Integrating Science, Technology, Society and Environment (STSE) into physics teacher education: Pre-service teachers’ perceptions and challenges

By

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Abstract

Although STSE has recently received attention in educational research, policy, and science curricula development, fewer strides have been made in moving theory into practice. There are many examples of STSE-based and issues-based teaching in science at the elementary and secondary levels, which can be found in the literature (Alsop, Bencze, & Pedretti, 2005; Hodson, 1993, 2000; Pedretti & Hodson, 1995), yet little has focused specifically on physics education. This doctoral thesis will examine pre-service physics teachers’ beliefs and perceptions, challenges and tensions which influence their adoption of STSE education in the context of a pre-service physics education course (Curriculum and Instruction in Physics Education at the B.Ed level). An interpretive case study design as described by Merriam (1988) has been employed for this research (Merriam, 1988; Novodvorsky, 2006). The specific phenomena this case study examined and explored were the pre-service physics teachers’ beliefs and perceptions, challenges and tensions influencing their adoption of physics curricula that explicitly emphasizes an STSE orientation to physics education. The pre-service physics teachers’ evolution of perceptions and attitudes show growth in the areas of curricula understanding and implementation issues, potential student concerns, and general fit of the subject within the context of a student’s learning journey. This study contributes to our
understanding of the challenges pre-service physics teachers face when considering teaching physics through an STSE lens, and provides some implications for both pre-service and in-service teacher education.
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This research has been inspired by and is dedicated to my own children and those who will journey through the ‘school system’. May your curiosity about the world continue, your questioning never be silenced, and ‘the big picture’ always part of your learning journey.

To the rest of my family and friends, this is what I have been working on for so long. I know you did not always understand – thank you for all of your kind words and encouragement over the past number of years. Finally, to my husband, my rock of Gibraltar, my biggest supporter who always knew if I needed a cup of tea or a gentle push towards my office …thank you.
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Chapter 1: The Introduction

This doctoral thesis describes the research conducted by a physics teacher working within a faculty of education in the province of Ontario. Its purpose is to examine the understandings and perceptions of pre-service physics teachers as they begin their teaching journey with a physics curriculum, which challenges them to teach physics through a Science, Technology, Society and Environment (STSE) lens. It portrays what these pre-service teachers come to understand about teaching physics, teaching physics through an STSE lens, and the possible challenges and tensions for the various stakeholders if physics content is taught using an STSE lens.

1.1 STSE and Physics Education: Setting the Context

Science educators in the province of Ontario have embarked upon a dynamic change within elementary and secondary school classrooms. In 2007-8, the Ministry of Education of Ontario revised and restructured the kindergarten to grade 12 science curricula. With this restructuring, Science, Technology, Society and Environment (STSE) expectations now have a more central and prominent position within the framework of the science curricula. This could imply that the ‘new’ curricula’s primary focus is for the teaching and learning of science to be situated in an STSE context with the secondary focus being the teaching and learning of content. This change in focus, from a traditional science orientation to an STSE-orientation, for the elementary panel was introduced in January 2008 for implementation in September 2008. For the secondary panel, the curriculum was introduced in late January 2009 and was to be implemented in September of the same year. These changes, inevitably, affect curriculum and instruction science courses in pre-service teacher education programs within the province, as these courses examine the conceptual framework of the curriculum and raise pedagogical concerns. Pre-service
candidates are being asked, with this curriculum, to possibly re-orientate themselves from their own secondary school experiences and university science experiences (which are typically content based) to teaching science curricula which have a very different focus. The new focus, in light of the changes that have occurred, is to provide students with STSE-orientated learning opportunities – placing content into a context, which students will understand. This change in focus of the curricula for the pre-service teachers may require that they re-examine what they have come to understand as teaching and learning in science.

1.2 Defining an STSE-based Curriculum

There are many definitions of STSE education in the literature (Aikenhead, 1994; Hodson, 1993; Pedretti, 2005; Ratcliffè, 1997; Rubba, 1991; Sadler, 2006; Solomon, 1994). Pedretti and Little (2008) describe STSE as an “umbrella term that explores the interplay between science and society” (p. 14), while Aikenhead describes teaching with an STSE-orientation as:

…teaching about natural phenomena in a manner that embeds science in the technological and societal environments of the student. . . . [Its] instruction aims to help students make sense out of their everyday experiences, and does so in ways that support students’ natural tendency to integrate their personal understandings of their social, technological, and natural environments. (p. 48)

Common to all definitions is a notion of teaching science to students in a way that promotes scientific literacy and citizenship. It seeks to equip students with the knowledge and skills to make informed and responsible choices and decisions about socio-scientific subject matter, engage in action, and recognize that science occurs within a social cultural context. Teaching with an STSE orientation often uses issues-based approaches (e.g., cloning, water management, or hybrid vehicles) as a way of engaging students (Pedretti, 2005; Sadler, 2006).

1 In the earlier literature, STSE was referred to as STS. The term STS was coined in the early 1970s. For consistency, I will generally use the term STSE.
When examining the three orientations to curriculum proposed by Miller (1990) (i.e., transformational, transmission, and transactional), STSE is seen to fall predominantly under the transformational orientation, which can be described as the interdependence between the curriculum and the student whereby personal and/or social change can occur. With STSE falling under a transformational orientation, it includes and suggests a commitment to change and power to act, or rather agency (Roth & Calabrese-Barton, 2004) – providing students with the skills and competence to make informed and responsible decisions and take action. With this in mind, how will the next generation of science teachers, specifically physics teachers and their physics teaching adapt to a transformational orientated physics curriculum rooted in STSE principles?

1.3 Purpose of research

STSE education has been cited in curriculum and policy documents, worldwide for at least forty years (Pedretti & Nazir, 2011). Yet, the literature is sparse when probing for examples where STSE is moving from its theoretical framework into practice at all grade levels, particularly in secondary physics education. Keeping with the notion stated above, whereby teaching with an STSE orientation often uses an issue-based approach (Pedretti, 2005; Sadler, 2006), there are many examples of issues-based teaching which can be found in the literature from kindergarten to grade 10 (Alsop, Bencze, & Pedretti, 2005; Hodson, 1993, 2000; Pedretti & Hodson, 1995). For example, issue-based teaching can include examining the role of genetically modified foods from a science, societal, and economic impact, the use of air-bags in vehicles, or the impact of hydro-electric dams on the environment versus societal need for energy to name a few.

The science courses (kindergarten to grade 10) have specific units from each of the major disciplines of science, namely biology, chemistry, physics and Earth and space science. Due to
this diversity in units, integrating ideas and concepts between and within units at grade-level allows science teachers to use issues-based lessons, as all units of science can be drawn-in and the complexity of science as it pertains to everyday life can be addressed when teaching. By implementing an issue-based approach, scaffolding of ideas can occur, allowing for a deeper level of student understanding and providing parallelism, i.e., providing the student with a context for the content. Fewer examples of STSE-orientated lessons using an issue-based approach can be located with respect to grades 11 and 12, especially in the area of physics education. Hence, as a science educator with a background in physics, my primary interest in STSE is in the context of the physics curricula a student experiences as they move through K-12 and, secondly, in physics education as it continues into undergraduate programs.

As science educators, several important questions about this ‘new’ curriculum should be asked. These include: With the focus now on STSE in both the elementary and secondary science curricula, how will this change the teaching of science, if at all? How will the next generation of physics teachers perceive the senior physics curricula now that STSE education has a more prominent place? Is this a small or large shift in thinking, in practice, or both, for pre-service physics teachers? What challenges will be noted? These questions are important, since the subject and discipline of physics, traditionally, has not been taught through an STSE-lens or by using an issues-based approach. In fact, the physics classroom has been seen as a traditional, Socratic learning environment using predominantly transmissive teaching strategies to inform students of various laws, theories, equations, and their hypothetical use (Knight, 2004). The revised science curricula reflects an orientation that is different conceptually and, possibly, pedagogically then that of the past. Certainly, the next generation of physics teachers must consider whether they need to pivot their point of view from their own past physics classroom
learning experiences to today’s physics classroom and curricula which places STSE in a more
prominent position than in years past.

1.4 Research questions

This dissertation explores the perceptions and challenges for pre-service physics teachers
as they consider curricula that explicitly emphasizes an STSE orientation and is potentially
transformational in nature. Four research questions emerge regarding pre-service physics
teachers:

1. What are the physics pre-service teachers’ understandings about physics education?
2. How do physics pre-service teachers understand STSE education in the context of
   physics curricula and in their physics curriculum and instruction course?
3. What do the physics pre-service teachers perceive to be the challenges and tensions of
teaching physics education through an STSE lens? And,
4. What are the implications for the future of physics education and STSE education?

1.5 Rationale: Personal and Professional Perspectives

As a science educator who has made a professional transition from teaching science at the
secondary school level to teaching within a Faculty of Education pre-service program, certain
issues have become apparent. From my observations, it seems the role of a pre-service education
program is to assist the candidate in the transition from ‘science student’ to ‘science teacher’.
This shift can be significant since the teaching environment of today is very different then that of
five to ten years ago when the pre-service teachers who are participating in the study were
secondary students. This shift includes changes in both the content of the courses (moving
content between grade levels) as well as the context in which the content is placed (as the world
changes our contexts change). By better understanding and giving voice to this possible shift of
perception, I feel that I can become a better pre-service physics teacher instructor, while helping pre-service teachers become physics educators.

The transition from ‘science student’ to ‘science teacher’ is not uncommon. For example, when I was a child “playing school”, for me the idea of ‘teaching’ meant to give knowledge, to share what I knew with my ‘students’. I would write notes on my blackboard and my ‘students’ would copy them and later write tests based on the notes. This is logical since it was what I saw my own teachers do. Some might refer to this repeating of my own school experience in ‘my classroom’ as explicit modeling (Lunenberg, 2007). This was a very transmissive approach (Miller, 1990). Later, as I developed a love for science, physics, and mathematics, my ideas changed – I found it easier to understand topics, concepts, laws, etc. when they were applied to the real world, very much a “dialogue between the student and the curriculum in which the student reconstructs knowledge through the dialogue process” (Miller, 1990, p. 6). Then, during the years I was a teaching assistant during graduate school within a physics department and while teaching in a secondary school classroom, especially in Northern Canada, I found there to be a connection between what I was teaching (the content) and my students’ sociocultural background. Such connections affected their understanding of the implication of what they were learning and how it affected or related to their personal environment and to the environment in general.

It seemed that, when secondary students saw how physics could be used to explain experiences ‘outside of the classroom,’ the content had greater relevancy and importance. This view of placing content into context to show relevancy extends into the school system and is a concept supported by Eisner, “an education process that is genuinely meaningful to students,
challenging them with problems and ideas that they find both interesting and intellectually demanding” (Eisner, 2004, p. 8).

The connection between content and context is significant. It is important to remind ourselves of Apple’s question, “Whose knowledge is of most worth?” (Apple, 1998, p. 339) and from that question to remember “students will be living in a world different from the one they now occupy, and schools should enable them to deal with that world” (Eisner, 2004, p. 6). Ultimately, it is the teacher who takes the purpose of the curriculum and crafts meaningful lessons infusing the curriculum’s content (which has been set by the provincial Education department) into a context that the students understand and value.

It is also important to understand the connection between subject matter expertise, i.e., the teacher’s ability to understand the content, and a teacher’s ability to convey that expertise to their students, one of the goals of any pre-service teacher education program. As Holt-Reynolds states, “Helping talented, sophisticated prospective teachers identify their expertise, value it, and imagine ways to share and model it with their students may be a challenge teacher educators had not anticipated when we set out to recruit more subject matter experts into teaching” (Holt-Reynolds, 1999, p. 45). Following this, “the surprise for teacher education is that we may need to work hard to help prospective teachers identify their expertise and transform it into effective instruction” (Holt-Reynolds, 1999, p. 45). Understanding the content, which is to be taught is the first step, being able to find reasonable teaching strategies and the context to engage students so as to learn the content is yet another skill onto itself. In my view, this is the challenge in a pre-service teacher education program, especially when the subject is physics and the curricula now clearly states the importance of STSE by it’s positioning within the document. By giving the pre-service physics teachers another opportunity to voice their perceptions of this possible
shift in focus on content, as pre-service teacher educators, we will be better able to assist future pre-service physics and science teachers.

1.6 Situating the study

This dissertation explores how pre-service physics teachers come to understand the integration of science, technology, society, and environment (STSE) education into the high school physics curricula. I outline and substantiate the core ideas and conceptual foundations for this area of study, specifically focusing on pre-service physics teachers’ perceptions about STSE education and discussing shifts in perceptions as the study proceeds. This study occurs at the intersection of four areas of research, namely, science education for scientific literacy, the nature of STSE education, physics education research, and pre-service teacher views and learning. The following diagram illustrates the four areas of research with the central rounded-square being the targeted research area for this dissertation, as further discussed in chapters 2 and 3.

![Figure 1.1: The four areas of research this dissertation employs.](image-url)
Limited research can be found in this targeted area of research (STSE and physics education) and little research has been conducted that focuses solely on pre-service physics teachers’ views and perceptions about teaching physics through an STSE approach. By better understanding the intersection of these realms, insight and awareness of issues in the preparation of pre-service physics and science teachers emerge. This, in turn, leads to recommendations in pre-service physics and science education and, eventually, secondary student engagement levels within the physics classroom or during physics units in intermediate science courses. Research literature offers little by way of understanding the perceptions, challenges, and tensions pre-service physics teachers hold regarding their possible adoption of an STSE orientation into their teaching and whether these views are any different from those of general science teachers. Finally, there is limited data on pre-service physics teachers’ attitudinal changes towards an STSE-orientated physics curricula. This study will assist in establishing a database for this important topic, and make a contribution to the research literature.

1.7 Overview of the thesis

This thesis consists of six chapters with appendices. In chapter two, the focus is on reviewing research literature in the area of scientific literacy and STSE education. The current understanding and meaning of scientific literacy is explored. The nature and development of STSE education is discussed and the role of the Nature of Science (NOS), as it is connected to STSE, is emphasized. From here, cornerstones of STSE are examined, namely the role of NOS, the history and philosophy of science, coupling science and values education, decision-making, and action and agency. When considering moving STSE from theory into practice, possible avenues are described, including futures studies and socio-scientific issues. Since STSE research
is ongoing, the notion of ‘STSE currents’ (a fluid and dynamic metaphor) rather than ‘STSE cornerstones’ will be explored with implications of this research.

Chapter three focuses on Physics Education Research (PER) and what connections can be made between PER and STSE and pre-service teacher learning. The chapter begins with a literature review of PER from both a physicist’s and education perspective. It then examines the lessons learnt from PER, and discusses physics and its connection to STSE. Following this, an examination of pre-service teacher learning and STSE is given, discussing challenges and opportunities.

From these foundational chapters, a detailed description of the case and a review of the literature supporting the methodologies employed in examining the case are described in chapter four. Each of the stages in the five-stage research program is explained, along with the various procedures used to both obtain data and then complete the analysis of the collected data and the ethical assumptions.

Chapter five provides an analysis and discussion of the first two research questions. It gives voice to the pre-service physics teachers who are the next generation of physics teachers to enter the teaching profession in Ontario. These pre-service teachers describe their understanding of physics education and the development of their ideas concerning STSE education as it pertains to the physics curriculum.

Chapter six continues the analysis of data in that it focuses on the third and fourth research questions. Here the challenges, tensions, and implications of STSE education as perceived by pre-service teachers are discussed. It is through the acknowledgements of these challenges and tensions that suggestions are generated. Possible next steps for the pre-service teachers to consider on their learning journey and the importance of discourse among pre-service
teachers concerning the use of an STSE lens to teach physics are also examined. Chapter six also provides conclusions and implications from this research. It attempts to provide those who instruct pre-service physics teachers and pre-service science teachers with ideas and considerations, which can be included in curriculum and instruction courses at the bachelor of education level. It discusses the implications of preparing pre-service physics teachers and pre-service science teachers to teach STSE-based physics curricula. It also discusses possible next steps with this research.

Ethical approval from the University of Toronto and the University where the research was conducted was sought and obtained prior to the research commencing. In the appendices, supporting documentation of the research can be found. These include the pre-service physics teachers’ consent forms, the pre-service teachers’ anonymous on-line initial survey, the individual interview questionnaire, the three rounds of focus group questionnaires, the anonymous on-line exit survey and the individual exit interview questionnaire. In addition to these documents, the course outline for the Curriculum and Instruction in Physics has been provided for the reader. Following the course outline, a breakdown of each lesson that took place during the course is given and to the orientation of the lesson is provided.

1.8 Summary

In this chapter, the foundation and reasoning has been set for the research represented by this dissertation. The context for the study has been set with definitions given and research questions posed. This chapter’s focus has been on ‘What is this dissertation about?’ and ‘Why would this research be important?’ to both a pre-service teacher educator and to the science education community at large. This study is important because it adds to our understanding of physics education and STSE education from the pre-service physics teachers’ perspective adding
to our understanding and the already existing literature. STSE is a complex, layered, and multi-dimensional in its appearance. It is also a more prominent focus of the Ontario science curriculum. Therefore, as educators, the more we can come to understand the physics pre-service teachers’ perceptions, challenges, and tensions concerning STSE, the better we will be able to infuse STSE into physics teaching and learning.
Chapter 2: A Review of Scientific Literacy and STSE Research Literature

Exploring pre-service physics teachers’ perceptions of teaching physics with an STSE emphasis and their responses to an STSE oriented physics curriculum requires a review of relevant literature. As discussed in chapter 1, the study for this dissertation occurs at the intersection of four areas of the literature: science education for scientific literacy, the nature of STSE education, physics education research and pre-service teacher views and learning. Science education for scientific literacy and the nature of STSE education are discussed in this chapter, while physics education research and pre-service teacher learning are discussed in chapter 3.

