (2001) representation of STSE (or STS) education](image)

Figure 1 illustrates that STS education considers science in a larger social, cultural and political context to make decisions, such as decisions about genetically modified foods, but with the aim of promoting informed decision-making and action. STS education has been a major force in science curriculum development in the last 20 years (Solomon and Aikenhead, 1994). The goals of STS education have evolved to encompass scientific literacy, responsible citizenry, and informed decision making. (Kumar and Chubin, 2000). Solomon (1993) outlines the features of STS education to be the following:
1. Understanding environmental threats, including global ones;
2. Understanding economic and industrial aspects of technology;
3. Understanding the fallible nature of science;
4. Discussion of personal opinion and values, as well as democratic action and;
5. Understanding the multi-cultural dimensions of science and technology. (p. 18)

Though similar, Pedretti (1996) offers a more in-depth framework for the features of STS education as shown in Table 2.

Table 2: A summary of Pedretti’s (1996) framework for the features of STS education

<table>
<thead>
<tr>
<th>Feature of STS education</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainable development</td>
<td>The study and utilization of resources for human long-term needs in order to create an environment that gives and sustains life.</td>
</tr>
<tr>
<td>Decision-making</td>
<td>Understanding how decisions are made in the government at the federal, provincial and municipal levels, as well as within private and industrial sectors.</td>
</tr>
<tr>
<td>Ethics</td>
<td>Combining science and values education.</td>
</tr>
<tr>
<td>Personal and political</td>
<td>Having discussions about politics, economics and science. In addition to addressing whether science is good, addressing who benefits and who loses.</td>
</tr>
<tr>
<td>Action</td>
<td>Creating a sense of empowerment, which leads to personal and social change, and prepares students to function as responsible and effective citizens.</td>
</tr>
</tbody>
</table>

With a better understanding of what scientific literacy means, we can understand why it is a term useful for defining a goal cluster for STSE or STS education (Aikenhead, 2006). To recap, the SCCS defines a scientifically literate person as someone “who is scientifically capable, is not
only knowledgeable and skilled but is also able to draw together and apply her/his resources of knowledge and skill, creatively and with sensitivity, in response to an issue, problem or phenomenon” (Hodson, 1998, p. 5). Aikenhead (2006) uses Bybee’s (1985) research to define 3 general goals for STSE education:

1. Acquisition of knowledge, including concepts within and concepts about science and technology.
2. Development of learning skills involved in processes of scientific and technological inquiry.
3. Development of values and ideas. Dealing with the interactions among science, technology and society.

Aikenhead (2006) also defines another cluster of goals as outlined by Waks and Prakash (1985):

1. Cognitive competency. This includes standardized knowledge and skills needed for reading and speaking accurately about STS issues.
2. Rational or academic. Students obtain a grasp of the epistemology and sociology of science required for understanding the dynamics at play in STS issues.
3. Personal. Students understand their everyday lives better.
4. Social action. Students participate in responsible political action.

An STS curriculum embraces all of these goals but with differing emphasis. Ideally, an educator should incorporate all these goals in their science curriculum, but may give some higher priority than others. For example, in an environmental course or unit, social action may take higher priority due to its relevance to the issues discussed.

Now that some of the key ideas surrounding science education and scientific literacy have been explored, and terms including NOS and STSE education have been defined, I will
unpack the relevant literature on writing as a curricular structure. In doing so, this paper strives to describe how educators might meet the goals of STSE education through writing strategies, and what that looks like in practice. There is a great movement and advocacy for the value of writing-to-learn strategies regardless of the content area of the curriculum. The main conception emerging from literature in this field is that writing “enhances students’ conceptual knowledge, develops scientific literacy, and familiarizes students with the expectations, conventions, and reasoning skills required of scientific writing” (Hand & Prain, 2002, p. 752). There is extensive but inconclusive research literature to date on the effects of using different kinds of student writing-to-learn in science. Though there is advocacy for these strategies, the implementation of them poses many challenges for teachers, most of which have been underestimated in the literature. For student learning through writing to be effective, teachers need a clear sense of why they are implementing the writing strategy, as well as appropriate strategies to enhance student focus on the writing task, in order to accomplish the goals for this writing. The broader issue of how teachers might be supported in making significant changes to their understandings of writing to learn, in developing writing tasks for this learning, and in building a supportive learning environment for new practices, has been generally ignored (Hand & Prain, 2002). Educators acknowledge that writing and teaching are both challenging tasks, but how does recognizing these challenges inform our teaching? Fristrom (2007) likens writing to a business operation where both are reducible to their subparts. Like a business operation, we isolate the key features of writing, we divide up the work so we can assess student skills and use that to assess our coverage of the curriculum. But the goals of writing have evolved to include a mass production of texts in today’s world, from magazines to advertisements to social media to texting. Essentially, we have more of a demand to shape and mold the writing and communication skills of our students.
It is useful to employ components of complexity theory in order to understand and implement writing strategies. The challenges facing teachers emerge as a result of writing being viewed as a complicated task, as opposed to a complex curricular structure. As defined by Davis and Sumara (2006), a system that is complicated may be reducible to its parts, it may be based on a simple input and output model, it may be efficiency-seeking (i.e., the number of people graduating from a program), or may be hierarchical or mechanistic. A complex system, however, is non-compressible, it may follow feedback loops, and it is sufficiency rather than efficiency-oriented (i.e., the depth of learning in a program). Davis and Sumara (2006) posit: “Complexity thinking is not a hybrid. It is a new attitude toward studying particular sets of phenomena that is able to acknowledge the insights of other traditions without trapping itself in absolutes or universals” (pg. 4). Complexity theory, therefore, is not just interested in the agents that make up the system, but rather interactions among the agents and the structures.