This chapter begins by examining science educational literature dealing with the meaning of scientific literacy and the implications of scientific literacy in the science classroom. From here, the nature and development of STSE is discussed. Within this chapter, it is suggested that a possible way to achieve scientific literacy may be through the use of STSE-orientated curricula. STSE-orientated curriculum is based on a number of ‘cornerstones’ (Pedretti & Little, 2008). These ‘cornerstones’ represent the components of STSE education and include the Nature of Science (NOS), History and Philosophy of Science (HPS), science and values, and decision-making, action and agency. The notion of ‘cornerstones’ has been used extensively in this dissertation’s data analysis. Therefore, these ‘cornerstones’ will be discussed in detail. It is important to note that research in the area of STSE education has continued to evolve from the notion of ‘cornerstones’. Because of this, a discussion of a new conceptual framework for STSE, namely ‘currents of STSE’ (Pedretti & Nazir, 2011), is given. The currents framework appeared in the literature well after data analysis for this research was completed; therefore, a ‘currents’ framework was not employed during the analysis stages. However, comments and connections
are made between these two frameworks in both this and the data analysis chapters to show similarities and congruencies with certain ideas.

2.1 Understanding the Meaning and Implication of Scientific Literacy

The origin of Science depends on a person’s culture and academic perspective. It has been argued that science has been around since we, as humans, began to question ourselves, our surroundings and our interactions with the environment (Aikenhead, 2006). Western science, the typical ‘science’ studied as a subject within our educational system, has been in existence for nearly 200 years (Aikenhead, 2006; DeBoer, 1991). However, science education has varying definitions. For example, Aikenhead defines it as “the systematic knowledge of nature” (Aikenhead, 2006, p. 7), whereas Bybee describes science education as, “[combining] the specific content and processes of science and technology with the general purposes of education” (1993, p. 89). Bybee makes the claim that:

Science educators have tended to pay more attention to science and less to education in their definition and justification of goals…. Science describes the type of education with which we are involved. Concentrating on education clarifies our larger purpose while maintaining the integrity of scientific and technologic content and method. (p. 89)

From these definitions, we can see that our understanding of science and what science education should be varies depending on our perspective —whether it is the diversity and content of the science we may study and teach, or how we, as teachers, reach our students on their learning journey (Bencze & Hodson, 1999; CMEC, 1997; Cobern, 2000; DeBoer, 1991; Donovan-White, 2006; Lederman & Lederman, 1998; 2004; Matthews, 1998; STAO, 2000). A review of the literature suggests that the goals of science education range from preparing today’s students to become future scientists, to rendering our students capable of responsible decision-making in terms of economic, social, and environmental concerns (Pedretti & Little, 2008), to socio-political action and activism (Roth & Calabrese-Barton, 2004).
Over the past 50 years, science education researchers, in examining the purpose of science education, have adopted the term *scientific literacy* (Roth & Calabrese-Barton, 2004). Although widely used, scientific literacy has no one specific agreed upon definition. In reviewing the evolution of this term, in the late 1950s and 60s, it was used to “call attention to the need to specify science curriculum appropriate for students not planning to pursue further science studies” (Roberts, 2007, p. 735). This meant that scientific literacy, from its very beginning, has “signified a curriculum orientation intended to be different from pre-professional preparation for scientifically orientated careers” (p. 735). In 1966, Pell, O’Hearn and Gale defined the scientifically literate person as:

[an] individual [who] presently is characterized as one with an understanding of the basic concepts in science, nature of science, ethics that control the scientist in his [sic] work, interrelationships of science and society, interrelationships of science and the humanities, [and] differences between science and technology. (cited in Roberts, 2007, p. 737)

Possibly a more interesting way to describe and bring meaning to the term “scientific literacy” is to follow Roberts’ suggestion. He offers two ‘visions’, which are much broader than any single definition and which seem to be useful in categorizing and comparing the literature written on and about scientific literacy. The first vision, *Vision I*, is described as:

[It] gives meaning to scientific literacy by looking inward at the canon of orthodox natural science, that is, the products and processes of science itself. At the extreme, this approach envisions literacy (or, perhaps, thorough knowledgeability) within science. (Roberts, 2007, p. 730)

An example of this type of vision for scientific literacy can be found in *Benchmarks for Science Literacy, AAAS 1993*. The second vision, *Vision II*, is said to:

…derive its meaning from the character of situations with a scientific component, situations that students are likely to encounter as citizens. At the extreme, this vision can be called literacy (again, read thorough knowledgeability) about science-related situations in which considerations other than science have an important place at the table. (Roberts, 2007, p. 730)
This second vision of scientific literacy is not new in that, as Roberts (2007) describes, Layton, Davey, and Jenkins (1986) “introduced and exemplified the concept of ‘science for specific social purposes’” and, later, these authors, along with McGill, suggested that “often the science taught in schools does not mesh, or articulate, with the science needed to come to grips with science-related situations” (as cited in Roberts, 2007, p. 730). This Vision II is embodied in *Rethinking Scientific Literacy*, by Roth and Calabrese-Barton (2004). Within this text, the authors state:

We need to treat scientific literacy as a recognizable and analyzable feature that emerges from the (improvised) choreography of human interaction, which is always a collectively achieved, indeterminate process. (Roth & Calabrese-Barton, 2004, p. 3)

Scientific literacy, as defined by Pedretti and Little (2008), is also in keeping with *Vision II* as:

[It is] acquiring and developing conceptual and theoretical knowledge, developing expertise in scientific inquiry and problem solving, and developing an understanding of the complex interactions among science, technology, society, and the environment. (p. 10)

In reviewing the literature, it is clear that the goals embedded within the calls for scientific literacy can be diverse and often competing. For example, from the Canadian context, the Council of Ministers of Education (CMEC, 1997) described scientific literacy as:

1. encouraging students at all grade levels to develop a critical sense of wonder and curiosity about scientific and technological endeavours;
2. enabling students to use science and technology to acquire new knowledge and solve problems so that they may improve the quality of their own lives and the lives of others;
3. preparing students to critically address science-related societal, economic, ethical, and environmental events and issues; and
4. providing students with a foundation in science that creates opportunities for them to pursue progressively higher levels of study, science-related occupations or science-related hobbies. (p. 5)
Here, both views are present – the first three points seem to fall under Vision II and the fourth under Vision I. Perhaps, a broader definition of scientific literacy – one that incorporates and blends both ‘knowledgeabilities’ within science and about science-related situations might be more feasible and functional.

Adopting a broad definition of scientific literacy would imply science being accessible and meaningful for all students (Hodson, 1998). Traditionally, as Aikenhead alleges, “school science attempts to socialize students into a scientific way of thinking and believing . . . students who do not see themselves as future scientists and engineers are screened out” (Aikenhead, 2005, p. 384). This is highly problematic if we, as educators, accept the notion that all students should have the opportunity to be scientifically literate. A broader definition of scientific literacy which would encompass both visions would suggest that we can meet the diverse goals of science education, that is, training for future scientists, while developing responsible, “savvy” citizens capable of effective decision-making and action.

In an attempt to understand how scientific literacy fits into science education, Hodson (2000) offers a useful framework for thinking about scientific literacy. He describes scientific literacy as encompassing learning science, learning about science, and learning to do science. He defines learning science as “acquiring and developing conceptual and theoretical knowledge” (Hodson, 2000, p. 136). He writes:

If conceptual development and refinement is assisted by encouraging students to explore, elaborate, and test their existing ideas against experience . . . then laboratory work . . . has an important role to play, but only when such activities are theory-led and well understood by the learner. (p. 138)

One could compare this to Vision I. Learning about science means “developing an understanding of the nature and methods of science, and an awareness of the complex
interactions among science, technology, society, and environment” (Hodson, 2000, p. 136). The goals for learning about science are:

   [for] students to learn much more about the phenomena under investigation and concepts that can be used in accounting for them because they have more time and opportunity to manipulate those concepts, . . . acquire some of the thinking and strategic planning skills of the creative scientist, …and to learn that science is about people thinking, guessing, and trying things that sometimes work and sometimes fail. (Hodson, 2000, p. 139–140)

Again, this is similar to Roberts’ Vision I. Hodson suggests science can be de-mystified and can provide accessibility to all through such experiences. Finally, doing science is “engaging in and developing expertise in scientific inquiry and problem solving” (Hodson, 2000, p. 136). Doing science promotes three types of learning:

   Enhanced conceptual understanding of whatever is being studied or investigated; enhanced procedural knowledge concerning the relationships among observation, experiment, and theory; [and] enhanced investigative expertise. (Hodson, 2000, p. 141)

This would be similar to Roberts’ Vision II of scientific literacy.

From the positions presented from the literature on the understanding of the meaning and purpose of scientific literacy, it is clear that the goals are broad, diverse, challenging, and interconnected. How can teachers address scientific literacy in their science classrooms and make learning meaningful for their students, i.e. how does one move from theory into practice? What might a science curriculum, which addresses the larger goals of scientific literacy, look like? One possible way to achieve the broader goals of scientific literacy is through the lens of Science, Technology, Society and Environment (STSE) education (Aikenhead, 2005; Pedretti, 2005). STSE provides a lens through which students can learn science, engage in the practice of science, and learn about the situation of its practice. In the following sections, I discuss how and why STSE can address the larger goals of scientific literacy, and the features/characteristics of STSE education.
2.2. The Nature and Development of STSE Education: A Brief Overview

Today, science education aims to create scientifically literate citizens (Aikenhead, 2005) in a world, which is increasingly affected and shaped by our understanding and use of science and technology. As a traditional school subject, the vision of science education was as an objective, linear, and context-free subject (DeBoer, 1991). This view remained steadfast in both the public eye and within the school context for many years, and it was not until World War II (DeBoer, 1991) when the vision of a ‘different’ science curriculum was considered (Aikenhead, 2005). It should be noted that this view of the complexity of the study of science and its connection to society goes by many names, as Ziman suggests,

…plain or fancy: Social Studies in Science; Science of Science; Science and Society; Social Responsibility in Science; Science Theory; Science Policy Studies; Science in a Social Context; Liberal Studies in Science; Social Relations of Science and Technology; History/Philosophy/Sociology of Science/Technology/Knowledge; etc. Lets us call it … STS[E]. (Ziman, 1980, p. 1)

There is an entire spectrum of reasons, which gave rise to what is now known as STSE education. The motivation for moving towards an STSE approach to science is eloquently summarized by Aikenhead (2005). He states traditional science teaching has:

…three major evidence-based failures…[They are]: crises in student enrolment, myths conveyed to students, and a ubiquitous failure of school science content to have meaning for most students, especially outside of school. (Aikenhead, 2005, p. 385)

With research and development of STSE over the past 50 years, the depth of understanding and complexity of STSE and its associated intricacies has evolved. Describing these intricacies has become essential to the understanding and, in some cases, the acceptance of STSE. Many have attempted to capture the layers of complexity of STSE in various schematics. Three are described here to illustrate the progression of our understanding of STSE. Aikenhead (1994) suggested a pyramid where science, technology and society were located at the vertices
(at this point in history the environment was not a discrete component as it is in more recent models or schemata), the student was at the centroid (centre), then between the student and each of the vertices was the environment, which would encompass each. Between each of the terms, a double-sided arrow indicated that movement was not uni-directional.

Figure 2.1 Aikenhead’s diagram describing the interplay between Science, Technology and Society (Aikenhead, 1994, p. 48).

Later, in 1996, Pedretti, after completing a case study with practicing teachers, developed another schematic to visually describe the model for STSE education. In this model, the terms ‘Science,’ ‘Technology,’ ‘Society’ and ‘Environment’ flow and feed into the centre, the ‘issue’ in question. She describes an issue-based approach as suggested by the Action Research Group, which participated in the research as:

…science knowledge demands (“learning science”) be located within a social context (“learning about science”): for example, food production, waste management, energy, and so on. The required science content could be fed in through the curriculum through social issues, problems or contextual settings, leading ultimately to action. Thus, issues would be used as organizers for science curriculum and instruction where appropriate.
Instead of the usual way of teaching science – teach the content then infuse applications or societal aspects this group suggested that the process be reversed. (Pedretti, 1996, p. 436)

This point of view is in keeping with Ramsey, 1994, whereby an STS issue (as described above) “utilized as a context for instruction, offers the greatest potential for capturing the dynamic interplay of science, technology and society” (p. 241).

After the gathering of facts and completing the analysis of the issue, the student can move on and upward to the ‘decision making’ process and up to ‘action.’ In this description, by Pedretti, an issue-based approach is central to STSE education.

Figure 2.2 Pedretti’s diagram conceptualizing an issue-based approach for STSE education (Pedretti, 1996 as cited in Pedretti & Little 2008, p. 73).
Another visual representation of STSE education by Bencze (2008) is a Venn diagram whereby the ‘fields of science’ and the ‘fields of technology’ are expanded to give more detail indicating the contents of each of these fields. These two fields are then encapsulated by the term ‘societies.’ The ‘societies’ are further encapsulated by ‘environments,’ since the societies exist within environments and the environments help shape each society. The term ‘wise activism’ is placed at the bottom of the diagram as a means to convey the idea that further understanding of the interrelationships will allow for activism on the part of the participant.

Figure 2.3 Bencze’s model of STSE education take from: http://webspace.oise.utoronto.ca/~benczela/STSEEd.html (Bencze, 2008)

There is no one schematic which is more correct than another; rather, they all attempt to convey the complexities and development of STSE education and, depending on the reader and context, one schematic may resonate more than others. Regardless of the schematic, common to each of
these various visual representations of STSE education is the commitment to better understand
and describe that understanding of the interplay between science, technology, society and the
environment. It is clear from the schematics that, as science educators continue to research and
question how the components of STSE inter-relate and address the development of scientific
literacy of students, our understanding of STSE will mature, becoming more complex. For
example, in a recently published paper by Pedretti and Nazir (2011) a new analogy for
conceptualizing STSE was described – that of ‘currents.’ This concept takes the notion of static,
inner-connected components of STSE education and re-conceptualizes them as fluid and
dynamic.

There have been many attempts at defining STSE education in the literature (Aikenhead,
1994; Hodson, 1993; Pedretti, 2005; Ratcliffe, 1997; Rubba, 1991; Sadler, 2006; Solomon, 1994;
Verma, 2008). Common to all recent definitions is a notion of teaching science to students in a
way that promotes a broader view of scientific literacy and citizenship. STSE seeks to equip
students with the knowledge and skills to make informed and responsible choices and decisions
about socio-scientific subject matter so that students are able to successfully and responsibly
engage in action, and recognize that science occurs within a social cultural context. Aikenhead
(1994) describes STSE as:

Teaching about natural phenomena in a manner that embeds science in the technological
and societal environments of the student…. [Its] instruction aims to help students make
sense out of their everyday experiences, and does so in ways that support students’
natural tendency to integrate their personal understandings of their social, technological,
and natural environments. (p. 48)

By way of contrast, Pedretti and Little (2008) describe, define, and summarize STSE as an
“umbrella term that explores the interplay between science and society” (p. 14).
STSE education can thus be described as being rooted in a “context-based” approach to science teaching, whereby a rich social-cultural context is used to kindle students’ interest in exploring scientific ideas. Aikenhead’s (1994) definition of STSE, discussed earlier, is widely accepted. From the outset, science environmentalists and sociologists who focused on integrating “values” and “social responsibility” with science education supported STSE education. Over time, STSE has evolved, as Aikenhead (2005) explained:

A conceptual framework for STS was achieved through the integration of two broad academic fields. The two fields could be described as the relationships between science, scientists, social issues external to the scientific community and, secondly, those internal to the scientific community. These relationships would examine the communal, epistemic, and ontological values. (p. 384)

Note that early thinking and writing described STS – which later evolved into STSE as was mentioned in Chapter 1. Also, earlier in this section, Ziman gave alternative titles for STSE. Other methods of conceptualizing science education include ‘future studies’ (Lloyd & Wallace, 2004) and ‘socio-scientific issues’ (Sadler, 2006). These share some similarities to STSE, but are often not considered synonyms with STSE.

In a “futures studies” (Bell, 1996; Lloyd & Wallace, 2004; Pedretti, 2005) approach, students propose various scenarios that may occur in the real world. They are then encouraged to examine how these scenarios would be caused and their possible outcomes or effects. This results in the student having a greater understanding and awareness of the situation, and a plan for possible action (Pedretti & Little, 2008).

Another method used to conceptualize school science is through examining socio-scientific issues (SSI). These can be defined as “controversial issues, which bridge science and society” (Sadler, 2006, p. 353). Some researches argue that what distinguishes SSI from STSE is “the SSI movement’s explicit attention to the ethical aspects of social issues with conceptual,
methodological, and/or technological ties to science” (Sadler, 2006, p. 354). As well as requiring scientific understanding, SSI, then, is values-based. This combination requires students and teachers alike to move beyond the comfort of traditional, knowledge-based, transmissive science and into a realm that may involve ethics, values, and political actions to bring about social change (Hodson, 2006; Ratcliffe, 1997; Roth, 2004; Sadler, 2006).

STSE, futures studies, and SSI all overlap considerably in meaning and can aid in students’ understanding and development of science concepts and connection to real world issues and events (Bennett, Lubben, & Hogarth, 2007). STSE goes by many names as previously discussed (Ziman, 1980). What is important to realize, as stated by Ziman, is that regardless of the title given to this vision of teaching and learning about science, the end is often the same. We strive to find ways to increase a student’s level of scientific literacy so that they may be better prepared citizens, having a deeper understanding and appreciation of the intricacies of the world in which they are a member and contributor.

2.3 The cornerstones of STSE

To understand the scope of STSE education, it is critical to examine the ‘cornerstones’ of its foundation as laid out by Alsop & Pedretti, 2001, “Generally speaking, STS[E] is a multi-disciplinary subject that includes moral, ethical, political, philosophical, historical and economic perspectives” (p. 196). The framework for STS[E], which included five guiding principles, dates back to Pedretti, 1996. At this time the principles included sustainable development, decision – making, ethics, personal and political, and action (Pedretti, 1996).

These cornerstones are analogous to the pieces, which make up a puzzle; the puzzle being science education viewed through an STSE lens. The cornerstones, which will be discussed, include the role of the Nature of Science (NOS), the History and Philosophy of Science (HPS),
coupling science and values, and decision-making, action and agency. Each of these cornerstones plays an important role or part, in teaching science through an STSE lens. Also, these were the cornerstones, which were discussed and used during the data analysis for this dissertation as the “currents paper” by Pedretti and Nazir (2011) had not yet been published.

2.3.1 The Role of NOS

STSE education seeks to develop an understanding of the Nature of Science (NOS). NOS has frequently been described in the literature and can be summarized by the following two descriptions. First, it has been described as the epistemology of science. It is a way of knowing that typically refers to “the values and assumptions inherent to scientific knowledge and the development of scientific knowledge” (Lederman & Lederman, 2004, p. 36). Secondly, it has been described as:

An understanding of how scientific knowledge is generated and validated, an appreciation of what scientists do, and how the scientific enterprise operates. NOS essentially lies at the intersection of science, technology, sociology, history, philosophy, economics, and ethics. (Pedretti & Little, 2008, p. 5)

Others have shared this view (Donovan-White, 2006; Lederman & Abd-El-Khalick, 1998).

Broken down, and for the purposes of this dissertation, NOS can be considered a list of ideas about science as a field of research and science learning that both science educators and scientists share. This ‘list’ may not be completely obvious (nor necessarily agreed upon) but it can help explain and give context to the practice of science, science curricula, lessons and classroom dynamics. Although there has been great progress by researchers to characterize science and science learning, there is still no complete definition of NOS that accurately portrays and applies to all sciences at all historical and present stages (Aikenhead, 2006). This is understandable, as a single definition would not capture the minutiae of such a complex and
evolving area of study. Yet, the question, ‘How can we, as teachers, include the nature of science in our classroom teaching?’ needs to be addressed.

We first must understand the components of NOS as science teachers, then determine if there is a strong enough connection and correlation between the components of NOS, the framework of STSE, and the desire to have students achieve scientific literacy. Ideally, as teachers, we want our students to incorporate the ideas of NOS into their own science learning so they will have a deeper understanding of the institution and practice of science, and recognize that science, as a human endeavor, is deeply embedded in a social cultural context. That is, as NOS ideas are woven into science teaching and learning, students will have the opportunity to see that science, as a field of study, is not purely objective, as some educators and scientists would argue. Science is open to interpretation and is subjective, since it relies on human interpretation of both the ‘facts’ and weighting of facts.

The most common components of NOS have been compiled by McComas, Clough and Almazroa (1998), after comparing eight international science standards documents. They are:

1. Scientific knowledge, while durable, has a tentative character.

2. Scientific knowledge relies heavily, not entirely, on observation, experimental evidence, rational arguments, and skepticism.

3. There is no one way to do science (therefore, there is no universal step-by-step scientific method).

4. Science is an attempt to explain natural phenomena.

5. Laws and theories serve different roles in science; therefore, students should note that theories do not become laws, even with additional evidence.

6. People from all cultures contribute to science.

7. New knowledge must be reported clearly and openly.
8. Scientists require accurate record keeping, peer review and replicability. Observations are theory-laden.

9. Scientists are creative.

10. The history of science reveals both an evolutionary and revolutionary character.

11. Science is part of social and cultural traditions.

12. Science and technology impact each other.

13. Scientific ideas are affected by their social and historical milieu. (McComas, Clough, and Almazroa, 1998, p. 6-7)

As can be seen from this list, the common points included in NOS align well with the previous definitions, aims and themes of STSE, and those of scientific literacy. For example, one can see that scientific knowledge can change and, therefore, is not an absolute truth. Secondly, observation and human inference play key roles in the development of scientific knowledge. Thirdly, scientific knowledge is culturally and contextually dependent.

The ideas presented in the major tenets of NOS should assist science teachers in that, when teaching about science and scientific ideas, teachers can help students become aware that science and scientific knowledge has been developed by people to address their needs and wants. Secondly, an aspect of science that is often forgotten is the history of science and scientific developments (which will be further explored below). This is also an important aspect of science to include in science teaching, since it is important to acknowledge that developments in science have, in many cases, come at great costs, i.e., financially, physically, environmentally, economically, etc. Regardless of the label for the inclusion of the epistemology of science in a science curriculum, STSE provides a channel to address these aspects of scientific literacy.

From these definitions, NOS could be achieved through a curriculum that is oriented towards or focuses on science, technology, society, and contemporary or historical
environmental issues. Such a curriculum would include elements from history, philosophy, economics, and ethics as they pertain to science and scientific development, thereby giving students a broader understanding of science and the practice of science.

2.3.2 The History and Philosophy of Science

The inclusion of the history and philosophy of science (HPS) can be considered an important part of STSE education and aid in increasing scientific literacy and interest of science among science students. There is much to learn from studying the history and philosophy of science. As Matthews (1994) suggests, HPS does not supply all the answers to the issues in science education at the moment; however, it has a contribution to make to the overall improvement of science learning and teaching. These improvements may include:

1. HPS can humanize the sciences and connect them to personal, ethical, cultural and political concerns.

2. HPS, particularly basic logical and analytical exercise, can make the classroom more challenging, and enhance reasoning and critical thinking skills.

3. HPS can contribute to the fuller understanding of scientific subject matter – it can help to overcome the ‘sea of meaningless,’ as Novak (cited in Matthews, 1994) suggested.

4. HPS can improve teacher education by assisting teachers to develop a richer and more authentic understanding of science and its place in the intellectual and social scheme of things.

5. HPS can assist teachers appreciate the learning difficulties of students, because it alerts them to the historic difficulties of scientific development and conceptual change.

6. HPS can contribute to the clearer appraisal of many contemporary educational debates that engage science teachers and curriculum planners. (Use a more critical eye for fashionable ideas). (Matthews, 1994, p. 7)

As can be seen from this list, many of the improvements suggested by Matthews mirror and support NOS ideas and would aid in the teaching of an STSE-orientated science curriculum.
It seems that it is no longer enough to ask “what we know about science but how we know what we know” (Matthews, 1994, p. 5). The integration of HPS has been called for and advocated for by a number of educational and governmental bodies, including the American Association for the Advancement of Science, the British National Curriculum Council, the Science Council of Canada, the Danish Science and Technology Curriculum and the Netherlands PLON curriculum (Matthews, 1994, p. 5). Matthews is not the only scholar who is pro-HPS. Nearly 15 years before, Ziman (1980) wrote:

The STS[E] movement favors an historical approach for the same reason – to demonstrate science as the epitome of the spirit of change. The extraordinary self-transforming character of science is unique amongst social institutions, and diffuses outwards until it flavors all branches of material life and culture. (p. 119)

Further, Ziman discusses and describes his view of those who oppose the idea of including elements of history and philosophy of science into science education. Here he states:

The only opponents in principle are tough-minded technocratic realists, who take as revealed truth all that they are at present teaching, or have personally discovered, or widely imagined for the future, and who simply have no conception of the historical background of their current position. (Ziman, 1980, p. 119)

For Ziman and others who have commented on including HPS into science education via the use of STSE education, a few points remain clear. First, that it is the role of the teacher to decide how and when HPS is to be included in the science curriculum to create the most significant impact, i.e.,

It is the responsibility of the STS[E] teacher to make sure use of these diverse slants on the subject as is appropriate, and not to assume that any of them is a correct view. The history of science is not, of itself, an ‘approach’ to STS[E] education: it is a method, or a mode by which very important STS[E] themes can be enlarged or illustrated. (Ziman, 1980, p. 123)

And, echoed by Matthews (1994), “science teachers with HPS interests will make science more interesting and more supportive of students’ educational development” (p. 9). The second point
is that, by including HPS into science education, teachers are able to promote social justice and empowerment. As Jones and Carter state:

This position is based on beliefs that for students to become scientifically literate and capable of participating in democratic decision-making, they need to be able to understand the past complexities of science and society (Conant, 1951) as well as the conceptual, procedural, and contextual aspects of science (Klopfer, 1969). (Jones & Carter, 2007, p. 1090)

If STSE is a vehicle that can increase the level of accessibility of science for all students, then, logically, it should improve students’ understanding of the cornerstones that constitute STSE—namely, the nature of science, as was stated in the previous section, and the need to examine historical and philosophical issues as well as socio-political issues, thereby, developing students who are scientifically confident and, in a broad sense, scientifically literate.

2.3.3 Coupling Science and Values

Traditionally, science was seen to be objective, linear, devoid of context and perhaps ‘values-free’ (Deboer, 1991; Aikenhead 2006). Yet science is conducted by people for (ideally) the betterment of society, both morally and ethically (Reiss, 1999). And, since the experiments and results of scientific experiments, inquiry and enterprise are conducted and their value decided by the researcher, the development of science will be directed by the values held by those who ‘do’ science, followed by those ‘using’ science. But what is meant by “values”? Using Aspin’s definition of values, “ideas, conventions, principles, rules, objects, products, activities, practices, procedures or judgments that people accept, agree to, treasure, cherish, prefer, incline toward, see as important and indeed act upon” (as cited in Pedretti & Little 2008, p. 43).

Now the question of ‘Who’s values should be used as a benchmark in science’? is commonly posed. It is quite conceivable that addressing science and values could become
controversial when introducing alternative cultural ideas, traditions and norms in science education. However, it is the exploration of science with values that leads to students holding ‘scientific positions’ on various issues, which affect them and the world as they perceive it.

Exploration of socio-scientific issues is a wonderful entryway into both science and values education. Because SSI is ‘values-based’, it is then important to understand how students make decisions after discussing a science-related event (Aikenhead, 2006). This process, along with the implications for teachers, researchers and curriculum developers, has been synthesized by Aikenhead in *Science Education for Everyday Life*. What is interesting to note is:

Values are a constant feature of decision making. They include economic, ethical, religious, social, and political values. Researchers have consistently found that students give much higher priority to values, common sense, and personal experience than to scientific knowledge and evidence, even when that knowledge and evidence are relevant to the issues discussed in the classroom (Bell & Lederman, 2003; Dawson & Taylor, 2000; Grace & Radcliffè, 2002; Kolsto, 2001; Levinson 2004; Ratcliffe, 1997; Sadler, 2004). (As cited in Aikenhead, 2006, p. 101)

If this is the case, it becomes most important to engage students in the whole process of science and science learning; in both the science content and the decision making process which shape and affect the world. However, in order to engage in the ‘decision making process’, ethics and values come into play. It is at this point one must examine whose ethics and values are most important along with the role ethics play in the decision-making process. It is important to advocate for and encourage students to contemplate and argue their own positions and values while acknowledging other view points, beliefs, principles, and ethics, rather than merely blindly accepting the teacher’s ‘views.’

2.3.4 Decision-making, Action and Agency

Values and decision making are interlinked as was seen in the previous section. One can only make decisions depending on one’s values and vise versa. Making decisions requires an
understanding of the issue. This understanding comes with (hopefully) learning and studying the issue from many different perspectives – i.e., becoming literate. This connection between scientific literacy and decision-making is voiced by the Canadian Council of Ministers of Education, “Scientific literacy is an evolving combination of the science-related attitudes, skills and knowledge students need to develop inquiry, problem-solving, and decision-making abilities…” (CMEC 1997, p. 4). And if the method of achieving scientific literacy is STSE education, then, as Aikenhead stated, “STS[E] science is also expected to fill a critical void in the traditional curriculum – the social responsibility in collective decision making on issues related to science and technology” (Aikenhead, 1994, p. 49). However, what does decision-making involve and why is it complicated? As Pedretti and Little stated:

Decision making involves identifying and analyzing an issue and selecting from alternative solutions. Decision making, however, is a complex process, encumbered by multiple possibilities, values, and agendas. In trying to manage the complexity, decision makers rely on criteria to distinguish among the possible solutions. This involves understanding the underlying value positions of various stakeholders as well as the values underlying the criteria, and analyzing the advantages and disadvantages of the various alternatives. (Pedretti & Little, 2008, p. 45)

Decision making is a complex undertaking and there is no one formula or procedure that is universal. Typically, decision making does loosely follow a framework that includes the following points, as presented in Pedretti and Little’s work, taken from the 1993 Saskatchewan Education curriculum documents. Here, the process of decision-making involves six steps. They are:

1. Identifying the issue,
2. Identifying the alternatives,
3. Researching (identifying and evaluating related scientific knowledge, perspectives on each alternative and consequences of each alternative).
4. Reflecting and deciding (considering consequences, perspectives and building consensus).

5. Taking action (demonstrating responsibility through personal action, actions as member of a group).

6. Evaluating (effects of actions and the decision-making process used). (Pedretti & Little, 2008, p. 46)

It is interesting to note that step five involves ‘taking action.’ Action follows decision-making and, as with decision-making, is part of the STSE framework using an issues-based approach. Similarly, Hodson describes “four levels of sophistication that lead to preparing students to take action” (Hodson, 2003, p. 655). Incorporating action into a science curriculum implies that a shift must occur from teaching from a transmissive orientation, whereby knowledge, facts, concepts are transmitted to students, to one of a transformational orientation as described by Millar (Millar, 1993). To teach science with a transformational orientation entails that an emphasis be placed on the student’s personal growth and social change within the student’s milieu.

This personal growth and change can lead to action, and “the power to act is known as agency” (Roth, 2009, p. 2). A curriculum, which uses STSE, encompasses a broader notion of scientific literacy – it includes the content, i.e., learning and doing science (Hodson, 2000). However, it also includes learning about science (Hodson, 2000). Learning about science (and its impact while considering values and ethics) may lead to action and agency because content will have been placed into context for the students. This may lead to a deeper level of understanding – on a more personal level. This deeper understanding allows for students to connect science and values leading to decision-making and action. This power to act is agency. As Roth observed from the compilation of his text, *Science Education from People for People*:
We can learn from the chapters in this book that people will learn when they know that what they do will expand their room to maneuver, that is, their agency. The frequently heard student question ‘what is this good for?’ or ‘what do I need this for’ is an expression of the problematic…we found that knowing more…would expand our power to act, and our endeavor in learning more was inherently motivated in the process. (Roth, 2009, p. 210)

Allowing for agency within a science curriculum moves the experience of learning science, learning about science and learning to do science from a transmissive setting to a transformational experience, engaging learners wherever they may be on their learning journey to actively contribute to their own understanding and beyond.

2.3.5 Moving from Cornerstones to Currents

As discussed earlier in this chapter, the nature of STSE education is complex and there have been a variety of attempts to discuss, acknowledge, and describe the interplay among its many components. Aikenhead (1994; 2003) discussed the diversity of STSE and how it can be integrated into and with traditional science content. In Aikenhead’s 1994 work, it is said that “he does not attempt to prescribe any particular set of goals or goal priorities, nor does it address teaching methods [when referring to teaching STSE]” (as cited in Pedretti & Nazir, 2011, p. 5). As noted by Pedretti and Nazir (2011) Aikenhead describes the ‘how’ of integrating STSE into a science curriculum.

On the other side of the spectrum is Ziman’s work, which is much more philosophical and theoretical in nature - he provides checklists and frameworks for STSE education. In consideration of all that has been written on and about STSE education, one could argue that there is a gap (as Pedretti and Nazir do). This gap is the ‘why’ and the ‘what’ of STSE education and it is this gap that Pedretti and Nazir’s paper addresses, whereby they use the notion of ‘currents’ to describe the components of STSE education. Their notion of ‘currents of STSE’ may have stemmed from Ziman’s comment of “the movement for STSE education springs from so
many different sources…” (1994, p. 21) and, as noted by the authors, the work of Lucie Sauvé (2005) who used the notion of currents to map the field of environmental education.

The ‘currents’ identified are labeled: application/design, historical, logical reasoning, value centred, socio-cultural and socio-ecojustice (Pedretti & Nazir, 2011). As the authors state, “these currents co-exist, some overlap, and can be utilized in harmony” (p. 5). This sense of fluidity (borrowed from Sauvé) helps accentuate the inner connectedness and movement between and among the more traditional ‘cornerstones’ of STSE, adding to our understanding of the scope of STSE education. The ‘currents’ identified in this paper are highly similar to those discussed earlier in this section, i.e., the ‘cornerstones’ of STSE and, although the ‘content’ is essentially the same, the primary difference is that the analogy of ‘cornerstone’ does not impart the same degree of ‘movement’ as does the term ‘current’, thereby inferring that movement from one ‘cornerstone’ to another is more difficult than perhaps it is in reality. More importantly, the currents also provide a more comprehensive view of the ideological assumptions that underpin different enactments of STSE education (i.e., from a application/design approach to a more critical approach). As indicated within the article by Pedretti and Nazir, this notion of ‘currents’ will be of great value to those beginning their study in the field of STSE education, as well as for those who are already in the field and searching for a new perspective or analogy to aid in a deeper understanding of the scope of STSE.

2.4 STSE and the Ontario Curriculum

As mentioned previously, STSE has been incorporated into the science curricula of various countries. As Aikenhead explains, the development of STSE in localized curriculum exists around the world and in various regions in Canada.

The Atlantic Science Curriculum Project worked 15 years to publish a Canadian humanistic textbook trilogy Scienceplus… other successes include the Science and
Technology in Action in Ghana Project, the Science, Technology, Environment in Modern Society (STEMS) project in Israel and the Science Through Applications Project in South Africa. (Aikenhead, 2006, p. 60)

From these examples mentioned by Aikenhead, it is clear that STSE is not new and certainly not limited to just Canada or Ontario. In Canada, the Canadian Council of Ministers of Education has supported scientific literacy and STSE education (CMEC, 1997). However, elementary and secondary school education is a provincial jurisdiction in this country and we do not have a ‘National Curriculum’. Therefore, since this study is placed within a Faculty of Education in Ontario and the pre-service teachers will be experiencing science learning and teaching within Ontario classrooms, it follows that an examination of the Ontario science curriculum for STSE expectations and suggestions be considered.