In the case of writing, there may be a multitude of agents, which simultaneously act upon one another to enhance student learning, and as educators we must pay attention to as many of these agents as possible to maximize learning. Traditional forms of science writing, such as report writing, become reducible to its parts, which consist mainly of hard facts and technical terms. There is an input in the form of a question, there is a test of that question, and there is a result produced. This form of writing is highly efficient whereas non-traditional scientific forms of writing in science can be viewed as sufficiency seeking—that is, these forms are written to meet the needs of the scientific content and of the writing task itself (Hand & Prain, 2002). Lab reports and technical reports serve to report findings in order to improve a scientific phenomenon, and are highly hierarchical and mechanistic in nature. Complexity theory allows us to view writing as a nested structure; that is, a phenomenon that has complex unities, which comprise smaller
interacting components that, as a result of their interactions, give rise to new structural and behavioral possibilities that would not be possible by the subcomponents alone (Davis & Sumara, 2006). In this manner, writing becomes a complex task that enables the emergence of learning when it serves a different purpose rather than just reporting and seeking to improve existing phenomena, as in the case of a lab report. On the other hand, the diversified writing approach allows for writing to be a complex pedagogical tool as it calls for students to produce texts for different readerships.

So then how do we move away from thinking of writing as complicated, and start treating it like a complex pedagogical tool with great advantages? What are the specific unities that are nested and interact to give rise to effective learning? One of the many challenges that teachers face, as mentioned previously, is not having a clear sense of the rationale and demands of the writing tasks they set (Garaway, 1994). To address this issue, Hand and Prain (2002) devised a model, on the basis of past research on writing, which is useful as a conceptual overview to guide teachers in designing writing tasks. The model, as seen in Figure 2, displays the complex interconnectedness between five subcomponents of writing. “These are: writing purposes; writing types; audience or readership; topic structure including concept clusters; and method of text production, including how drafts are produced, both in terms of technologies used as well as variations between individual and composite authorship processes” (Hand & Prain, 2002, pg. 743).
Each subcomponent in the above model represents a variety of choices for teachers, and there are multiple ways or ‘combinations’ in which an educator may devise writing tasks. This model renders writing as a complex pedagogical tool, as teachers not only have to think about science content but also consider the interconnectedness of the components of the writing task in order to best represent content knowledge and maximize learning. Teachers must consider this interconnectedness in theory, as well as from a pragmatic pedagogical perspective (Hand & Prain, 2002). The final chapter of this paper will come full circle with appropriate pedagogical approaches for successful writing strategies, particularly those that teach to STSE education.
Chapter 3

Interview with a science teacher: Methodology and findings

The majority of this project consisted of conducting a literature search on STSE education, the goals of STSE education, general writing strategies, and those used in science. To supplement the literature, an exemplary science teacher was interviewed about STSE education and the writing that he implements in his classroom. The science teacher chosen was someone with whom I built professional rapport during my practice and volunteer teaching, and who has over 5 years of experience teaching science at the junior-intermediate level (grade 7-10). A series of open-ended questions were developed, each of which was framed by some of the issues surrounding STSE education. The interviewee was asked to illustrate his ideas by relating some examples from his own practices. The set of questions used is as follows:

1. What do you think are the main purposes of science as it is taught in school?
2. How do you typically design a unit in science?
3. What does that (STSE education) look like in your classroom?
5. How do you link your writing strategies with STSE education?
6. What sorts of opportunities has STSE education provided for designing your writing strategies? Give examples.
7. What are some of the challenges you have come across with designing your writing strategies to meet the goals of STSE education? Give examples.

I kept an audio transcript of the interview, which I later transcribed. In this paper, I offer a detailed analysis of the interview by comparing themes in the literature to themes in the interview. I used salient teacher quotations from the interview (see Appendix A for interview transcript) to illustrate and support the points being made.

In my pre-service year, I had the opportunity to practice teach at a senior middle school, where I taught two classes of Grade Seven core subjects including math, science, language arts,
and guidance. This was a great learning opportunity for me. Being an Intermediate/Senior teacher candidate, I was gaining valuable experience in the Intermediate grades. This is where I met my associate teacher—an exemplary science teacher, who I will be referring to as Simon to ensure confidentiality. During my practicum, Simon helped me provide differentiated instruction to my students and practice gradual release of responsibility by allowing them to direct their own learning after my lessons. I quickly developed a cordial, professional relationship with Simon, and he has since proven to be very supportive throughout my graduate and professional career. By interviewing Simon, I hoped to find out what STSE can look like in the science classroom. In other words, I wanted to know a teacher’s perspective on implementing an STSE-centered curriculum, specifically through writing.

I started out by asking Simon about his views on what science education is for. He described the purpose of school science to be intrinsic: “The purpose of school science is to learn a few foundations and put them to use, and see how they work in the real world.” Wellington (2001) uses three sets of arguments to form a framework for justifying science education funding and its curriculum development: intrinsic, citizenship, and utilitarian. Simon’s definition fits in more with the intrinsic argument as this definition alludes to science being used to help people understand some of the events and phenomena happening in the world. The foundations mentioned by Simon are the necessary building blocks for understanding the world better. Most of the rest of our conversation alluded to this intrinsic argument for science education.

Since Simon values the intrinsic argument to be the most relevant, it is natural that he uses a bottom-up approach to unit planning. He starts off with first planning his assessment and working his way up to the teaching strategies:
So we have to know what we want them to know, how we’ll assess that and help them understand that and then go back and give them the tools and the information of what they need to know to be successful ... We also tell them what the culminating task is so they always know where they are going. So they don’t just hang there unattached to a task or a goal.

Simon’s reference to the culminating task also makes me aware that he is planning his curriculum with the end goal in mind, which again makes his view of science education to be intrinsically important. He values science education to the extent of its relevance to the world, or in the case of the classroom, to the extent of the culminating task.