When we inspect the introduction of the revised 2008 science curriculum from the Ministry of Education in Ontario, the curriculum document states that the goal of secondary schools:

…is to support high-quality learning while giving individual students the opportunity to choose programs that suit their skills and interests…to better customize their high school education and improve their prospects for success in school and in life. (Ministry of Education, 2008, p. 5)

According to the Ministry, science is playing an increasingly important role in the lives of all Canadians and the role of science will continue to grow as we move further into the twenty-first century (Ministry of Education). Because of this growing importance of science, scientific literacy has become one of the goals of science education. The curriculum document states:

A scientifically and technologically literate person is one who can read and understand common media reports about science and technology, critically evaluate the information presented, and confidently engage in discussion and decision-making activities regarding issues that involve science and technology. (SCCAO, STAO/APS0, “Position Paper: The Nature of Science” (2006, p.1), cited in Ministry of Education, p. 5)
Further on, the curriculum states one of the goals of the science program is to “relate science to technology, society and the environment” (p. 6). Interestingly, it is the first goal given. The curriculum document also goes on to discuss NOS in relation to scientific literacy. It stresses the change in the science curriculum using Erickson’s comment, “Change the focus of the curriculum and instruction from teaching topics to ‘using’ topics to teach and assess deeper, conceptual understanding” (Erickson, 2006, p. 7, as cited in Ministry of Education, p. 6). The curriculum also argues the importance of bringing into the science classroom ‘big ideas’ where students should retain the information and knowledge long after they have left the science course.

If we are to use the senior science curriculum document as an indicator to predict the future of STSE education in Ontario, a few points can be made. First, the students currently in the educational system will now receive a curriculum which is more rooted in STSE principles than ever before. Secondly, it will be up to the teacher to determine the degree of STSE incorporated into the everyday classroom experience. Thirdly, curricula within the province are typically reviewed every five to seven years; therefore, this will give both science teachers and students opportunities to experience an STSE orientated science curriculum and to evaluate its potential and relevancy. Finally, with the comments made in the curriculum document and those offered above, it appears that an STSE-orientated science education is here to stay at both the elementary and secondary school levels. It is this recent set of curriculum revisions in the secondary science education curriculum that has, in part, prompted me to explore physics pre-service teachers’ understanding of STSE education and their attitudinal changes concerning a curriculum which is conceptually and possibly pedagogically different from that which they were taught.
Could these curriculum changes be an indicator of what the future of STSE may look like? Perhaps one indicator of the future of this approach to science education is to examine what was written about STSE almost 30 years ago. Ziman (1980) commented that:

> The STS[E] movement draws this vitality from both the bottom and the top of the educational pyramid – from the changing needs and aspirations of those to be taught and the scholarly drives of its most learned teachers. (p.166)

From here, he later comments that:

> It is enough to say that there is no end to the potentialities of STS[E] as a field of investigation for sociologists, social psychologists, political scientists, economists, philosophers, social historians and many other contemporary academic breeds. This research justifies itself by its contributions to science policy making, and by the more reliable image it can give of the role of science and technology in all spheres of material culture, ideology, education and social action. The constraints are shortages of properly trained people, and of financial support – not of problems worthy of investigation. (p. 166)

It is clear that Ziman and others (Aikenhead, Bybee, Pedretti, Roberts, Wallace, etc.) feel that this is the way of the future for Science Education.

### 2.5 Moving Theory into Practice with STSE

Regardless of the analogy or metaphor used to describe the components of STSE education, teachers need to understand how to move theory into practice. What does it mean to include NOS into a science lesson? How can HPS be included and still meet curriculum outcomes and expectations? What does teaching an STSE-lesson look like and is it as effective as other teaching strategies? These questions are at the heart of pre-service teachers’ concerns and can also be heard when at in-service teacher professional development seminars. Examples of STSE-lessons and topics can be found within the literature; i.e., using issue-based approaches such as cloning, water management or hybrid vehicles are ways of engaging students using an STSE framework (Pedretti, 2005; Sadler, 2006). Within the literature, there are examples of how ‘everyday issues’ can be woven into the experiences of students while in the science classroom.
and which connect the content of the given curriculum to the student’s everyday life experiences.

As stated in Pedretti and Little (2008), “concrete examples of scientific issues might include the effect of technology on human health, reproductive technologies, genetically modified foods, climate change, pollution, dietary advice, and so on.” (p. 15).

Other excellent examples of moving STSE theory into practice can be found in the text by Aslop, Bencze and Pedretti (2005), whereby teachers and students were asked to contribute lessons and comments about these ‘exemplary practices.’ With each account covering physics, biology or chemistry, a variety of teaching strategies are employed, yet common to all are Hodson’s elements of learning science, learning about science, and/or learning to do science (Alsop, Bencze, & Pedretti, 2005, p. 6). The accounts include kidney function and dysfunction, vibration and waves, and the Burgess Shale fossils, to name a few. What makes the work of Alsop, Bencze and Pedretti most interesting is the hypertext used to connect the ‘teacher/student accounts’ with the research literature – making this a conversation between the theory and practice of STSE.

Examples of moving theory into practice when considering STSE can also be found in everyday science classrooms, where lessons are being taught which have been inspired by world or local events. For example, as a physics teacher teaching momentum, the common discussion was airbags and seatbelts to give ‘practical examples’ of momentum, impulse and the effects on a human body. In 2004, while I was teaching physics and momentum, there was a pellet gun shooting in Toronto, which resulted in the death of a young girl. My students did not see the connection between this incident and their physics, so I developed a laboratory experiment where students could calculate the muzzle velocity of their favorite water gun as a means to determine
why it ‘hurts’ when shot by a super-soaker. This was a very meaningful lesson for all involved and the ‘how to’ of the experiment was described in MacLeod (2007).

2.6 Summary

Science education, as, offered to students today, is not, perhaps, the science we (as children) remember taking. The focus of science education, as we move further into the 21st century, expands upon the notion of what it means to be scientifically literate, recognizing the interconnectedness of science and society, and providing students opportunities, which involve all the ‘cornerstones’ of STSE.

Scientific literacy in its broadest purpose aims to elevate a person’s level of science understanding – whether it be for everyday life or scholarly activity. Similarly, when examining the various definitions and examples of STSE and its purpose, the over-arching idea is to have the student understand how science is relevant to themselves, others, and their surroundings, and to participate in decision-making and agency. STSE can be a vehicle to achieve scientific literacy, as they have a common purpose.

Conversely, one could argue that, through scientific literacy, it is possible to achieve STSE goals. Perhaps, regardless of the sequence (scientific literacy leading to STSE or STSE leading to scientific literacy), the 2008 Ontario Curriculum has placed STSE expectations at the forefront of each unit of study, perhaps to bring context to the content and addressing scientific literacy in a less abstract manner for both teachers and students. Learning science is more than just about learning independent facts – it involves values, ethics, decision making, action, agency and science’s relevancy - a result of the context in which the subject has been taught.

In the next chapter, I explore the development of physics education research from both the physics and educational perspectives, alluding to suggestions from this body of literature of
possible correlations to the concepts of scientific literacy and STSE. I also examine the underlying ideas and principles of pre-service teacher learning.
Chapter 3: Physics Education Research and Pre-service Teacher Learning

3.1 Physics Education Research

To some extent science is hard because it simply is hard. That is to say, the material to be learned involves a great many concepts, some of which are very counterintuitive….This fact is well understood by the students, the professor, and the general public. What is not as well understood are the various ways in which this already hard subject matter is made even harder and more frustrating by the pedagogy itself. Eric, a physics student in Sheila Tobias’ study of science education, 1990, as cited in Knight. (p. 2)

Eric was a graduate student taking and commenting on a first year physics course as part of Sheila Tobias’ 1990 study dealing with the perceptions of graduate students taking a first year physics course at a large university. In a text designed to help improve physics instruction for physicists, Knight (2004) explains that Tobias’ students “uniformly, [the students] found the standard introductory physics course to be boring, crammed with too much material, narrowly focused on numerical manipulation and computation, and biased against any attention to the ‘big picture’ of what physics is all about” (p. 2). Similar comments were echoed by my secondary students when I taught physics at the grade 11 and 12 level, where curricula stressed content knowledge. I propose that the findings reported by Tobias, in Knight’s book, would also reflect the perceptions of many students enrolled in traditionally based, high school physics classrooms. Why is this point worth consideration? Simply, it is quite often the physics student who later becomes the physics teacher, and what the student saw and experienced within the classroom often becomes the basis of his/her pedagogy.

When considering the sciences, how is physics defined? The essence of ‘physics,’ the subject, can be described as “constructing idealized models of the physical world, which can be subjected to mathematical analysis, and the checking and validation of these models through
precise and objective measurements” (Hart, 2001, p. 542). Physics, like all other areas of science, has its own persona or, rather, social mask where it is perceived to be a ‘hard’ subject or only for those who are ‘really smart’. This attitude, along with the fact that physics enrolments at the secondary school level continues to decline (Alsop & Watts, 2000; Brickhouse, 2001; DeBoer, 1991; Hart, 2001; Zohar, 2005) has led to the question, why and what can we do to reverse or address this negative attitude and declining enrolment? Research into this problem has been undertaken both by physicists and by science education researchers, as both groups realize the importance of a physics education component to a scientifically literate individual. Some argue that this decline is related to the learning and teaching of physics. As McDermott (1998) states:

Unless we are willing to apply the same rigorous standards of scholarship to issues related to learning and teaching that we regularly apply in more traditional research, the present situation in physics education is unlikely to change. (p. 8)

This area of research has come to be known as physics education research (PER). It has been and continues to be conducted worldwide (McDermott & Redish, 1999) with similar findings regarding student enrolment and levels of understanding, regardless of the language or culture of the students.

Physics education research can be approached via two perspectives (Beichner, 2009) when examining the research literature, one being as a physicist who is very knowledgeable about physics (as this is his/her focus) and who approaches educational research under the guise of methodologies utilized in the physical sciences or, the second, as a science educator who may understand and have great experience in current educational research methodologies and trends (as education is the focus) yet has less depth in the physics content when compared to that of a physicist (Harrison, 2010). Regardless of the label, members of both groups have the same goal at the heart of their research – to help students who will take physics and those who teach physics to better understand the science, to comprehend the relevancy of the study of physics,
and to promote its value. A review of the relevant literature from both perspectives will now be
given and, as will be seen, the primary goal of both groups is the same. Yet very few researchers
straddle both groups. Recently, however, physicists and physics educators are beginning to
dialogue and consider what can be learned from one another’s findings.

3.1.1 A Physicists Perspective

PER researchers, who are predominantly trained physicists, have conducted systematic
studies of student learning at the university level. As described by Beichner (2009), “They are
physicists who treat education as topic worthy of scientific study” (p. 3). Further, as Beichner
(2009) states:

Physics education research is not just curriculum development or instructional design. It
is not merely a service enterprise for teachers, although its findings can certainly be put to
good use by them. Instead, PER is focused inquiry into what happens as students struggle
to grasp and use the concepts of physics. Obviously there are limitations to discerning a
person’s thoughts, but repeated patterns of responses (either in a single student or across
many students at different times and places) can lead us to generate theories that explain
other situations and, in some cases, have predictive power. This would be considered
“basic” PER…. There is also “applied” PER where the researcher uses results from basic
PER to modify instruction, examine the educational efficacy of the new approach, and
use these results to iteratively improve instruction with more follow-up
assessment….[Others] examine socio-cultural issues like learning in collaborative
groups, discourse models, etc. (p. 3)

Often, PER researchers employ methodologies similar to those which would be used in their
physics laboratories for conducting research into student thinking and learning; i.e., to “attest to
the fact that scientific tools and methods can and should be used to improve teaching and
learning” (Beichner, 2009, p. 2). This work has used two primary research methods. The first
employs an individual demonstration and interview that enable the researcher to probe deeply
into the way students think; the second uses widely administered written tests that provide data
on prevalence. Researchers have also engaged students in dialogue, examined homework and
written reports, conducted classroom observations, and used pre- and post-testing of students
Beichner (2009) acknowledges that PER can also be conducted by those in Education, “depending on the type of investigation” (p. 4). However, he notes that the studies conducted by physicists involve college students. He gives the following argument for physicists and education researchers to work together:

First of all, physicists are familiar with the complex and often subtle aspects of physics as covered in college-level coursework and they appreciate the peculiar culture of physics. Also, it can be argued that the researchers studying learning by college students should actually teach those classes. Researchers looking at learning by pre-college students are usually, but not exclusively, found in education departments. An unfortunate truth is that some physics faculty will only listen to other physicists, and not regard the work of science education researchers as valid. This is regrettable because science education researchers have usually had training in the complicated methodologies needed to carry out this type of work. Not surprisingly, both PER workers and science education researchers can benefit from each other’s knowledge and background. (Beichner, 2009, p. 4)

From the research, physicists have found that there is a wide gap between the learning objectives of most physics instructors using traditional forms of instruction, and the actual level of conceptual understanding attained by students (Beichner, 2009; Leonard, 1996; McDermott, 1991, 1998, 2001; McDermott & Redish, 1999; Redish, 2003; Saul, 1998). The students’ level of conceptual understanding has been the main focus of this research; “conceptual understanding enters into any consideration of problem solving in physics because the solver’s knowledge base is a critical factor in how the solver proceeds” (Maloney, 1994, p. 327). In addition, assessments of the epistemological beliefs of these students, and of how these beliefs influence learning and the students’ expectations of physics, have been developed and completed (Redish; see van
Aalst, 2000). Other areas of study by PER physicists have included problem solving, attitudes of students, social aspects, technology, evaluation of specific instructional interventions and instructional materials (Beichner, 2009). The results of these research initiatives have been used to guide the development of curriculum at the university level (Beichner, 2009).

In November 2005, the National Research Council released *Rising above the Gathering Storm* (as cited in McDermott, 2006). The report focused on improving K–12 science and mathematics education and suggested that teachers were the key to improving student performance. “To make science meaningful to young students, teachers need to know how we know as well as what we know” (McDermott, 2006, p. 760). This is an interesting and important point in that the content (the what) and process (the how) needs to be understood by the teacher, and then relayed to the student. The point of ‘how we know’ could be suggestive of Matthews (1994) point made in Chapter 2 concerning HPS and NOS (Lederman & Lederman, 2004) concerning issues of epistemology and knowledge generation: i.e., It seems that it is no longer enough to ask “what we know about science but how we know what we know” (Matthews, 1994, p. 5).

If this connection is made, then where does STSE fit into McDermott’s teaching and learning framework? Interestingly, the question of ‘why’ and the implications of this knowledge are not mentioned. Are these not important and relevant? At no time does McDermott or any other PER researchers (Redish, Knight, Harrison, Beichner, etc.) mention or allude to the idea of teachers placing the content of their science courses into today’s context. There is no mention of the use of STSE as a possible teaching approach to make science and more specifically, physics, more meaningful, no discussion of placing physics education as it may relate to a social, cultural, political context, and no discussion of using an issue-based approach. Finally, she does not
specifically mention the role or importance of scientific literacy within the physics educational context. If the question of ‘why’ and the implications of our knowledge were addressed, then perhaps movement towards STSE and advancing scientific literacy would be possible.

The teaching strategies used in physics classrooms (usually at the university level) have also been scrutinized. Physics education research studies conducted by physicists have illustrated that traditional teaching methods are ineffective (Beichner, 2009; Harrison, 2010; Knight, 2004; Redish, 2003). Although this might be obvious for an educationist, it was not for many physicists and, in some cases, is still up for debate. For example, “students are able to correctly answer traditional test questions without understanding the basic physics concepts or learning the useful concept-based problem-solving approaches of physicists” (Wieman, 2005, p. 37). Information transfer has also been explored; “[a] 10% level of retention after 15 minutes is typical for a non-obvious or counterintuitive fact that is presented in a lecture” (Wieman, 2005, p. 37). When examining students’ beliefs about physics and problem-solving, “students were found to be less expert-like in their thinking than before [they began], and students see physics as less connected to the real world, less interesting, and more as something to be memorized without understanding” (Wieman, 2005, p. 37). As Harrison (2010) states:

If conventional instruction is not effective, the diagnostic instruments allow us to conduct research to try to find pedagogy that actually works. After forming a baseline with the pre/post test protocol in a course, the following year make a change in the instruction and use the instruments to determine whether the change actually worked. This method of applying the scientific method to pedagogy is the heart of PER. (Harrison, 2010, p. 2)

How can physics teachers enhance student learning in physics? How can physics educators connect physics to the real world? The “better approach” suggested by many authors is to use a variety of teaching strategies that encourage students to participate in lectures, to talk about methods, and to discuss the meaning of problem-solving tasks (Parallelism)—that is,
students learning about physics (reminiscent of Hodson’s ‘learning about science’) while learning to do physics (Bloom, 2006; Redish, 2003; Saul, 1998; Wieman, 2005); and to contextualize physics (Kortland, 2005). In addition to examining the ‘teaching approaches,’ Viennot (2003) also suggested the need to examine students’ preconceptions and how physics teachers address these within the classroom. Some of the ‘key’ results of PER as described by Harrison (2010) are:

1. Most students learn best by interacting with their peers. This result was particularly shocking to me. My preferred learning style is give me the textbook or journal article and a quiet corner and leave me alone! I suspect this is also the preferred learning style of many people who end up academics. However, it is not the best learning style of most of our students.

2. The peer interactions are most effective when they are based on conceptually based activities. These activities are particularly effective when they force students to confront their mis-conceptions.

3. The activities are particularly effective when they involve real physical apparatus. The apparatus need not be sophisticated or expensive: often material available at minimal cost from the local hardware store can be effective. (Harrison, 2010, p. 2)

From these results, many educators have suggested a change in pedagogy. This shift in teaching technique should include peer instruction (in contrast to pure lecture), interactive lecture demonstrations whereby the students are asked to do a ‘POE’ (predict, observe, and explain), although it was not described as such, tutorial sessions where groups of students investigate and report on conceptually-based activities where the instructor uses the guided study technique of instruction, and laboratory sessions (Beichner, 2009; Harrison, 2010; Knight, 2004; Redish, 2003).

Another technique described in the literature to make physics more ‘accessible’ to students is the incorporation of a history and philosophy of science (HPS) approach. As Knight states in his text designed for physics instructors, “from a pedagogical perspective, historical
issues provide a good entry point into a class discussion about difficult conceptual issues” (Knight, 2004, p. 17). Here the argument is that students’ opinions often are similar to those of ancient or medieval times, allowing the teacher to set up a wonderfully rich paradox for the student to work through. Further, it has been reported in the literature that:

A shift in how high school students perceive physics could also result from an HPS perspective. In a recent study, concern was expressed by high school students and their teachers that the mathematics involved in doing physics limited which students could actually take the courses. [It] was suggested that using HPS could “remove math phobia from physics” thereby having the potential to engage more students. (Nashon, Nielsen & Petrina, 2008, p. 397)

This point is of interest since HPS is considered one of the ‘cornerstones’ of STSE education (Aslop & Pedretti, 2001; Pedretti, 1996; 2005), yet no explicit mention of STSE occurs within this (PER) literature. What is interesting to note is that the idea of moving away from pure lectures and attempting to make the classroom more student-centered was advocated by education at least 15 years ago. Will it now take another 15 years for the university community to come to the idea of teaching science or more specifically physics through an STSE lens?

Physics education research ideas and study are not exclusive to the United States, or to the University setting alone. PER has influenced other countries in their pursuit of better curriculum and teaching. Viennot’s (2003) text, Teaching Physics, provided six instructional sequences that have been reworked as a result of PER, based on the Grade 9 curriculum in France, and the “text illustrates how it is possible to better design curriculum so that things are explained better” (van Aalst, 2005, p. 421).

The Netherlands has also been a leader in connecting physics education with the ‘real world.’ There, the physics curriculum is context-based, with the student’s life as the starting point. It moves on to develop ideas using technological artifacts and natural phenomena, and
finishes with socio-scientific issues and ideas concerning the nature of science (Kortland, 2005). Similarly, new curriculum in the Czech Republic also stresses the idea of “including more environmental problems in physics teaching and learning” (Holubova, 2005, p. 17). These are clear, although limited, examples of the movement of physics education away from the use of traditional teaching strategies towards a more student-centred, STSE-like physics experience.

Placing physics in context is also a theme found in the literature concerning PER from Germany. Here, an attempt has been made to take the content of physics and place it within the context of the student, using medicine or biology perspectives. The reason for this is, “Physics instruction that is student orientated will generate a long-term individual interest and therefore a lifelong openness to science” (Waltner, 2007, p. 502). Further, as cited in the article by Waltner et al., is a comment by Hoffmann et al. which summarizes the scope of context which can (in their opinion) be used within physics instruction:

Fields of interest which provide context leading to great student interest in their physics classes include:
1. Accentuation of the social relevance of physics and its findings;
2. Connection to everyday situations;
3. Clarification of potential fields of practice;
4. Implementation in medicine;
5. Environmental protection;

Although neither Waltner nor Hoffmann use the term STSE, this list does allude to the suggestion of an STSE orientation when instructing physics to provide the student with a context for the content of the lesson.

An overview of the state of PER in Canada as of 2005 was published by the Canadian Association of Physicists (Hawkes & O’Meara, 2005). PER can be found in many Canadian universities—including Acadia and Mount Allison, and the Universities of Toronto and British Columbia—and the list continues to grow (Hawkes, 2005; Hillel, 2005; UBC, 2008). The
Ontario Association of Physics Teachers, in conjunction with Ryerson University’s Department of Physics and the Perimeter Institute, is currently working in partnership to establish a grassroots movement of PER in Ontario. In addition, the Ministry of Education in Ontario has dabbled in PER with their 1987 report examining teaching and learning physics in Ontario in the senior division. As part of this report, a province-wide survey of teachers, students, curricula, and achievement was conducted. The intention was to complete a “test run of Ontario Assessment Instrument Pools (OAIP) Physics” (McLean, 1987, p. 7). The survey information was to have assisted with interpreting the achievement results, but no direct follow-up from this report has been located.

PER, as a field of research has been conducted globally over the past two decades in the hope of shedding light on how to improve the learning experience of physics students. It is mainly conducted by physicists and the research produced benefits those who follow this body of literature in terms of improved teaching techniques, as seen from the research and richer student learning experiences (primarily at the university level). This body of literature should also be consulted by educationalists that are interested in physics curriculum studies.

3.1.2 A Science Educationalist Perspective

Often, when examining science education literature, it is a research body rich in practical examples and studies based on advances in biology, chemistry, and physics curriculum and instruction practices. However, it seems there is less in the area of physics, specifically. This, I assume, is reasonable and reflective of the demographics of science teachers and science education researchers in general. From the research literature, it is interesting to note that the literature produced from the field of science education promotes similar ideas, methods and pedagogy regardless of the specific subject area – they advocated for all areas of science
education in a holistic manner – not necessarily for physics education alone. This is a void in the literature; one that I hope this dissertation will help fill.

When considering the science classroom in general, what constitutes a “good science teacher?” As Lederman and Stefanich (2006) state:

The role of the effective teacher is to focus on the science processes and their meaning rather than the product (Martin, 1997), to focus on the students’ reasoning skills rather than on accurate direct answers. Always keep in mind that the primary goal of the instructor is to develop higher order thinking skills in the learner, not to disseminate information (Victory & Kellough, 1997; Zorfass, 1991). Teachers must address nature of science or their students will suffer and lag behind those who have been exposed and understand this concept. Reflect on the statement, ‘If a teacher criticizes a child for inventing the wheel, s/he must be more interested in wheels than invention.’ It is an understanding of the nature of science and scientific inquiry that empower students as citizens in a world with myriad scientifically and technologically-based personal and societal issues. (p. 72)

Could this be applied specifically to the physics classroom and physics classroom teacher? When students (regardless of the level of education one is dealing with) are unsuccessful, teachers need to reexamine what they (the teachers) are doing and why it is not working; i.e., their pedagogy.

Teachers must make adaptations when the learning style or skills of a student do not match the instructional delivery or content objectives (Stainback et al., 1996). Rather than relying on pull-out programs teachers should make carefully designed adaptations in the general education setting. (Lederman & Stefanich, 2006, p. 72)

As Bybee writes, although each science area has its own unique character, there are common ideas among all sciences:

Although difference in the concepts that form a discipline and the questions that guide inquiries are important, there is a set of common goals for any scientific inquiry. All scientists are trying to improve their understandings and explanations about the natural world. Further, they agree that using empirical data reasoning in constructing explanations, avoiding bias, and presenting explanations for skeptical review are all “rules” of the scientific process…. Science is a human activity. Scientists may share some fundamental assumptions such as the essential place of data, the importance of logic, and the need to base their explanations on evidence, but scientists vary in their talents, imagination, intuition, and courage….This discussion leads to the conclusion that we need to provide students with a broader view of scientific inquiry and the nature of science. (Bybee, 2006, p. 3)
In 1902, Smith and Hall made recommendations concerning inquiry as a method for better student engagement, as discussed by Deboer (2006):

Hall, speaking for physics, likewise offered a range of inquiry-based teaching methods and analyzed the advantages and disadvantages of each. The first he called the ‘true discovery’ or heuristic approach in which students were given the maximum amount of freedom to explore the natural world on their own. As did Smith, Hall felt that this method required too much time and that students were often not well enough equipped to draw anything but the most superficial conclusions from their investigations. The second method he called the verification approach in which students confirmed scientific facts or principles in the laboratory…Hall felt that the method led to unscientific attitudes because students were too tempted to look for the right answer or consider only the evidence that supported the expected result. The third method was the guided discovery approach, what Hall called ‘inquiry’. Using this method, students did not have to discover everything on their own but they did have to seek solutions to questions for which they did not have the answers. In this way they would still be acting as genuine investigators and not simply confirming something that was already known to them. (p. 25)

Why is this an important point? I suggest, it is what Hall did not say – he did not recommend lecturing. In fact, in the text by Smith and Hall, they “argued against the textbook approach to school science teaching and offered specific suggestions on how the science program could be strengthened” (Deboer, 2006, p. 24).

How can these points affect science teacher education? It seems that, for teachers (and teacher candidates), the theme is to engage students in their learning, not just listening to the teacher conveying information. From here, the Nation Education Association’s Commission on the Reorganization of Secondary Education (CRSE) issued a report in 1920 whereby the physics committee of this body “addressed the importance of the laboratory as a place for genuine inquiry rather than as a place to ‘verify laws’, to ‘fix principles in mind,’ to ‘acquire skills in making measurements,’ or to ‘learn to be accurate observers’” (Deboer, 2006, p. 26).
Later, in 1932, the National Society of the Study of Education (NSSE) indicated “the best use of the laboratory was for the solution of students’ own science problems” (Deboer, 2006, p. 27). As Deboer describes, “Many science educators during the early years of the twentieth century felt that the laboratory should be used as a place where students could work on problems of interest to them and that had social, as well as scientific, relevance and importance” (p. 27).

Since inquiry is being suggested as a possible teaching strategy to improve the learning and understanding of students and we know that, typically, inquiry takes more classroom time, what happens to the content of the course? Isn’t it better to cover as many topics as possible to give students a breadth of understanding and knowledge? Must the content be reduced? And, where does this leave the ‘knowledge building enterprise’ as described by Metz (2006) when describing physics education? Here she writes:

The cognitive science research of physics cognition documents the highly structured quality of physics expert’s knowledge and how they use these connections and superordinate explanatory constructs in solving problems (Glaser, 1988; Greeno, 1984; Lesgold, 1988). Physicist/cognitive scientists, Reif and Larkin (1991), emphasized the centrality of the conceptual structure… they characterized science as ‘conceptual structure enabling numerous predictions’. (Metz, 2006, p. 116-117)

How does this translate into the physics classroom? As Sadler and Tai (2001) reported “Students who had high school courses that spent more time on fewer topics, concepts, problems and labs performed better in college than those who raced through more content in a textbook-centered course” (p. 111, as cited in Metz, 2006, p. 118). This finding implies that it is better for students to have a deep understanding of a few concepts rather than a ‘surface’ level understanding of many. More eloquently, as Phillip Morrison, a physicist and author of PSCS stated, “less is more.” As Metz explains:

To understand [the comment made by Morrison], one needs to understand the nature of scientists’ knowledge and how they use it. As physicist William Bragg explained, ‘The
important thing in science is not so much to obtain new facts as to discover new ways of thinking about them’. (Metz, 2006, p. 118)

It seems more curriculum does not imply that more learning occurs, nor does it imply that a connection will be made by the student between and among topics to provide the ‘big picture’ or even how the content is related to their lives. Therefore, when examining curriculum, it is also important to know whether it is content-structured or task-structured since “content” will contain a vast number of concepts to be learned and “task” will have less content but allow for time so deeper understanding can be obtained. Regardless of the chosen structure, the key concepts of the discipline need to be known and logically organized into concepts so that students are able to understand the progression of the field of science (Sherin, Edelson, & Brown, 2006).

Another concern within the physics classroom, or rather physics education, related to students seeing the ‘big picture’ is the “solving of word problems depicting a physical event” (Magnusson, Palincsar & Templin, 2006, p. 138). Does solving text-based word problems reconstruct the student’s world or environment? As described by these authors,

In actual practice, of science, one would need to determine what events to observe and what variables to measure and how to measure them before arriving at a point that might resemble solving a word problem, and of course in science, an underlying theoretical frame would be a part of selecting particular events and variables of interest. It is no surprise then that those who have learned problem solving by completing word problems focus on the surface features of the problem rather than underlying principles as is typical of a scientist’s approach to problem solving. (Champagne, Klopfer, & Gunstone, 1983, as cited in Magnusson, Palincsar & Templin, 2006, p. 138)

If continually solving pre-determined word problems is not assisting students in relating the content to the context – either their own context or the scientific context, how should one proceed? Again, the literature suggests the idea of ‘inquiry;’ not necessarily ‘scientific inquiry,’ as scientists/physicists are not provided the answers by some other person, but rather ‘school science inquiry’ whereby students can develop explanations and support their explanations with
evidence, knowing that (in most cases) acceptable answers already exist (Abell, Smith & Volkman, 2006). If the idea of inquiry is followed, then the concern of what and how much to tell students often arises. In a case of teaching science instruction techniques to pre-service teachers, “Volkmann’s case of physics instruction informs us that we should consider how we help students of teaching recognize and address dilemmas of telling in their own science teaching” (Abell, Smith & Volkman, 2006, p. 197). Inquiry does not imply any involvement of the teacher – just selective involvement.

Further reasons for moving towards inquiry and away from lecturing were summarized by Shipman, “The momentum for change has come from two other sources [not including the AAAS and NAS data and reports]: evidence that lecturing doesn’t work and local initiatives” (Shipman, 2006, p. 359). An example of the research conducted showing lecturing doesn’t work was that completed by Hake (1998). As Shipman writes in reviewing the literature that compares inquiry learning verses lecturing, inquiry learning is significantly better for students,

One of the most comprehensive studies was done in physics by Hake (1998), comparing the results of inquiry-based instruction to the results of lecturing in a national sample of 6000 students taking courses at dozens of institutions. Some more comprehensive reviews include Johnson, Johnson, and Smith (1991, 1998). (Shipman, 2006, p. 359)

The findings from the science education perspective suggest lecturing is not in the best interests of students, rather the use of an inquiry methodology would be more beneficial for students (Wallace & Louden, 2000). This was echoed in the Physicists’ Perspective section, although coming to this conclusion seemed to be a longer path then from the education perspective. What is the connection between inquiry and STSE education and teacher candidates? If students are encouraged, for example, to use inquiry, then, the scope of the problem, issue, or topic is expanded by asking and including areas of technology, society, environment, history, philosophy, NOS, decision making, action and agency. Inquiry can be
understood through an STSE lens. The student is encouraged to see the relevancy of the content through context, including his/her own point of view. The student is also learning science, learning about science and doing science (Hodson, 2000) while making it personally meaningful.

It is the teacher candidate (and current in-service teachers) who need to see the value of this process for current and future students but, specifically for this research, the teacher candidate. It is important to ascertain and probe pre-service teachers’ views about STSE, physics education and physics so that a better understanding can be gained about what it means to teach science, especially physics through an STSE lens. It is also important so that connections can be made between physics and science, to broaden the pre-service physics teachers views about pedagogy in physics and enhance scientific literacy – so that an understanding of what using an STSE lens to teach physics education means in all its complexity.

3.2 Physics and Connections to STSE

How might physics education integrate STSE perspectives? Physics has been described as a science which allows for “constructing idealized models of the world” as was discussed in section 3.1. If this is indeed the case, then could it be implied that physics and physics education must be rooted in STSE principles or, at the very least, possibly be taught through an STSE lens, since STSE is one way to contextualize science. It has also been suggested that students who study physics and “who do well on examinations are generally unable to apply the concepts of physics to common everyday situations” (Hart, 2001, p. 525). Hart also comments that “other studies suggested that students perceive physics as boring and irrelevant to life outside the classroom (Gardner, 1975; Haussler, 1987; Lewis, 1975; Mauger, O’Brien, Malcolm, Pearce & Fallon, 1982; Nielsen & Thomsen, 1990), as well as excessively difficult (Nielsen & Thomsen,
1990; Ormerod, 1981), and that “they persist with the subject only if it is required for their chosen course of further study” (Hart, 2001, p. 525).

This is an interesting paradox in that physics is ‘constructing idealized models of the world’ and yet, ‘students are unable to apply concepts to common everyday situation’. Furthermore, physics – in its traditional gate-keeper role – seems to be only for those who continue in physics, yet the concepts of physics are all around us, everyday. Would it not be imperative that we as teachers strive to connect the content to the real world so that students better understand, have an increased level of physics literacy in terms of how the world works? It appears that there is a disconnect. Why?

Perhaps the reason is in the ‘critical details,’ as van Aalst points out in Viennot’s discussion concerning experiments, “The role of experiments is also discussed [Viennot makes the claim that].... ‘Increasingly, we are urged to relate what is taught to daily life, and to experiments that can be conducted in the classroom’ (van Aalst, 2005, p. 27). However, as van Aalst continues to comment and noted by Viennot, “student experiments are frequently difficult to interpret...The problem here is that, if such details are glossed over, the subject matter loses much of its coherence” (van Aalst, 2005, p. 419). This becomes an important issue:

…students know that things are more complicated than we lead them to believe and they are often not satisfied with the level of understanding they achieve. As a result, perhaps, they see physics as a loose collection of facts and statements. (Hammer, 1994; Redish, Saul, & Steinberg, 1998) (van Aalst, 2005, p. 421)

A more important question might be, how do we teach physics, connecting it to the ‘real world’ and STSE, yet have it ‘do-able’ for students who perhaps do not have the level of mathematics or the depth of understanding to take into account all variables which are in play at a given time in the chosen system?
When considering how physics education might integrate STSE into the daily lessons, Knight (2004) suggests, as previously discussed in section 3.1.1 that history and historical issues can provide an excellent ‘entry point’ into the content (17). As discussed earlier, students typically have opinions, which are reflective of the thinking from ancient or medieval times. This allows for the teacher (once this thinking has been acknowledged) to set up a ‘rich paradox’ for the student to work through. In addition to this point from Knight, further support for HPS can be found in the research of Nashon, Nielson & Petrina (2008). Another common problem is that students are not capable of ‘understanding’ the physics due to their fear or apprehension with the necessary mathematics. Nashon et al. (2008) suggests that, by using HPS, students would still be able to engage with the physics without having to deal with the ‘math phobia’ (p. 397).

This idea of including HPS into physics is not new. Lawrenz and Kipnis (1990) discuss a program whereby their aim was “to facilitate an increase in student experimentation by showing physics teachers how to repeat historically important experiments with simple and inexpensive replicas of historical apparatus” (Lawrenz & Kipnis, 1990, p. 54). Their research question was “Did the teachers’ training in open-ended historical experiments allow their high school students to perceive physics in a more favorable light?” (Lawrenz & Kipnis, 1990, p. 54). Although the authors state issues and limitations with their data collection and analysis, their findings were interesting when considering the connection between using a hands-on (‘doing science’ as proposed by Hodson) historical approach with physics content:

Nevertheless the results from both comparisons show a positive effect for students of teachers who are familiar with a hands-on historical approach. The institute appears to have enhanced a hands-on orientation. Participants were more likely than other teachers to promote student involvement with laboratory activities and to use historical information, and although their approach to teaching physics was consistently hands-on, participants were even more likely to involve students in laboratories dealing with topics
covered in the institute than in other topics… Students of these participants were more likely to enjoy their classes, to be involved in experiments, and to have received a historical perspective…adding a hands-on historical approach to physics can promote student enjoyment of their physics classes and perhaps help to encourage more students to study physics. (Lawrenz & Kipnis, 1990, p. 58)

As can be seen, attempts are being made to include HPS into physics education and those attempts do seem to yield positive results for both teachers and students.