Though Simon advocates the intrinsic value of science education, his teaching strategies follow the sequence for STS teaching outlined by Aikenhead (2006):

So they build a hot air balloon and then they need to be able to use what they’ve built and what they understand and they offer a reflection – an explanation as to why the balloon worked, why it didn’t work, because that’s also useful.

In this example, students are likely beginning in the realm of society, moving towards examining a technology (hot air balloon) through science content, and moving back through the realm of technology (by offering an explanation to why the balloon worked or didn’t work) in order to answer the bigger societal question. An excellent follow up question to this would have been how much time is spent in each domain. Having taught with Simon, I have observed that he devotes about 70% of the lesson to the science content domain, which is consistent with Aikenhead’s (2006) 60-90% figure. The traditional science is not watered down in his teaching but rather embedded so that students learn content while linking it with their everyday world.

Although Simon regularly uses STS in his Grade 7 and 8 curriculum, I was surprised to find out he did not know what STSE stood for or meant, even after spelling out the acronym:
I know in the textbooks that we use there’s always 3 chapters and the last chapter is always on an environmental – how it affects humanity, how it affects the globe. That’s always the piece of the material according to the textbook anyway.

It seems as if the environmental piece is an afterthought in the science textbook used in Simon’s classroom. This hardly seems to give rise to or support issues-based teaching. However, Simon regularly uses issues-based teaching in his curriculum, though he may not know what STSE stands for per se:

You know before we have the kids deciding where the landfills would go you know they need to understand some basics about the environment. You know we go right to those political and those environmental issues right off the bat before they have any real appreciation or love of nature or anything.

In the above quotation he refutes issues-based teaching by saying that kids need basics before we jump to issues, but I found this idea was isolated from what followed this statement:

I think some of the resources that come, textbooks and that sort of thing, they sort of miss that in that it’s just not an issue. Something that they’re designed to focus on, but we can use them as resources and in the last few years we’ve taken more of an integrated approach to science and math and sort of overarching big ideas and the large questions that tie into these things. So it could be a historical type of question, change, you know how does change affect the quality of lives. So there’s a scientific piece to that, there’s a historical piece to that and the changes might be improvements in one area but they have their downsides in other areas. So you can look at from different disciplines the same question. The kids get a much more rounded understanding of issues and understanding of science and history and those kinds of things.

In the example of ‘change affecting the quality of lives’, students are given an overarching big idea to consider across various subjects. So Simon does indeed use issues-based teaching. Instead
of teaching content then infusing applications or societal aspects, he aims to reverse the process and allow for these overarching big ideas to permeate each lesson so that it is relevant to the students’ lives. The issue of change is definitely an STS issue that can be contextualized for instruction. In fact, this example and approach captures beautifully the dynamic interplay between science, technology and society. This STS based question gives rise to pedagogical questions such as ‘how do we generate and evaluate ideas about change?’, ‘how do we handle controversial topics about change?’, ‘how do we distinguish between fact and opinion on change?’, ‘how do we present various viewpoints on change?’, and so on. These kinds of questions make the topic and its content socially relevant and emotionally compelling for the students (Alsop & Pedretti, 2001). This approach makes the corresponding teaching strategies student-oriented as opposed to scientist-oriented. Students will likely examine scientific content through the lens of this overarching question, making it more relatable and interesting for them. In a traditional curriculum, the science content related to change would be isolated from the technological and social aspects, making it isolated from the technological and social worlds that the students live in. Simon may not recognize STS teaching, but he is definitely using it in his curriculum.

On a different note, it was really interesting to hear about Simon’s gifted class and their inclination towards choosing an environmental approach to issues:

They don’t all, some take a very business approach. But even when they do, there’s always a challenge from the environmental point of view. Or a heritage and cultural point of view. They’re always being challenging or challenging one another on those kinds of fronts. Because yes the balance sheet will add up but there are other issues so how do we think about that. And they’re very open to those issues and discussions. I found that they are open.
I was left curious about these gifted students who may or may not go on into secondary IB or AP programs. In their current gifted class they have a learning environment that is more supportive than general education courses, they are removed from the frustrating mixture of lack of challenge, they are surrounded by students who want to learn, and have the support of a teacher who understands the desire of challenge. These students are inquirers, communicators, and thinkers. They are thinking about social issues that are external to the scientific community without being prompted in that direction. My youngest sister was part of a gifted program until the end of middle school, but chose to go to a general high school program. Though she excels in her studies, she constantly complains about a lack of challenge and a lack of support from teachers. This may mean that a general education teacher may not accommodate gifted students appropriately and may benefit from professional development in areas of STS teaching, no matter the subject or grade.

When asked how he uses writing in his science classroom, Simon explained that he has shifted form writing to other strategies in his classroom, with varying end products:

*Even though there’s not writing, there is some planning and organizing, which is all part of writing, it’s just that final piece. I use the same kind of graphic organizer and things and those all have to be done. The product, we give them a little more choice about...but we have a lot of tools that we didn’t used to have...a lot of graphic tools. We’ve got mind maps now and Fishbone and we’ve got a lot of graphical things that we also make use of, that require the thinking, require the ordering, the prioritizing, and you know, choosing good sources and all that kind of stuff which are all writing related, it’s just that the product isn’t always writing. We sometimes have to slow down and go back and...empty the pencil sharpener and put it to use again."