Final considerations when examining physics education and its connection to STSE are language and perspective. When discussing research initiatives with most physicists, they are usually quite good at explaining how their research can affect societal development, the impact on the environment, the technology used and possible advancements of technology from their research. However, at no time do they use the term STSE – it is quite often not part of their vocabulary – yet they agree upon and advocate for the importance of research being for the good and betterment of society.

For example, in examining Natural Sciences and Engineering Research Council granting requirements, when reviewing the Discovery Grants, it states “…collaborative programming…support a program of quality research that can have a meaningful impact on the field of study…” (NSERC, 2011, p. 2). When examining the section on scientific or engineering excellence, it states, “[The researcher(s) need to comment on the] quality of contributions to, and impact on, the proposed and other areas of research in the natural sciences and engineering. …[They also need to state the] importance of contributions to, and use by, other researchers and end-users” (NSERC, 2011, p. 3). In the description of the merit of the proposal, researchers must “[explain the] significance and expected contributions to research; potential for technological impact and the extent to which the scope of the proposal addresses all relevant issues, including the need for varied expertise within or across disciplines” (NSERC, 2011, p. 4). There is no
place on the granting forms which indicates that researchers need to explain the significance of their research using STSE terminology (quite often only found in Education literature), yet STSE ideas, cornerstones, and currents are implied in the application. The importance of the STSE perspective is acknowledged, but the language and terminology is different.

3.3 Pre-service Teachers’ Beliefs about Physics and STSE

Research literature in the area of Science Education indicates that there has been very little examination or focus on physics teachers’ or pre-service teachers’ perceptions of an STSE-oriented physics curriculum (Nashon, Nielsen & Petrina, 2008; Pedretti, Bencze, Hewitt, Romkey & Jivraj, 2008). Yet, “research has shown that there is no school factor more important to learning than the quality of teachers” (Franz, 2010, p. 2).

Most science teachers, currently teaching science in Ontario and those pre-service science teachers about to enter the secondary school system, have probably not experienced an explicit STSE-oriented science curriculum as students, although they may have experienced some issues-based science education. With a change in science curriculum which is now STSE-oriented, what will the impact be on both teachers and pre-service teachers? What challenges will teachers experience? How will prospective physics teachers respond to an STSE-oriented curriculum? These questions frame the following review of literature concerning teachers, pre-service teachers, and their adoption of STSE.

It is science teachers who will bring an STSE-oriented science curriculum to life: “The decisive component in reforming science education is the classroom teacher. . . . Unless classroom teachers move beyond the status quo in science teaching, the reform will falter and eventually fail” (Bybee, 1993, p. 144). Other authors agree: “The studies reviewed . . . suggest that teacher beliefs are a critical ingredient in the factors that determine what happens in the
classroom” (Tobin, 1994, p. 64). And, “some people believe that beginning teachers might be more effective, entering the profession with fresh ideas” (Stigler & Hiebert, 1999, p. 143-144). However, it was also noted “pre-service education, no matter how effective, cannot by itself produce continuous improvement” (Stigler & Hiebert, 1999, p. 158).

Aikenhead’s (2005) article on STSE education research noted three teacher orientations towards adopting STSE: those who will be supportive; those committed to pre-professional training who resist or even undermine STSE; and those who can be persuaded to adopt STSE. Aikenhead also cited many reasons why teachers may be unable or unwilling to implement an STSE curriculum. These include, and are not limited to, lack of resources, unfamiliarity with transactional and transformation teaching orientations, frustration with combining everyday and scientific language, lack of confidence with an integrated content and its assessment and evaluation, uncertainty about the teacher’s purpose in the classroom, lack of support from both inside and outside the school, pressure to prepare students for university and government exams, greater need for cultural sensitivity with some STSE topics, and pre-service teachers’ survival mode (Aikenhead, 2005; Rubba, 1991). When examining reasons why pre-service teachers struggle to adapt to an STSE-oriented curriculum, it has been found that they lack confidence in teaching basic science content and are usually repeating their undergraduate experiences where the focus was on “lecturing pure content” (Aikenhead, 2005; Forbes, 2008; Novodvorsky, 2006; Schwartz, 2002).

A teacher’s self-identity and self-efficacy play an important part in determining which of Aikenhead’s three categories a teacher will gravitate towards (Pedretti et al., 2008). Part of this self-identity is a professional self-identity, developed during the undergraduate years when students are socialized into a particular scientific discipline (Aikenhead, 1994). A determining
factor will be whether the person can move beyond this socialization to examine other views of teaching science that benefit students (Aikenhead, 2003).

In a study by Lumpe, Haney, and Czerniak (1998), that examined science teachers’ beliefs and intentions to implement STSE, the authors found that “[teachers] believe that including STSE in the classroom can develop decision-making skills in students, foster science learning, and provide meaningful applications of science to real life” (p. 17). Although the teachers who took part in this research project felt STSE could benefit students, there was evidence that implementation of STSE depended on external factors and support (Lumpe et al.). They also concluded that “teachers with fewer years of experience possess stronger perceived behavioral control, subjective norms, and intent to implement STSE than their more experienced counterparts” (Lumpe et al., p. 17). This is somewhat contradictory to Aikenhead’s discussion concerning pre-service teachers and new teachers (Aikenhead, 2005). It is uncertain whether this case is data- or individual-specific.

Examining teachers and pre-service teachers’ self-efficacy is also an important element in determining their ability to accept and implement an STSE-oriented curriculum:

In general, science teachers’ self-efficacy influences their overall ability and confidence to implement successful learning programs, as well as their choice of specific instructional practices. Those with low self-efficacy resulting from lack of subject matter knowledge use compensatory strategies. . . . [Those] with high self-efficacy employ instructional strategies that favor academic self-directedness and open-ended problem solving. (Yoon, 2006, p. 15)

Ways of increasing pre-service teachers’ self-efficacy include using cases and case methods that allow for multiple points of entry, through the use of scaffolding (Yoon, 2006). Implementing an integrated module during the pre-service education program which combines a “foundations of education course” and a “curriculum and instruction in science education course” has also proven useful. Basing activities on inquiry-oriented approaches was also
reported to increase levels of pre-service teachers’ self-efficacy (Sherman et al., 2007). STSE multimedia case studies have also been used to introduce pre-service teachers to STSE, and to examine their adoption of STSE based on their science teacher identity (Pedretti et al., 2008). The findings indicated that pre-service teachers felt confidence and motivation towards STSE in the classroom, but would hesitate to teach these perspectives early in their career (Pedretti et al., 2008). Many of the reasons given in this study are similar to Aikenhead’s reasons as discussed above.

Why would teacher identification and self-efficacy be important in the adoption and implementation of STSE by teacher candidates? As described by Forbes and Davis, “Science teacher educators must work to learn more about how science teachers’ thinking about these issues influences practice which, in turn, largely determines the nature of students’ learning opportunities” (Forbes & Davis, 2008, Page number). This is a complex question that also takes into account three types of knowledge a teacher requires: content knowledge (the knowledge of the subject area; for example, what momentum is and how to calculate it), pedagogical knowledge (the knowledge of the connections between teaching and learning), and pedagogical content knowledge (i.e., knowledge of the physics curriculum, instructional strategies, and assessments) (Etkina, 2005). The role of pre-service programs is to assist candidates to develop all three knowledge bases (Wenning, 2007) and then to help the pre-service teachers:

.. adapt, modify, and refine existing science curriculum materials. This authentic dimension of practice can be characterized as a teacher’s pedagogical design capacity or his or her ability to draw on [a] variety of resources to adapt curriculum materials toward constructive ends. (Forbes & Davis, 2008, p. 831)

It can be argued that if pre-service teachers feel inadequate in their level of content knowledge, and/or do not have an opportunity to experience STSE-oriented lessons as part of their pedagogical content knowledge instruction, then this pedagogical design capacity will
suffer. What is the relationship amongst these knowledges and STSE education from the perspective of the pre-service physics teacher? The answers to these questions are complex and vague, with little clarification in the research literature.

3.4 Summary

This chapter has focused on the knowledge and understanding from research concerning the teaching of physics – what is best for students from both the physicist’s and the science educator’s perspectives and points of view. From here, connections were explored between physics and STSE education whereby it has become clear that there is a true connection possible between physics content and the tenants of STSE education.

This connection between physics and STSE could act as the catalyst in moving physics from a gate-keeper science to a gate-opener whereby physics could become more accessible to the everyday student as well as those who wish to move on and study physics at university.

There is some research which has been found that connects physics education and STSE although most of the research literature focuses on science in general and not physics specifically. Finally, ideas, dilemmas, and concerns were discussed, taken from the literature concerning pre-service teacher learning, especially as it pertains to STSE.

In the next chapter, a detailed description of the research methodology and rationale for the model will be given. The case will be described along with an overview of the participants and the various roles of the researcher.
Chapter 4: Methodological Foundations

This chapter describes the methodological framework employed for this interpretive case study. It provides a rationale for the methodology chosen. An overview of the case is given whereby the context (and current course) is described and participants are characterized. Following this, my multiple roles (as instructor and researcher) are examined philosophically, epistemologically, and practically. The literature foundations for the data collection instruments are discussed to help describe and give the background for instruments selected, followed by an explanation of the five stages of the data collection process used for this interpretive case study. Finally, I discuss ethical assumptions, validity, and trustworthiness of data. The chapter closes with a summary.

4.1 Overview of Methodology

To conduct this research, a constructivist paradigm was utilized as a “net that contains [the] researcher’s epistemological, ontological and methodological premise” (Denzin & Lincoln, 2005, p. 24). It is understood that, by using this paradigm, a relativistic ontology is acknowledged where multiple realities exist. It also adheres to a subjectivist or transactional epistemology where the “knower and respondent co-create understandings” (Denzin & Lincoln, 2005, p. 24). It could also be argued that the epistemology for this particular research is also partially interpretive since the “knower and known interact and shape one another” (Denzin & Lincoln, 2005, p. 22). Typically, this paradigm is said to use a naturalistic set of methodological procedures, which are set in the world. Often these include pattern theories (Denzin & Lincoln, 2005). In this research, I employ an interpretive case study design in my research (Novodvorsky, 2006). This type of case study is,

…an examination of a specific phenomenon, such as a program, an event, a person, a process, an institution, or a social group. The bound system, or case,
might be selected because it is an instance of some concern, issue, or hypothesis. (Merriam, 1988, p. 9)

The specific phenomenon this case study examines and explores is the views, adoption issues and challenges, and perception and attitudinal changes physics pre-service teachers face as they consider a physics curriculum that explicitly emphasizes an STSE orientation to physics education. In order to make ‘sense’ of the data collected during the study, I will use a constant comparative method for data analysis. This will be discussed in later sections within this chapter.

4.2 Rationale for the Interpretative Case Study Model

This research is rooted in qualitative case study methodology. This means it is focused “on discovery, insight, and understanding from the perspectives of those being studied and offers the greatest promise of making significant contributions to the knowledge base and practice of education” (Merriam, 1998, p. 1). Here, ‘those being studied’ are the physics pre-service teachers who were enrolled in a curriculum and instruction course within a faculty of education in Ontario during the 2008-9 academic year. The ‘knowledge base and practice of education’ is the understanding and adoption issues faced by these physics pre-service teachers as they consider an STSE-orientated secondary science curricula. It is hoped that this research will add to the knowledge and literature base of both pre-service teacher education and STSE education. As Yin describes, “a case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident (Yin, 1994, p.13, as cited in Merriam, 1998, p. 27).

This case study work is also characterized as interpretive research. According to Merriam (1998, p. 4), interpretive research is “considered to be a process … understanding the meaning of the process or experience constitutes the knowledge to be gained from an inductive,
hypothesis- or theory-generating mode of inquiry.” An interpretive research model is highly applicable for this research project since the pre-service physics teachers will be, over the course of their bachelor of education program, developing, changing and challenging their understanding of physics curricula, the meaning of STSE, appropriate teaching strategies, and how to make science (physics) meaningful for their students. It is a process that takes time and constantly evolves. By investigating the process that pre-service physics teachers go through to understand and bring meaning to an STSE oriented physics curricula, the research community will be better able to address concerns which may arise from this group and future groups of pre-service science, specifically physics, teachers.

Further, “multiple realities are constructed socially by individuals” (Merriam, 1998, p. 4). These multiple realities, voiced by the participants through the qualitative data, are helping to understand and explain the meaning of the social phenomena with as little disruption of the natural setting as possible” (Merriam, 1998, p. 5). The complex meanings of STSE and how these pertain to teaching physics is voiced through the pre-service teachers’ experiences within the course, previous learning opportunities that influence their perceptions, and their practicum experiences as they move through the course. As suggested by Merriam, “it is assumed that meaning is embedded in people’s experiences and that this meaning is mediated through the investigator’s own perceptions” (p. 6). If we accept Merriam’s suggestion, then the experiences the physics pre-service teachers had prior to the bachelor of education program (for example at both the high school level, as students, and from their own undergraduate experiences) along with those during the program (their perceptions of what it means to learn and teach physics in today’s society, to teach an STSE-orientated physics curriculum, to make connections between
and among their various education classes and to relate their learning to their practicum experience) will serve to bring forth meaning and understanding of and to the research questions.

An interpretive case study model was therefore chosen for a number of reasons. First, an interpretive case study presupposes use of a relatively small number of possible participants, in a bound system. This research includes a predetermined number of participants (non-random) who are in a closed, bound system, namely the bachelor of education curriculum and instruction senior physics elective course offered at an Ontario university. Second, the method allows for the use of various collection tools—including online surveys, interviews, and focus group discussions. These tools will allow for rich, descriptive qualitative, as well as quantitative, data (i.e., descriptive statistics) to emerge, resulting in valuable and multi-layered analysis and conclusions. Third, interpretive case studies allow for observation and recording of the participants’ growing understanding and development of key concepts and ideas related to STSE as part of physics education. This development is important as the participants’ perceptions and challenges, discussed at the beginning of the study, evolve over time. Within the interpretative case model, triangulation was used between and among data sets to increase the validity and reliability of these findings and progression of participants’ insights and understanding of the research topic.

This interpretative case study is particularistic, meaning that it focuses on a particular phenomenon (Merriam, 1998), specifically, and as stated earlier, the challenges pre-service physics teachers face as they consider a physics curriculum that explicitly emphasizes an STSE orientation to physics education. As Shaw describes, “[one must]concentrate attention on the way particular groups of people confront specific problems, taking a holistic view of the situation…they are problems centered, small scale, entrepreneurial endeavors” (Shaw, 1978, p. 
2, cited in Merriam, 1998, p. 29). This is fitting for this particular research since the group is small (only 11 pre-service teachers) and they are faced with having to understand and teach the physics curricula (published in 2000) during their practica, yet must look ahead to the new curriculum which will be in place in 2008 and implemented in 2009. The same year they began their own teaching careers.

The purpose of employing this type of case study is to “develop conceptual categories or to illustrate, support or challenge theoretical assumptions held prior to data gathering” (Merriam, 1998, p. 38). Further, if little theory exists, then the researcher “gathers as much information about the problem as possible with the intent of analyzing, interpreting or theorizing about the phenomenon possibly creating a continuum or categories that conceptualize different approaches to the task” (p. 38). This will become the basis of chapter 5 where the data analysis is reported and, later, in chapter 6 where findings from the study are discussed and given context.

The next section begins with the particulars of the case. I provide a synopsis of the case, giving details of each of the relevant areas for the interpretative case study. Namely, this serves to give the case study context, and describes those who are involved and play an essential role within this case study.

4.3 Overview of the Case

There are three important areas of consideration when examining this case study; 1) setting the context (although alluded to in Chapter 1, I provide significantly more detail here); 2) description of the participants; and 3) examination of the instructors’ multiple roles paying particular attention to philosophical and epistemological issues.
4.3.1 Setting the Case Study Context

This case study was conducted at a small northern Ontario university, which has a faculty of education. Within this faculty, both bachelor and masters of education degrees are offered. The bachelor of education program has approximately 750 candidates annually, and the program commences in late August and is completed at the end of April. Within the bachelor of education program, candidates are placed within one of three divisions, namely primary-junior for those who wish to teach kindergarten to grade 6, junior-intermediate for those who would like to teach children from the grade 4 to grade 10, and the intermediate-senior division for pre-service teachers who are interested in teaching grades 7 to 12. To be accepted as a candidate into the intermediate-senior division (as this is the division where the research was conducted), candidates must have an undergraduate degree from an accredited university and have two teachable subjects (subjects which could be taught within the publically funded education system).

The research for this case study was conducted with those pre-service teacher candidates who were enrolled in the senior curriculum and instruction course for physics during the 2008-9 academic year. The course was 36 hours in length and met once a week for a 2 hour block. The complete course outline can be found in Appendix I. The learning expectations for the course were in line with the Ontario Ministry of Education’s professional and ethical standards as well as the various provincial science curricular documents. Instructional practice varied to include ‘modeled’ lessons, which were both STSE and non-STSE oriented. They utilized and illustrated a range of teaching strategies for the benefit of the pre-service teachers’ understanding of how to include ‘variety’ into lesson planning and delivery as it pertains to teaching physics. The pre-service teachers were given a schedule of class topics and assignments.
For the purposes of the course, a ‘STSE’ lesson had to meet certain requirements. Those requirements were:

1. The lesson had to be constructed around specific curriculum expectations, which were found in the STSE section of the grade 11 or 12 Ontario physics curriculum guides.

2. Using the model described by Pedretti, Figure 2.2, and STSE as outlined in From Engagement to Empowerment: Reflections on Science Education for Ontario by Pedretti and Little (2008), the lesson had to:
   a) include elements of sciences (sometimes more than just physics so pre-service teachers could experience a ‘physics lesson’ that also had elements of other science areas for a more ‘integrated science’ feel),
   b) consider how the sciences affected the ‘environment,’ meaning both the natural environment and the situational environment,
   c) consider the societal impact of the lesson,
   d) include technology in the teaching and data gathering as well as including a discussion of how technological advances have made the topic of the lesson possible,
   e) include a question or series of questions which went along with the lesson that would require some level of decision making to occur and,
   f) conclude with a discussion of ‘how to act’ and/or ‘possibilities for action’ either verbally in class or in the portfolio entries of the pre-service teachers; i.e., placing the physics content into the student’s environment and providing a social context.