There are several components of a writing task that Simon identified here. Mind maps and Fishbone as ‘graphical things’ fall under the subcomponent of *type* of writing task as outlined in Figure 2. Simon clearly identifies that these make use of the components that fall under *purpose* in Hand and Prain’s (2002) model, namely ordering, prioritizing, and choosing good sources. In
identifying these components, Simon verified that he uses writing strategies in his classroom, although he may not think of it as writing in the traditional sense (i.e. pen on paper). Even so, ‘pen’ is just one of many methods of text production outlined in Figure 2. As well, we see him mention point of view at several points during the interview as something he focuses on in his classroom:

*We work on point of view a lot in grade 7 and 8. We work on it in history and we work on it in language and when we’re reading... um... sources, reading information, doing research we have to look who’s writing this because they’re writing it for a purpose, what is their purpose, and understanding that sort of thing. So then we have to look at when we’re writing what is our purpose? What are we selling? What is the message we want to get across? And you’ve got the support and the sentence structures and there’s all that but there’s that whole point of view.*

In this quotation the interconnectedness between point of view as a type of writing, purpose as the overarching objective, and topic being applying concepts (i.e. what is the message), is evident. Point of view also falls under audience as the writing strategy aims to identify the audience it is written for. We see all of these components at play coming together to form a writing strategy that is used across Simon’s classrooms, be it history, science, or language arts. Support and sentence structure are mentioned, but not emphasized. In this manner, Simon has made clear that he is not solely concerned with the writing conventions, so much as he is with the five interconnected components interacting to create opportunity for writing to serve as a means for learning.

During the interview, I clarified what I meant by writing strategies by explaining that my questions were aiming to find out how he uses writing to learn in his classroom, as opposed to writing to communicate. By doing so, I wanted to find out whether Simon is using the model for
writing-to-learn as illustrated in Figure 2. I made reference to the landfill example that Simon gave, and explained that students were to come up with the best three sites for a landfill to be made, and they were to take action on this. They would be asked to write a letter to a municipal government to take action for this landfill. I then asked Simon how he would use a similar writing strategy to teach them about the process of taking action in a society that gives importance to where landfills are made. He responded by saying:

*I think part of that is the point of view thing. I think that's a piece of that. Recognizing that just because the developer says that these are going to be beautiful condos and that they are going to put a fence up and protect the stream, isn't enough...and so they see that the one point of view has been expressed, what are some other points of views that need to be expressed. And I think that would be the place...as opposed to sort of maybe having them take a side, just looking at what are all the sides. Not saying that they don't have an opinion, but I think the approach I take is through that point of view thing.*

The above quote is yet another example of Simon’s consideration for the various possibilities for representing scientific knowledge given the components of writing, namely the point of view. I also begin to see that he incorporates STS elements in his strategies, and see personal and political features of STS, as outlined in Table 2, when he mentions the developer in this example. There is a sense of who benefits and who loses, and the point of view writing piece would teach to these elements in this particular example. So, this further confirms that Simon uses STS elements in his teaching, specifically in his writing strategies, though he may not always be aware of it.

Interestingly, when asked what opportunities STS education provides for designing writing strategies, Simon said that the opportunities are limited:

*Well.. I think it might be a little bit limited... We have them do a piece, you know, where is separating used in industry, and where is combining things used in industry. So you*
can look at mining or you could look at metal or you could look at medicine. And we’ve done that kind of thing as a research community based kind of scientific science activity.

Though he claims that STS education provides limited opportunities for writing, we see that the STS elements themselves are present in his teaching when he mentions the community based scientific activity. The activity he mentions teaches the citizenship argument for why we need science education. There is mention of discussions surrounding a research community, and the ‘society’ element is interwoven in these discussions when talking about industry. It was important for me to bring the focus back to writing, however, to which Simon said:

*The business of writing newspaper articles...the kids don’t even read newspapers they don’t even see newspapers. They just don’t. Yeah that’s in the textbook but it’s not part of their world, and it’s not going to be part of their world. So, some of those sort of old writing things, you know, letter to the council... you’re more apt to make a presentation to the council. You’re not going to just write a letter, nobody writes a letter, you go... you show your face, your arguments, your supporters... and you do it that way. Writing a letter of protest... it’s going to go in the pile, maybe. Writing in the world today is rapidly changing, rapidly changing.*

Though the components of a writing task, namely *topic* (applying STS concepts), *purpose* (designing solution) and *audience* (the council) are mentioned, Simon is clear that he does not believe that writing articles is the best way to teach to STS because the avenues through which students are exposed to different methods of text production has rapidly changed. It is again evident that Simon views writing strategies to be limited to the traditional method of text production, which is pen and paper, and does not necessarily consider other *methods of text production*, as outlined in Figure 2, to constitute writing to learn strategies. Of the challenges,
Simon mentions that writing is becoming more of a specialty than an effective strategy for learning:

*I think one of the big ones is that the kids hate it. The way it’s been done... you’ve taken something that they kind of like and they are interested in and turned it into a nasty piece of work because they’ve got to write and write and write and... I think writing is becoming more of a specialty. I don’t think it’s something that everybody is going to be good at.*

Another challenge that Simon highlights is that non-traditional, or diversified, writing strategies are difficult to implement in a science classroom:

*...the script writing we would probably do that as a drama... not in science... I think we would probably do that as a drama. Because a) it’s more successful as an undertaking. Because the writing... some of it would be fine, some of it we would miss. How do you assess science based on writing if they are a poor writer? Their science understanding might be terrific, their writing might not be. And I guess that’s part of what I was saying earlier... the science curriculum... it sometimes gets overloaded by literacy and numeracy and these other things.*

There are two identifiable issues raised in this quotation. One issue is that non-traditional forms of writing, or a diversified approach to writing in science, are not the most successful undertaking. Simon mentions that the writing conventions (and students varying abilities in them) would hinder his ability to assess learning of the science. The other issue raised is the overloading of literacy and numeracy in the science curriculum.

*I think a lot of science teachers forget that teaching science is a science itself. The first step to implementing accommodations includes willingness on the teacher’s part. Science is a really heavy curriculum and so it becomes difficult to cover all the objectives and cater to the students’ learning needs. The teacher must be willing to put extra time into his/her lesson plans in*
order to include effective writing activities that will cover multiple objectives of the curriculum while engaging the students in the best possible learning environment. There must be rigor and methodology on the teacher’s part. The difficulty is that it requires extra time on the student and the teacher’s parts, as well as potentially extra financial resources if there are field trips, as mentioned by Simon. The systemic reason for all these difficulties is the objective-crammed science curriculum in Ontario. There is not enough attention paid to teaching-learning strategies such as issues-based teaching because teachers are afraid of not being able to cover the curriculum in time as well as not hitting key components such as literacy and numeracy. In order for these accommodations to be effective in enhancing the student’s learning experience, the curriculum documents need to be revised to provide a comprehensive course outline with a realistic timeline of completion. Ultimately, it is up to the teacher to direct the learning in ways that are effective for the students, and not in ways that simply cover as many curriculum objectives as possible.
Chapter 4

Designing an STSE-oriented curriculum through writing: Strategies for teaching

Before designing a curriculum through writing, I must first identify some key design elements of an STSE-oriented curriculum. Issues-based teaching and learning is best delivered when, instead of teaching content then infusing applications or societal aspects, the process is reversed (Alsop & Pedretti, 2001). “An STS issue utilized as a context for instruction offers the greatest potential for capturing the dynamic interplay of science, technology and society” (Alsop & Pedretti, 2001, p. 241). The main issue is building a block of curriculum where explorations become socially relevant and personally compelling for students. STS in the classroom gives rise to pedagogical questions and challenges. For example, how do we generate and evaluate ideas? Interpret arguments? Handle controversy? Present various viewpoints? Decide on course of action? Distinguish between opinion and fact? There seems to be a lack of STS resources, awareness, time, and in turn there is a need for assessment strategies and for integrating values and ethics into an STS curriculum (Alsop & Pedretti, 2001). “The fundamental weakness of valid science as it is usually taught is not what it says about the world, but what it leaves unsaid. The task of STS education is to fill that gap” (Alsop & Pedretti, 2001, p. 22)

Aikenhead (2006) focuses on the curricular features of STS teaching by alluding to the four aspects of a curriculum:

1) Function: what are the goals for teaching science through STS?
2) Content: what should be taught?
3) Structure: how should the science and STS content be integrated?
4) Sequence: how can we design STS instruction?

Since STS is student oriented as opposed to scientist oriented as per traditional science teaching, it must make logical sense to students as to how STS elements are interconnected. Figure 3 below shows this sense-making as being depicted by the solid arrows between student and the three different environments they come in contact with. The broken arrows superimpose a pedagogical structure that harmonizes with the solid arrows. In this manner, teaching emerges in a way that embeds science in the technological and social environments of the student. On the contrary, the science box at the top of the figure would be isolated from the technological and social realms of the student in a traditional science curriculum. In STS teaching, science is integrated with these two of the students’ worlds.

![Figure 3: Alsop & Pedretti’s (2001) depiction of the essence of STS education](image)

So how do educators determine content, and what types of social issues can be chosen?

According to Aikenhead (2006) there are two main types of social issues in STS science:

1) Social issues that are external to the scientific community. For example, energy conservation or pollution.

2) Social aspects of science itself. These may include issues internal to the scientific community. For example, the nature of scientific theories.
STS content in a curriculum is comprised of the interaction between science and technology, science and society, and any one of the combinations of a technological artifact, process, or expertise. The interactions between technology and society may include a societal issue related to science or technology (Aikenhead, 2006).

Aikenhead (2006) also illustrates a sequence to develop an STS-oriented curriculum. The arrow in Figure 4 below shows this sequence:

![Figure 4: A sequence for STS science teaching](image)

The arrow begins in the society realm, perhaps by posing a question. In order to understand the problem being posed, students need to examine a technology, which is represented by the black donut. This technology comes out of a response of human needs and societal problems. Both these realms require the need to know science content, which is depicted by the central circle. This sequence helps students understand the technology and the societal issue, as it moves through the domain of technology again. Revisiting this realm allows students to use the science they have learned in order to make more sense of it. At last, we end in the domain of society—addressing the original key question, then making a decision or taking action. This sequence is
useful for a lesson, a unit, or even in designing a textbook for science. How much time a teacher spends on the science domain is entirely their decision. Aikenhead (2006) proclaims that on average 60-90% of instruction is currently dedicated to the science domain, which leaves little room for STS-teaching in the true sense through this sequence. Nevertheless traditional science must not be watered down, but rather embedded in an STS curriculum. Students learn the content while constantly linking it with the worlds that they encounter every day.

Now that some key design elements of STS-oriented curriculum have been outlined, I will move on to planning a unit in science, focusing on using writing strategies. For this example, I have chosen the Ontario Grade 11 Genetic Continuity unit. (Ontario Ministry of Education, 2008). First a teacher must decide what students will learn and why by considering what she wants her students to learn and remember long after they leave her class. This is the enduring knowledge that will help a teacher decide which of the curriculum objectives she will target through her STS teaching.

For this unit, the following elements may be the enduring knowledge: genes, DNA, how traits are inherited, what the social implications are of genetics, and why it is applicable in our world. I have chosen the concepts of mitosis/meiosis, inheritance, and the practical applications of genetics as being the most important. There are at least 3 questions that are linked to these concepts, are related to the real world, are interesting and meaningful for students, and relate to my enduring knowledge (what I want my students to remember long after they leave my classroom). This enduring knowledge must drive my STS teaching. These questions are the following:

1. Why do we study genetics?
2. How are traits inherited?
3. What are the real-world applications of genetics?

In this example, the social issue chosen is external to the scientific community. That is, the social and ethical implications discussed in this unit will focus on the technologies related to genetic issues. Figure 5 will help me envision these three questions in order to answer my enduring knowledge. I have branched off the specific expectations (denoted by the letter D followed by a number) from the Ontario curriculum document that best answers each question:

![Figure 5: An exemplar to structure an STS unit](image)