To give an example of an STSE type of lesson, I will describe a lesson entitled ‘Carousel physics’ where the class participated in a fieldtrip to the local carousel. To begin this lesson, the pre-service teachers were asked to form groups to complete various calculations on the carousel such as speed, period, amplitude, phase of the carousel, and to determine a ‘function’, which mathematically described a carousel horse’s motion. They were required to examine and calculate the centre of mass for the carousel as the centre post suspended it and to determine how much weight would tip the carousel. They investigated the electrical and mechanical systems of the carousel to explain how such a small motor could produce the ‘power’ to run the carousel, etc. As a secondary project, pre-service teachers were asked how the carousel could assist with
the teaching of the Coriolis effect and ‘meaning’ of frame of reference. Various tools were used for this STSE-based lesson, including pre-service teacher’s laptops, Logger Pro 3 software, video/digital cameras, duct tape, tennis balls (Coriolis effect), measuring tapes, etc.

Why was this lesson classified as an STSE lesson? First, it looked at the different scientific quantities that could be calculated from the operation of the carousel (the science and physics calculation) as well as being asked ‘what other sciences come into play?’ In other words, integration was important. Secondly, pre-service teachers were given an overview of the carousel and the ‘technology at that time’ by one of the carousel operators and restorative volunteers, as the carousel was built in the early 20th century (the technology). They also explained the history of carousels along with the importance and significance of this particular carousel, its impact on society at the time of its fabrication (1920) and with the local community today (society). Thirdly, the volunteers discussed the environmental impact of the carousel with the pre-service teachers. At the time of its primary operation, it used coal; today it uses electricity and (hopefully) when funds are found, the volunteers plan on converting the operation of the carousel to either wind or solar power (environment). Finally, this can be considered an STSE lesson since the pre-service teachers were able to venture outside of the ‘classroom’ and visit one of the city’s local attractions to view the attraction not necessarily as a ‘tourist’ but as a viable example of science and technology interacting with society in a ‘fun’ and inclusive manner. It also began to address the questions of action and agency in that pre-service teachers were asked to consider the ‘usefulness’ and ‘impact’ the carousel has on the development of ‘community’ – for example, why would this be important and was it a successful venture to bring the community together?
Other lessons, which were taught during the curriculum and instruction physics course, are listed in Appendix J. These lessons have been classified as being either non-STSE or STSE-orientated as described earlier in this section. In all, there were 16 lessons. The pre-service teachers experienced a relatively equal number of opportunities to engage in both types of lesson orientations.

For the evaluation of the teacher candidates enrolled in the curriculum and instruction course, they were required to complete three assignments. The purpose of these assignments was to ascertain the level of pre-service teacher understanding and knowledge of content, pedagogical understanding, and ability and opportunity to experience moving theory into practice. The first assignment was the development and completion of a physics portfolio, which would document their learning for the duration of the curriculum and instruction course. Here, candidates began the collection and refinement of pieces at the beginning of the course, and the final product was due at the end of the course. This assignment was similar to one given in previous years but had required some revisions, on the part of the instructor (me), of the entries to be made by the candidates. Entries included a discussion of the meaning of STSE for the pre-service physics teachers and how this might affect their classroom planning experiences, how PER factored into their classroom experiences, and an overview and write-up of four of the many in-class STSE and non-STSE projects. These projects included ‘Carousel physics’, ‘Water guns and momentum’, ‘Thin lens lab’, ‘Pulleys and levers’, ‘Developing water pumps’, ‘Flight’, ‘Electricity and magnetism’, and others which can be seen in Appendix I, which is the course outline, and in Appendix J, which gives a breakdown of the orientation of each lesson completed in class.
The second assignment was the creation and development of a lesson plan for one period of physics. The lesson did not have to be taught, but the complete lesson plan was to be submitted along with all supporting documentation. This assignment was to be completed on an individual basis. The third and final assignment was the creation and development of a unit of study within the grade 11 or 12 senior physics courses using the new curriculum (Ontario Science Curriculum document 2008) with STSE ideas incorporated in as many lessons as possible. This assignment was completed in pairs or on an individual basis, depending on the preference of the pre-service teacher(s).

As part of this course, pre-service teachers were asked to purchase a textbook by Knight (2004). Although this text is not specifically for pre-service teachers, (it has been written for professors of physics who are instructing first year physics courses), it has a wealth of information in it. This information can be applied to the senior physics classroom by the physics teacher and used as a bridge for those students in the classroom who may be going on into physics as a discipline. In the first part of this text, it offers an interesting approach to teaching physics, which does not involve lecturing. It discusses physics education research and gives the reader the basics of this research field. The text also describes an active-learning classroom – something that many in education advocate. The second part of the text is broken down into the various ‘areas’ of physics, which are encountered in both first year university physics and in high school physics curricula. For each area it gives some background information, possible student learning objectives, pedagogical approaches, and possible use of class time, discussion questions and sample exam questions. As stated previously, although not written for the ‘high school’ student, it is very useful for the beginning teacher, regardless of the level of the student they teach. Interestingly (and perhaps not surprisingly), the text makes no reference to STSE
education. This text was supplemented with readings from Aikenhead, Pedretti and Little, Redish, and a host of websites that were related to the course content in the areas of PER, STSE, computer simulations of physics content, on-line physics teachers’ research journals, etc.

The physical environment of the class varied. Depending on the topic to be taught or discussed, the class would be held in different locations. Most times, the class was held within the science education laboratory at the university. However, the class also used the grounds of the university for activities and lessons, which were more conducive to the outside; fieldtrips were planned to the local carousels and larger spaces were used within the university for motion activities which required ‘room.’

4.3.2 The Participants

A group of pre-service teacher candidates enrolled in the curriculum and instruction physics course at an Ontario university during the 2008/2009 academic year comprised the participants in this study. In this particular academic year, there were 11 pre-service teachers taking this course, 9 male and 2 female. All were Canadian. There was some diversity in terms of ethnic background, education, and life experiences. The following table describes the individuals who chose to participate in the research study.
<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>Age</th>
<th>Ethnic or cultural background</th>
<th>Educational Background</th>
<th>1st Teachable</th>
<th>2nd Teachable</th>
<th>Life experiences prior to B.Ed</th>
<th>Observed interests and characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ben</td>
<td>20-24</td>
<td>Caucasian Anglophone</td>
<td>B.Sc.</td>
<td>Geography/ Biology</td>
<td>Physics</td>
<td>Catholic Elementary teacher 2007-8</td>
<td>Very excitable, curious, willing to dive into any hands-on activity. Sometimes opinionated but was willing to listen and change ideas based on others.</td>
</tr>
<tr>
<td>Colin</td>
<td>20-24</td>
<td>South African Anglophone</td>
<td>B.Sc.</td>
<td>Physics</td>
<td>Mathematics</td>
<td>University co-op placement as a supply teacher/ Travel abroad</td>
<td>Well read, enjoyed calculations but was a “thinker” first, then approached building activities once a plan had been formulated.</td>
</tr>
<tr>
<td>Diana</td>
<td>20-24</td>
<td>Caucasian Anglophone</td>
<td>B.Sc.</td>
<td>Biology</td>
<td>Physics</td>
<td>Drama substitute teacher</td>
<td>Enjoyed both calculations and hands-on activities. Very interested in connecting ideas to society and ethical issues.</td>
</tr>
<tr>
<td>Jeremy</td>
<td>25-29</td>
<td>Caucasian Francophone</td>
<td>B.App.Sci. (Mechanical Engineer)</td>
<td>Mathematics</td>
<td>Physics</td>
<td>Engineer</td>
<td>Oldest pre-service teacher in the class, well respected, quite opinionated, interested in</td>
</tr>
<tr>
<td>Name</td>
<td>Age</td>
<td>Ethnicity</td>
<td>Degree</td>
<td>Subject(s)</td>
<td>Co-op Program/Other Experience</td>
<td>Comments</td>
<td></td>
</tr>
<tr>
<td>-------</td>
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<td></td>
</tr>
<tr>
<td>Jesse</td>
<td>25-29</td>
<td>Caucasian Anglophone</td>
<td>B. App.Sci. (Mechanical Engineer)</td>
<td>Physics, Mathematics</td>
<td>Engineer/ Travel abroad</td>
<td>Hands-on type activities and needed time to consider theoretical aspects. Quite opinionated relating many ideas back to his previous work experience. Enjoyed both hands-on and theoretical calculations. Highly engaged in discussions concerning societal issues and ethics.</td>
<td></td>
</tr>
<tr>
<td>MJ</td>
<td>20-24</td>
<td>Caucasian Anglophone</td>
<td>B.Sc.</td>
<td>Biology, Physics</td>
<td>Outdoor Ed. Intern Supply teacher</td>
<td>Most sports orientated member of the class. Related many lessons back to understanding of various sports/human kinetics. Enjoyed hands-on learning and admitted to needing time to conduct calculations.</td>
<td></td>
</tr>
<tr>
<td>Patrick</td>
<td>25-29</td>
<td>Caucasian Anglophone</td>
<td>B. App.Sci. (Electrical Engineer)</td>
<td>Physics, Mathematics</td>
<td>Co-op program in Engineering (work experience)</td>
<td>Enjoyed the historical aspects of physics as well as the societal and ethical implications. Enjoyed hands-on activities, was comfortable with calculations. Often found</td>
<td></td>
</tr>
</tbody>
</table>
connections between content of the class and Star Trek or other science fiction shows.

Robert 20-24 Caucasian Anglophone B.Sc. Chemistry Physics Research assistant during B.Sc. Somewhat opinionated, the youngest of the class. Sometimes discussed his faith as it pertained to teaching topics/ideas (societal issues and ethics). Interested in hands-on activities and comfortable with calculations. Often saw connections between chemistry and physics.

Seamus 20-24 Caucasian Anglophone B.Sc. Physics Mathematics Personal Banking Representative for RBC Enjoyed both the calculations and hands-on activities. Could see the value of STSE education and was its biggest supporter within class. Made many connections between his own schooling and new curriculum.

Table 4.1: This table describes the participants of the study.
As can be seen in table 4.1, the participant’s pseudonym, age, ethnic or cultural background, teachable subjects, teaching experience prior to the B.Ed program and observed interests and characteristics as seen by the researcher have been given. From the data, it can be seen that all candidates have a completed undergraduate degree from an accredited university. As well, the candidates must have a minimum of three full-year courses (18 credits) in physics at the university level to be qualified to take this particular course. This group of pre-service teachers ranges in age from 23 – 29 years of age. Most have entered the bachelor of education program directly from their undergraduate degree; however, three have returned to change their career paths, two from engineering and one from the banking industry. All of the pre-service teachers within this class have graduated from Ontario high schools, most from urban areas. All of the pre-service teachers are new to the university, where they completed their B.Ed degrees and where this research was situated.

All pre-service teachers who were enrolled in this particular course were informed of the research that would be taking place during this course. They were introduced to the research initiative after ethical approval was granted from both the host institution and OISE. The pre-service physics teachers were informed that participation was completely voluntary; it would not impact on their learning of course material and/or the evaluation of their ability to complete course requirements since all data was collected by a research assistant until final marks were submitted. More will be said about the ethical implications of this in sections 4.3.3 and 4.5.

4.3.3 The Researcher

My role in this research is complex and has both philosophical and epistemological implications, as I have had to assume a variety of roles. I will first explain the various roles I held or, as an analogy, the various ‘hats’ I wore during this research. Then, I will describe the
various personal conflicts and struggles, which I had to overcome with the sometimes competing and overlapping responsibilities, citing the research literature for such cases.

Since the research was conducted with my class, my first role was as the teacher or, rather, the instructor for the course. As such, I was responsible for the development of the course outline, daily lessons, and development of tasks, which would later be completed by the students and evaluated by me. Because I had taught the class prior to the 2008-2009 academic year, I already had a working course outline, lessons and assignments. As with every year, I had revamped the 2007-2008 course outline to better suit the goals of the course, keeping in mind that I would have to address the changing curriculum within the 2008-2009 year. At the time of preparing the 2008-9 course outline, I did not know I would be collecting data and using this course and participants as part of my doctoral research group. Therefore, I prepared the course outline, lesson plans, and assignments with rubrics, as I had done in the past. Because I did not know this would be my research group, the course content was prepared without or with little bias.

Due to the small class size, hiring a ‘marker’ to evaluate the required assignments the pre-service students completed was not possible since funding was limited. Therefore, I was also the evaluator for this course. Again, since I had taught the course in the past, and kept some of the previous year’s assignments, I felt confident in being able to evaluate these without bias. For the new assignment that was added, as part of the evolution of teaching the course and retooling the course, the requirements were mapped out and a rubric created prior to the knowledge that I would be using this course to gather data for my dissertation.

Once the research focus for this dissertation was decided upon, I became the researcher. As such, after consideration of the various relevant research literatures, I examined the course
outline, lessons, and assignments along with the time frame of the course to develop the contents for each of the five phases of the research program. From there, due to being both the teacher and researcher, I requested funding for a research assistant to assist with data collection and to minimize any conflict of interest. This was also a university requirement for ethical reasons. Once funding was awarded, ethics approval was sought and obtained by both the host university and the University of Toronto for this research. Data collection was therefore at ‘arms length’ and I was not aware of who was or was not participating in the research.

As the researcher, I set in motion the various data collection tools, but was not privy to the immediate responses of the participants or the findings of each stage of the research until final marks were submitted. Therefore, I felt at times at the mercy (to some extent) of my research assistant in the collection of data (with respect to artifacts, interviews and surveys) for this dissertation. The only time I would ‘hear’ about their perceptions was when conversations would overflow into class time and I would hear the pre-service teachers making connections and sense-making between what they had read, their conversations with the research assistant and in-class experiences. However, although I felt ‘in the dark,’ I knew that, without these safeguards in place, I could inadvertently create bias affecting teacher candidates’ ‘comfort’ in my class, and obscure the findings. Using a research assistant reduced power struggle issues and helped ensure the anonymity of the participants (Creswell 2007; Gall 2005; Maxwell, 2005; Rubin, 1995). She assisted with the data collection while the course was running.

Because I was the teacher and the researcher, it only seemed reasonable for me to be a participant observer and recorder. In this way, recording my perspective on the progression of the course content, the comments and attitudes revealed during class time by the pre-service teachers, and the ideas and reflections of what I had, as the teacher. By including myself within
the data collection, I was able to record conversations and situations that I would not have been privy too if I had not been in the classroom. The recording of this type of data from the teacher perspective provided a layer of richness that would have otherwise been lost if I had not included it into the data collection. As a participant observer and recorder, I did not to initiate or engage pre-service teachers in conversations that directly related to this research topic. I attempted to listen to their thoughts, comments, suggestions, heated debates and discussions concerning their understanding of the classroom experience I had planned and its relation to a new science curricula and the pre-service teachers development of STSE and PER as it evolved.

Conversations often were sculpted around moving from theory into practice and what that meant for a ‘real classroom physics teacher.’

The following schematic illustrates the complexity of my many roles during this research.

Figure 4.1 The author’s five different roles assumed during this research.
Each of these roles interacted with the participants who were enrolled in the C & I Physics Education course and, therefore, a double arrow indicates the interaction between this group and each of my roles. In addition to the interaction with the participants, there was also interaction between roles, which can be seen in the following schematic. Here the interconnectedness of the different roles is much more apparent, while simultaneously more complex.

![Figure 4.2 The interconnectedness of the five roles I assumed.](image)

With the interconnectedness of each of these roles, I now consider the philosophical and epistemological assumptions. I borrow from the constructivist paradigm, which allows for the “adoption of a transactional epistemology and a hermeneutic, dialectical methodology” (Denzin & Lincoln, 2005, p. 184). It has been suggested that users of this particular paradigm are “orientated to the production of reconstructed understandings of the social world” (p. 184). As Denzin and Lincoln describe (2005, p. 184), “Constructivists value what is known as transactional knowledge and attempt to connect action to praxis by building on antifoundational arguments while encouraging experimental and multi-voiced texts.” This is in keeping with the
ontological assumptions, i.e. the nature of the reality as described by Creswell where he describes “the idea of multiple realities” (Creswell, 2007, p. 17). The idea is that these multiple realities will be reported, as the individuals involved (the participants and myself) in the research will have different perspectives and, each of these perspectives, along with the experiences and concerns, should be voiced. These multiple realities will be acknowledged through numerous quotes and observations noted by both the participants and myself during the research project. These realities are unique to each of the individuals who participated in the study, including myself, and do not remain constant over the course of the study, as the pre-service teachers proceed through their bachelor of education degree. Their ideas and perspectives change, develop and deepen in both the level of understanding and application to practice of what it means to embrace an STSE-based physics curriculum. This research also touches on hermenutics, where one must consider the prior understanding and prejudices that may shape the interpretive process of the participants and myself (Denzin & Lincoln, 2005).

Next, I consider the epistemological assumptions. Here the question, which arises is “what is the relationship between the researcher and that being researched?” (Creswell, 2007, p. 17) From the discussion above, of my multiple roles, this is a highly complicated response. Yet, although heavy in detail, it is best described or labeled as a transactional epistemology where there is both co-creation of understanding occurring as well as an interpretive epistemology where the “knower and known interact and shape one another” (Denzlin & Lincoln, 2005, p. 22). Both of these epistemologies come into play since the relationship between me and the participants was very much a continuous dialogue in the teacher/pre-service teacher candidate relationship. It is through this continuous dialogue that a richness is brought to the data. Emotional aspects, be it passion, confusion, enthusiasm or frustration can be captured, beyond
recordings from interviews and focus group sessions. As Kincheloe and McLaren (2005) point out, in social research:

The relationship between individuals and their contexts is a central dynamic to be investigated. This relationship is a key ontological and epistemological concern of the bricolage (connection); it is a connection that shapes the identities of human beings and the nature of complex social fabric. (p. 320)

This was further reason, and validation for me to document my perspective while ‘wearing so many hats’ during this research project.