Next, I have created a sequence of learning activities that will allow students to answer the three questions prepared above. The following table summarizes and describes these learning activities, with an indication of how long I think each activity might take. The three questions have been combined into two questions that better reflect elements of STSE teaching. An explanation of the sequencing follows the table below:
<table>
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<tr>
<th>Class</th>
<th>Activity</th>
<th>Time</th>
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<tbody>
<tr>
<td></td>
<td>(<a href="http://www.nlm.nih.gov/exhibition/harrypottersworld/pdf/wordmatch.pdf">http://www.nlm.nih.gov/exhibition/harrypottersworld/pdf/wordmatch.pdf</a>)  &lt;br&gt;● Match the labels to the diagram of a chromosome unravelling into a DNA strand.</td>
<td>15 min</td>
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<td>3</td>
<td>Mitosis with Playdough <a href="http://ecc.pima.edu/~mdamadzadeh/Lab%20East/Lab11.pdf">(http://ecc.pima.edu/~mdamadzadeh/Lab%20East/Lab11.pdf)</a>  &lt;br&gt;● Students work with a partner to model mitosis with Playdough and present their model to the teacher before the end of the period.</td>
<td>60 min</td>
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<td>4</td>
<td>Genetics independent activity <a href="http://serendip.brynmawr.edu/sci_edu/waldron/pdf/GeneticsProtocol.pdf">(http://serendip.brynmawr.edu/sci_edu/waldron/pdf/GeneticsProtocol.pdf)</a>  &lt;br&gt;● Students learn about genes and monohybrid crosses.</td>
<td>60 min</td>
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<td>5</td>
<td>Gizmo: Human Karyotyping <a href="http://www.explorelearning.com">(www.explorelearning.com)</a>  &lt;br&gt;● Sort and pair images of human chromosomes. Identify gender and diseases based on the karyotype.</td>
<td>60 min</td>
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<td>Activity</td>
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<td>6</td>
<td><strong>NOVA DNA Fingerprint Activity</strong>&lt;br&gt;(<a href="http://www.pbs.org/wgbh/nova/teachers/body/create-dna-fingerprint.html">http://www.pbs.org/wgbh/nova/teachers/body/create-dna-fingerprint.html</a>)&lt;br&gt;● Computer activity in which students create a DNA fingerprint and use it to solve a mystery</td>
<td>20 min</td>
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<td><strong>Gizmo: DNA Fingerprint Analysis</strong>&lt;br&gt;(<a href="http://www.explorelearning.com">www.explorelearning.com</a>)&lt;br&gt;● Computer simulation in which students create a DNA fingerprint of a frog, identify possible identical twins, and determine which sections of DNA code for which traits.</td>
<td>40 min</td>
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<td>7</td>
<td><strong>Meiosis with Playdough</strong>&lt;br&gt;(<a href="http://ecc.pima.edu/~mdamadzadeh/Lab%20East/Lab11.pdf">http://ecc.pima.edu/~mdamadzadeh/Lab%20East/Lab11.pdf</a>)&lt;br&gt;● Students work with a partner to model meiosis with Playdough</td>
<td>30 min</td>
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<td><strong>Harry Potter Activity</strong>&lt;br&gt;(<a href="http://www.nlm.nih.gov/exhibition/harrypottersworld/pdf/teachershaircolor.pdf">http://www.nlm.nih.gov/exhibition/harrypottersworld/pdf/teachershaircolor.pdf</a>)&lt;br&gt;● Online activity in which students look at the hair colour of characters from Harry Potter and use genetics to predict traits.</td>
<td>30 min</td>
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<td>8</td>
<td><strong>Reebop meiosis activity</strong>&lt;br&gt;(<a href="http://cbe.wisc.edu/assets/docs/pdf/reebops/reebops.pdf">http://cbe.wisc.edu/assets/docs/pdf/reebops/reebops.pdf</a>)&lt;br&gt;● Students use their knowledge of monohybrid crosses to design and build marshmallow creatures with specific phenotypes.</td>
<td>60 min</td>
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<td>9</td>
<td><strong>Monster Genetics Lab</strong>&lt;br&gt;(<a href="http://www.nlm.nih.gov/exhibition/harrypottersworld/pdf/monstergeneticslab.pdf">http://www.nlm.nih.gov/exhibition/harrypottersworld/pdf/monstergeneticslab.pdf</a>)&lt;br&gt;● An activity for practicing monohybrid crosses using the traits of monsters from Harry Potter.</td>
<td>60 min</td>
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<td>10</td>
<td><strong>Dragon Genetics Summative Activity</strong>&lt;br&gt;(<a href="http://serendip.brynmawr.edu/sci_edu/waldron/pdf/DragonGenetics1Protocol.pdf">http://serendip.brynmawr.edu/sci_edu/waldron/pdf/DragonGenetics1Protocol.pdf</a>)&lt;br&gt;● Students flip popsicle-stick “chromosomes” (1 from each parent per locus) to determine the genotypes of baby dragons. They then draw the resulting phenotype.</td>
<td>60 min</td>
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<td>Activity</td>
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<tr>
<td>11</td>
<td>Spongebob Dihybrid Cross Activity</td>
<td>60 min</td>
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<td>(<a href="http://sciencespot.net/Media/gen_spbobgenetics.pdf">http://sciencespot.net/Media/gen_spbobgenetics.pdf</a>)</td>
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<td>● Student independent activity, in which they will use dihybrid crosses to discover the genotypes of Spongebob characters.</td>
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<td>12</td>
<td>Oompa Loompa Activity</td>
<td>60 min</td>
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<td>● Students will use dihybrid crosses to predict the genotypes and phenotypes of Oompa Loompas.</td>
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<td>13</td>
<td>Using Blood Types to Identify Babies and Criminals</td>
<td>60 min</td>
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<td>(<a href="http://serendip.brynmawr.edu/sci_edu/waldron/pdf/BloodTypeGeneticsProtocol.pdf">http://serendip.brynmawr.edu/sci_edu/waldron/pdf/BloodTypeGeneticsProtocol.pdf</a>)</td>
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<td>● Students can work through it alone or in pairs. They learn about the genetics of blood types and use that information to solve mysteries about whether or not babies were switched and to identify a criminal.</td>
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<td>14</td>
<td>Blood Type Lab (<a href="http://resources.educ.queensu.ca/science">resources.educ.queensu.ca/science)</a></td>
<td>60 min</td>
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<td>● Use pre-ordered slides (no safety precautions) to determine blood types in an interactive, hands-on lab.</td>
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**Question:** What can we do with knowledge of genetics and what are the social and ethical implications?

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<tr>
<th>Class</th>
<th>Activity</th>
<th>Time</th>
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<tr>
<td>15</td>
<td>Research a genetic disorder and give a class presentation on it (students have this period to get started on research)</td>
<td>65 min</td>
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<td>● Students will prepare a 10-min PPT presentation after conducting research on the causes, symptoms, treatments, and prognosis of a genetic disorder of their choice.</td>
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<td>16</td>
<td>Watch the movie GATTACA (<a href="http://biology4teachers.com/DNA%20RNA/GATTACA_qs%5B1%5D.pdf">GATTACA DVD, 1997</a>) while independently completing the student analysis</td>
<td>70 min</td>
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<td>● The student analysis questions are to provoke thought into the ethics</td>
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of human genomics.

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<tr>
<td>17</td>
<td>Finish the movie GATTACA and analysis questions</td>
<td>70 min</td>
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<tr>
<td>18</td>
<td>Should We Create Babies by Design? (opinion activity)</td>
<td>30 min</td>
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<td>(<a href="http://www.pbs.org/teachers/connect/resources/5697/preview/">http://www.pbs.org/teachers/connect/resources/5697/preview/</a>)</td>
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<td>● Students will take a poll to evaluate their opinion on “designer babies”, learn more about the issue, and then re-evaluate their opinions.</td>
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<td>For the rest of the period, students can work on their genetic disorder assignment.</td>
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<td>19</td>
<td>Engineer a Crop: Transgenic Manipulation Activity</td>
<td>30 min</td>
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<td>(<a href="http://www.pbs.org/teachers/connect/resources/5699/preview/">http://www.pbs.org/teachers/connect/resources/5699/preview/</a>)</td>
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<td>● Interactive computer activity in which students engineer a virtual transgenic crop and see the results.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Should We Grow Genetically Modified Crops? (opinion activity)</td>
<td>30 min</td>
</tr>
<tr>
<td></td>
<td>(<a href="http://www.pbs.org/teachers/connect/resources/5702/preview/">http://www.pbs.org/teachers/connect/resources/5702/preview/</a>)</td>
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<tr>
<td></td>
<td>● Students are polled on their opinions on genetically modified crops. They learn about the issue, and then they are asked to re-evaluate their opinions.</td>
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</table>

Many of the above activities call for students to use manipulatives as well as form opinions on an issue related to a technology. Having outlined some activities for the unit that are STS-oriented, the teacher now has a clear sense of the rationale behind each activity. Once this rationale is set (i.e., which activity targets which curriculum expectation to answer which question of the enduring knowledge), teachers can now enable effective student learning through writing strategies that can teach to STSE education. We, as educators, can now begin to devise
writing strategies that interweave the five subcomponents of the writing model outlined in Figure 2, in order to represent the enduring knowledge that we want our students to take away from our STS-oriented curriculum. Some writing strategies that teachers can implement, that have been tested in theory and practice, are the following:

1) Sentence stems to prompt student thinking (Bereiter & Scardamalia, 1987). This may include an activity that describes observations of a lab investigation on genetic continuity using the sentence stems in a graphic organizer. Some examples of these sentence stems are “How does…”, “I notice…”, “According to the data…”, and “I see…”. A good time to use these sentence stems is during the Reebop activity, as outlined in Table 3, Class 8. Students use their knowledge of monohybrid crosses to design and build marshmallow creatures with specific phenotypes, and will use sentence stems as prompts to describe their observations.

2) Concept maps to represent initial and emerging understandings (Ambron, 1991). An excellent example of a student generated concept map for genetics is found on Adlina Pauji’s wikispace (Concept Map-Genetic Variation). This concept map conceptualizes the differences between genetic variation and environmental variation and may be used as an introductory activity or as an extension of the diagnostic quiz as shown in Table 3, Class 1.

3) Fragments of information given to students who are then required to integrate it into a fluent text (Wiley & Voss, 1996). Students may be given excerpts of information from multiple sources and will be asked to write a fluent text. This text will be written in the form of arguments that are for or against a genetic issue, instead of a narrative, summary or explanation. A good time to integrate this activity in the unit is at the end, as shown in
Table 3, Class 19. For example, students may be given fragments of information about genetically modified crops and asked to re-evaluate their opinions and present it in the form of a fluent text.

4) Text models to be applied by students to new content (Cameron et al., 1995). Analogies are another way to take a new and unfamiliar subject through a writing exercise. It may be prudent to ask students to design their own analogies to a text they read in a textbook or online. Such an activity can be done at various points in the unit. For example, students can take a text they read in their textbook about dihybrid crosses, come up with a good analogy which may help them understand the concept, and apply it at the end of the unit in the research activities. This text model may be in the form of a narrative, a summary, a report, or even a dialogue.

5) Student re-drafting of computer-based texts (Prain & Hand, 1996). Here is a good chance for students to take the NOVA or Gizmo DNA analysis, shown in Table 3, Class 6, to re-draft the text associated with the computer simulation. In doing so, students learn the concepts associated with the fingerprint analysis exercise, and can summarize and synthesize information learned about the foundations of fingerprint analysis into a cohesive text.

6) Incorporation of information from the Internet into student texts (Prain & Hand, 1996). A strategy that can be helpful here is to pose a problem and to ask students to describe in plain English what the information from the Internet says about the problem at hand. The goal here is for students to write a text that represents the student’s train of thought regarding the problem posed. A good time to incorporate this strategy in the genetics unit is Class 18 as shown in Table 3, which is an opinion activity about designer babies. The
problem is posed (“Should we design babies?”), and students incorporate information from the Internet into their own texts, in order to form a viewpoint on an STS issue.

7) Use of various student-generated diagrams, captions, and “textbook” explanations (Hand & Keys, 1999). A good writing strategy to apply here is to ask students to write a segment of a textbook in which they must teach the principles underlying genetic continuity. The principle at play here is simple: we find that we never really understand a subject until we teach it. This strategy is best implemented at the beginning of the unit, where it is crucial for students to gain a solid understanding of the foundations of genetic continuity. For example, students may do this activity before Class 3, as shown in Table 3, when they learn about the foundational concept of mitosis.

Students learn more from writing where there is frequent verbal and written interaction between student and teacher, they are able to participate in a collaborative learning community, there are detailed guidelines for writing, and opportunities to write for other audiences are given (Chinn & Hilger, 2000). This observation by Chinn and Hilger (2000) is in line with the five subcomponents in Figure 2—the model for devising writing-to-learn strategies. As such, not one single component is at play, but rather several, if not all, components simultaneously interact with each other in order to maximize learning.
Chapter 5

Conclusion

This study does not give any conclusive findings on which kinds of writing are more effective than others in maximizing learning in science. Rather, the purpose of this project was to analyze and describe how science teachers might meet the goals of STSE education through the use of writing strategies. The issues noted by Simon concerning assessment, scaffolding, and purposes of writing in science need to be addressed in a variety of ways through effective professional development. The main issue to note from the interview with Simon is that many science teachers are using STS elements within their science curriculum without the conscious awareness that they are doing so. Teachers must be made aware of the STS elements and what purposes they serve for science education, so that they may be able to better design an STS-centered curriculum through writing.

Complexity thinking is an effective framework to adopt when designing professional development opportunities for teachers for designing an STS-oriented curriculum through writing. Teachers must move away from thinking of writing as complicated, and start treating it like a complex pedagogical tool with great advantages. By not having a clear sense of the rationale and demands of the writing tasks they set, teachers, such as Simon, face many challenges and ultimately opt-out of using writing tasks in their science curriculum. Complex interconnectedness between the five subcomponents of a writing task is the key, namely writing purposes; writing types; audience or readership; topic structure including concept clusters; and method of text production, including how drafts are produced. Any more than one of these components interacting with each other give rise to greater opportunities for writing in an STS-
centered curriculum. Furthermore, the research and frameworks outlined in this paper suggest that there is a further need for a comparative analysis of the learning opportunities that different writing types create for science education. In all related research, there is a lack of understanding of the learning environments that teachers create, and further research is also needed on teachers’ perceptions and practices in areas such as scaffolding and teacher support for writing strategies in science. As an extension to this project, I would like to study the environment created by a science teacher for her students as she carries out the STS curriculum unit designed here. As well, I would like to study creative writing strategies (i.e. writing science fiction) and their role in provoking deeper conceptual understanding and increasing student motivation. The pedagogical techniques presented in this paper will interest many science teachers, but the question of how they will go about implementing them is another matter. There may be several barriers at play, some of which are simply due to the fact that changing how one teaches can be a difficult task, especially if one has been teaching for many years. Starting slow is the key, and reaching a final state in which you give writing assignments often is the final state you should strive to reach. Once these writing strategies become part of a teacher’s pedagogy, they may serve to be a useful addition to their ‘toolbox’ of teaching strategies.
Works Cited


Appendix

General Research Ethics Board (GREB) Clearance

March 19, 2014

Ms. Anam Fatima Shahid
Master’s Student
Faculty of Education
Queen’s University
Duncan McArthur Hall
311 Union Street West
Kingston, ON, K7L 3N6

GREB Ref #: GEDUC-722-14; Romeo # 6012149
Title: "GEDUC-722-14 The Use of Writing Strategies in Science, Technology, Society, and Environment (STSE) Education"

Dear Ms. Shahid:

The General Research Ethics Board (GREB), by means of a delegated board review, has cleared your proposal entitled "GEDUC-722-14 The Use of Writing Strategies in Science, Technology, Society, and Environment (STSE) Education" for ethical compliance with the Tri-Council Guidelines (TCPS) and Queen’s ethics policies. In accordance with the Tri-Council Guidelines (article D.1.6) and Senate Terms of Reference (article G), your project has been cleared for one year. At the end of each year, the GREB will ask if your project has been completed and if not, what changes have occurred or will occur in the next year.

You are reminded of your obligation to advise the GREB, with a copy to your unit REB, of any adverse event(s) that occur during this one-year period (access this form at https://services.queensu.ca/romeo_researcher/ and click Events - GREB Adverse Event Report). An adverse event includes, but is not limited to, a complaint, a change or unexpected event that alters the level of risk for the researcher or participants or situation that requires a substantial change in approach to a participant(s). You are also advised that all adverse events must be reported to the GREB within 48 hours.

You are also reminded that all changes that might affect human participants must be cleared by the GREB. For example, you must report changes to the level of risk, applicant characteristics, and implementation of new procedures. To make an amendment, access the application at https://services.queensu.ca/romeo_researcher/ and click Events - GREB Amendment to Approved Study Form. These changes will automatically be sent to the Ethics Coordinator, Gail Irving, at the Office of Research Services or Irving@queensu.ca for further review and clearance by the GREB or GREB Chair.

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

Yours sincerely,

Joan Stevenson, Ph.D.
Chair, General Research Ethics Board

C: Dr. Rebecca Luce-Kapler, Faculty Supervisor
   Dr. Benjamin Bolden, Chair, Unit REB
   Ms. Stacey Boulton, c/o Graduate Studies and Bureau of Research