4.4 Methods

4.4.1 Literature Foundations for the Data Collection Instruments

This interpretative case study was designed to include both quantitative and qualitative data through the use of online surveys, individual interviews, and focus group sessions. The online surveys yielded mainly descriptive quantitative data from questions using a Likert-scale rating scheme, and some qualitative data from open-ended questions posed, included in the online survey (Gall, 2005). Questions examining identity and ideology are a combination, adapted and modified from those found in the literature including: VOSTS (Views on Science-Technology-Society) developed by Aikenhead and Ryan (1992), TBA-STS (Teachers’ Beliefs About Science-Technology-Society) developed by Rubba and Harkness (1993), and pre- and post- multimedia case study questions found in Pedretti et al. (2008). The focus groups and individual interviews provided rich qualitative data (Denzin & Lincoln, 2005; Gall et. al. 2005; Kamberelis, 2005).

Both quantitative and qualitative data was collected. Quantitative data have been analyzed using frequencies and percentages to help develop possible themes and descriptions and to provide a comparison between this case and those found in the literature (Aikenhead & Ryan, 1992; Gall, 2005; Merriam, 1998; Pedretti et al., 2008; Rubba & Harkness, 1993). However, due
to the small sample size (N = 10), further statistical analysis would have little meaning.

Qualitative data has been transcribed and read and themes identified and compared.

Triangulation between data sets helped identify and compare findings (Creswell, 2007; Denzin & Lincoln, 2005; Mathison, 1988). In the sections below, I describe the five stages of data collection in more detail.

4.4.2 Process of Data Collection

The data collection for this interpretative case study was organized into five stages. Each of these stages allowed the pre-service teacher participants to voice their ideas, perceptions, feelings, and concerns related to teaching an STSE-orientated physics curriculum. Each stage built upon the previous stage and acknowledged and illustrated the development of the phenomena within the context. Because of the possible power struggle involved in the pre-service teacher/professor relationship, a research assistant was hired to assist with the data collection. After final marks were submitted for the course, I reviewed data collected to that date and then completed data collected for stage 5.

The data collection began with the participants being asked to complete an anonymous online survey. In this survey the participants were asked questions concerning demographics, their views of STSE, physics, and physics education. The second stage of the research invited the pre-service teachers to participate in an individual interview conducted by the researcher’s assistant. The first two stages were completed early in the Bachelor of Education program. Participants were then organized into focus groups of four or five as their schedules permitted. Each group met with the researcher’s assistant three times during the year to discuss their understanding, perceptions, attitudes, and other factors affecting their adoption of an STSE orientation towards physics education. At the end of the academic year, the pre-service teachers
were again invited to complete an online anonymous exit survey and participate in an individual exit interview with the researcher (as marks had already been submitted), concerning their perceptions and attitudes towards an STSE orientation towards physics education.

During the academic year, I kept both field notes and a journal of classroom observations and reflections of pre-service teachers’ learning (Creswell, 2007; Gall, 2005; Rubin, 1995) as well as my own journal of this research journey.

The data from each of the five research stages was analyzed using the constant comparative method as described by Glaser (1956). This method obtains data via “a combination of observing what is going on, talking in rather loose, sharing, fashion with people in the situation, and reading some form of document that they have written” (Glaser, 1956, p. 436). For the development of this method, Glaser cites the work of Robert K. Merton. As Glaser discusses in his paper, *The Constant Comparative Method of Qualitative Analysis*, typically there are two approaches for analysis; the first being to code data, then to analyze it, and the second being to inspect that data for ‘new properties’ and to write memos of these properties which support the theoretical categories (Glaser, 1956). The constant comparative method uses a combination of these two approaches,

combining, by an analytic procedure of constant comparison, the explicit coding procedure of the first approach and the style of theory development of the second…of joint coding and analysis is to generate theory more systematically than allowed by the second approach by using the explicit coding and analytic procedure. (Glaser, 1956, p. 437)

This method has been specifically designed to

…aid analysts with these abilities in generating a theory which is integrated, consistent, plausible, close to the data, and in a form which is clear enough to be readily operationalized for testing in quantitative research. (p. 437)
It is important to note that this method is “not designed to guarantee that two analysts working independently with the same data will achieve the same result” (p. 438). This may be somewhat worrisome, however “it is designed to allow, with discipline, for some of the vagueness and flexibility which aid the creative generation of theory” (p. 438).

This sense of the creative possibility of theory generation is its strength. It should also be noted that the constant comparative method is “concerned with generating and plausibly suggesting many properties and hypotheses about a general phenomenon (p. 438). Some of these properties may be considered causes, some are considered conditions, consequences, dimensions, types, process and the list goes on. However, all of these, when considered together, will result in an integrated theory. Interestingly, the constant comparative method, according to Glaser, “does not require consideration of all available data, nor is the data restricted to one kind of clearly defined case… [it may include] observations, interviews, documents, articles, books, and so forth” (p. 438) It is also due to this wide range of data formats that the constant comparative method was chosen.

This method of analysis has four stages. They are:

(1) comparing incidents applicable to each category, (2) integrating categories and their properties, (3) delimiting the theory, and (4) writing the theory. Although this method is a continuous growth process – each stage after a time transforms itself into the next – previous stages remain in operation throughout the analysis and provide continuous development to the following stage until the analysis is terminated. (Glaser, 1956, p. 439)

Details of each of these stages can be found in the article by Glaser. He also discusses credibility of the proposed theory, which has been teased from the data explaining the importance of presenting enough material to facilitate comprehension while not confusing the reader or having them feel the theory is impressionistic (Glaser, 1956). These ideas proposed by Glaser predate the original state of the logic of grounded theory given by Glaser and Strauss (1967) as discussed
in Charmaz (2006). It is a return to the original notion of the constant comparative method as described by Kathy Charmaz (2006), whereby she takes a constructivist stance and argues that grounded theory does not have to be ‘tied’ to a single epistemology (Charmaz, 2006). Her stance can be summarized by:

1. The grounded theory research process is fluid, interactive, and open-ended.
2. The research problem informs initial methodological choices for data collection.
3. Researchers are part of what they study, not separate from it.
4. Grounded theory analysis shapes the conceptual content and direction of the study; the emerging analysis may lead to adopting multiple methods of data collection and to pursuing inquiry in several sites.
5. Successive levels of abstraction through comparative analysis constitute the core of grounded theory analysis.
6. Analytic directions arise from how researchers interact with and interpret their comparisons and emerging analysis rather than from external prescriptions. (Charmaz, 2006, p. 178)

This is also my interpretation of the use of the constant comparative method and it has been utilized as such within the literature, for example Boeije (2002).

In all, the constant comparative method has been used between and among data sets. As was previously mentioned and will be elaborated more in this section, there are five stages to the collection of data. In each stage, the questions remained relatively the same (see Appendices for a complete list of questions). By having consistency of questions between stages, the initial belief held by the pre-service physics teachers concerning a physics curriculum, which specifies an STSE approach could be obtained. Then as the pre-service physics teachers moved through the curriculum and instruction course (which contained both STSE and non-STSE lessons), their development, progress, and maturity of perceptions, along with the issues that influenced their adoption or rejection of an STSE orientation of teaching physics, emerged. Since questioning was fairly consistent, comparison between and among the data sets is reasonable. Further,
different data collection techniques were used so as to obtain both individual ideas and group interactions, thereby adding to the richness of the data.

Figure 4.3: A comparison between data sets collected during the research.

**Stage 1: Anonymous on-line initial survey**

The participants of EDUC 4506, senior physics elective, IS Division, Faculty of Education, at a University in Ontario, were invited volunteer to participate in this research by letter, sent by the researcher and delivered to them by the research assistant via their student mail unbeknownst to me (at that time), all students agreed to participate. The first part of this research was the completion of an on-line anonymous introductory survey. Once the pre-service students launched the survey, they were required to read the consent form and to click “Continue.” This action acknowledged consent by the participant for this information to be used in the research. The survey contained 26 questions and was posted on the World Wide Web using an online survey tool, namely, www.surveyconsole.com. The survey was accessible for one week. The survey took approximately 20 to 30 minutes to complete. The survey automatically generated a random identification number for the student so the student remained
anonymous. In the event they wished to have their data removed from the survey, they had to give the identification number to the research assistant. No one asked to have their data removed from this stage of the research project.

The data collected from the surveys was separated into quantitative and qualitative responses. The quantitative responses were analyzed using frequencies and percentages. From the preliminary analysis, the findings and comparisons evolved and they are discussed in more detail in chapter 5. The qualitative responses from this stage, along with all other stages, were analyzed for themes, coded, and compared using the constant comparative method as was discussed previously, using suggestions from Glaser (1956) and Charmaz (2006).

**Stage 2: Individual interviews**

In the second stage of the research project, pre-service physics teachers were asked to participate in an individual interview with the research assistant. Each interview was estimated to take under 30 minutes, was conducted face to face, and was structured. These interviews provided an opportunity for each participant, in a safe and non-judgmental environment, to elaborate on survey responses and served to enrich the data. Furthermore, the interview provided the participants with the opportunity to voice their individual views, experiences, concerns, understandings, and perceptions to help the researcher better understand the participant’s context and to explore the participant’s multiple realities and pre-conceived ideas. These types of interviews are of great value in the collection of rich data since they leave little to chance and non-sampling errors can be minimized (Fontana & Frey, 2005, p. 703). As well, the individual interview technique is one that is widely used in qualitative research, providing powerful insight into an individual’s perception of context (Boeije, 2002; Creswell, 2007; Gall et al. 2005; Glaser, 1956; Glaser & Strauss, 1967; Glaser & Strauss 1977; Maxwell, 2005; Rubin & Rubin, 1995).
After each interview, the audio file was saved and transcribed by the research assistant. It was then emailed to the participant for verification and, when necessary, clarification and correction of any of the points made during the interview were completed. This assisted in the reliability and validity, and trustworthiness of the content of the interviews. I did not read the interview transcripts until after course grades were submitted.

The structure of the interview was typical of qualitative studies (see for example, Cresswell, 2007; and Fontana & Frey, 2005). The participant was greeted, asked if comfortable, and then purpose of the interview explained. The participant was informed that the interview could be stopped at any time and that the participant may also ‘skip’ any questions which (s)he did not want to answer. As well, the participant was told of the security, anonymity, and other ethical protocols common to interviews of this nature. The interview began. Guiding questions for the interview can be found in the appendices.

Stage 3: Focus group discussions

For the third stage of the research, the pre-service teachers, with the support and aid of the research assistant, participated in focus group discussions. These discussions occurred three times during the university year; in December, early February and early April. For each of these meetings, the class was sub-divided into three groups, and an attempt was made to shuffle the pre-service teachers between groups as they proceeded through the focus group sessions. This was in an attempt to reduce ‘group-think’, curb domination of the group, and provide an atmosphere for meaningful and passionate discussion (Fontana & Frey, 2005). At each of these meetings, the research assistant posed semi-structured questions and situations for the group to discuss (Creswell, 2007; Fontana & Frey, 2005; Gall et al. 2005). As discussed in the chapter written by Fontana and Frey, group interviewing, or rather focus groups, can:
…be used successfully to aid respondent’s recall or to simulate embellished descriptions of specific events or experiences shared by members of the group. Group interviews can also be used for triangulation purposes or used in conjunction with other data-gathering techniques. For example, group interviews could be helpful in the process of ‘indefinite triangulation’ by putting individual responses into context. (Fontana & Frey, 2005, p. 704)

The advantages of conducting focus groups or group interviews are many. They are inexpensive and provide rich data, they are cumulative and elaborate, they are often stimulating for respondents and are very flexible in their design (Fontana & Frey, 2005; Gall et al. 2005). It is important to ensure, during focus group sessions, that ‘group think’ does not happen or that domination of one over the group is also discouraged – everyone has a voice and everyone should be heard (Creswell, 2007; Fontana & Frey, 2005; Gall et al. 2005). Further, Kamberelis and Dimitriadis conclude that:

Focus groups are unique and important formations of collective inquiry where theory, research, pedagogy, and politics converge. As such, they provide us with important insights and strategies for better understanding and working through the practices and effects signaled by the ‘seventh moment’ of qualitative inquiry (as cited in Lincoln & Denzin, 2000) with its emphasis on praxis, methodological syncretism, dialogic relations in the field, the production of polyvocal texts, and the cultivation of sacredness in our daily lives. (Kamberelis & Dimitriadis, 2005, p. 888)

When focus groups are used for research purposes, they allow:

researchers to explore the nature and effects of ongoing social discourse in ways that are not possible through individual interviews or observations. Individual interviews strip away the critical interactional dynamics that constitute much of social practice and collective meaning making…. Focus groups can be used strategically to cultivate new kinds of interactional dynamics and, thus, access to new kinds of information. (Kamberelis & Dimitriadis, 2005, pp. 902)

It is for these reasons, so eloquently described by Kamberelis and Dimitriadis, that focus group discussion sessions were included in this research.

The group discussions were audio-recorded and later transcribed by the research assistant. Pre-service physics teachers were given code names to protect individual
identification. The participants were given a copy of the focus group session transcripts to review. This gave the participants an opportunity to verify and, if necessary, clarify their previous comments. Again, I did not have access to any of the data collected until after the course grades were submitted.

Stage 4: Anonymous exit on-line survey

The fourth part of this research was the completion of an on-line anonymous final survey, and it was completed in mid-April. Once the pre-service students launched the survey, they were required to read the consent form and to click “Continue.” This acknowledged consent by the participant for this information to be used in the research. Similar in structure to the initial survey, the final survey contained 17 questions and was posted on the World Wide Web using an online survey tool, namely, www.surveyconsole.com. It was accessible for one week and took approximately 20 minutes to complete. As stated above, the survey was completed to provide balance and a point of comparison with the initial on-line survey – many of the same questions were asked in the final survey as were asked in the initial survey. Also, in the event that pre-service teachers did not participate in the exit individual interview, it would provide some final data as suggested by Creswell (2007) and Gall et al. (2005) of the perceptions held by the pre-service teachers.

The data collected from this survey was separated into quantitative and qualitative responses as was done with the initial survey. The quantitative responses were analyzed using frequencies and percentages. The qualitative responses were analyzed for themes, coded and compared (as was also discussed as part of stage 1).
Stage 5: Individual exit interview and artifact donation

In the fifth stage of the research project, pre-service physics teachers were asked to participate in an individual exit interview with the researcher. This took place in late April, after the course had been completed and marks submitted. Each interview took approximately 30 minutes and was conducted face to face with the instructor, not the research assistant. After each interview, the audio file was saved and transcribed by the researcher. It was then emailed to the participant for verification and, if necessary, clarification of any of the points made during the interview. This assisted in the reliability, validity, and trustworthiness of the content of the interviews.

The structure of the interview was typical of qualitative studies and the procedure found in stage 2 was adhered to for this stage. Guiding questions for the interview can be found in the appendices. This was also considered to be a structured interview, yet when the participant made contextually interesting or insightful comments, I probed for further clarification and understanding (on my part).

As part of the interview, the pre-service physics teachers were asked if there were any course materials from EDUC 4506, which they felt illustrated their learning journey of STSE. If so, I asked if they would like to donate them to the researcher as part of the collection of data, to be returned to them by the research assistant once I completed the analyses. The artifacts that were collected were labeled with the same code name as the transcribed interview. This idea of artifact collection goes back to Glaser’s notion of examination of documentation produced by the participants as a way to further integrate the data collected into an emergent theory (Glaser, 1956).
4.5 Ethical Considerations

This research required the participation of various individuals to divulge information regarding their current attitudes and perceptions of an STSE-orientated science curriculum. It is considered to be a ‘low risk’ with regards to group vulnerability. Therefore, as part of this study, ethics applications were made to the following bodies: University of Toronto: Ethics Review Office, and the Research Ethics Board of the Ontario university where the research was conducted. To ensure anonymity, submitted surveys were given a numerical code, which were made available only to the participant. With regards to interviews and focus group discussions, pseudonyms were used. In this way, the participants would not be able to be identified within the research.

All participants were required to read and sign a consent form to participate in the research project prior to it beginning, then the participants were also required to provide consent prior to beginning the on-line initial and exit surveys, then click to continue to launch the survey. Consent was asked prior to beginning individual interviews and focus group discussions. Any participant had the right to withdraw from the study at any time without penalty; they simply needed to give the researcher and or the researcher’s assistant the identification number for the on-line survey and ask for their interview and/or focus group remarks to be withdrawn. Finally, my relationship to the students needed to be carefully navigated. I was deeply aware of my multiple roles, and any ensuing power relationships. As described in section 4.3.3., I took measures to reduce biases, and/or discomfort on the part of students.

All data has been and will continue to be kept in a locked filing cabinet and/or on a password protected hard drive and will be destroyed five years after the information has been collected. Upon completion of the study and defense of the dissertation, participants will be able
to contact the researcher for a summary of the findings or will be able to visit the researcher’s website for the summary. The researcher will also be available to discuss the findings with the participants either through email, fax, telephone, or a pre-arranged meeting.

4.6 Summary

The methodological framework I used situates this research in a constructivist paradigm, a relativistic ontology and a subjectivist/transactional epistemology. These are in keeping with the use of an interpretative case study as a way of framing the study and understanding the multiple views and voices of the participants. I borrow primarily from the qualitative tradition to collect and analyze data. In the next chapter, I examine the findings with respect to pre-service teachers’ understandings of physics and STSE education.
CHAPTER 5: Physics Pre-service Teachers’ Understandings of Physics and STSE Education

This is the first of two data and analysis chapters, focusing specifically on the understandings the physics pre-service teachers hold about physics education and STSE education. The first section of this chapter will address the physics pre-service teachers’ understandings about physics education and their notion of the characteristics of a ‘good’ physics teacher with regard to their perceptions of how active engagement, applications to the real world, hands-on physics, and calculations and computations in physics play a role within the physics classroom. This will be followed by their understanding and perceptions of what the goals of physics education could and should be along with the challenges they see in being physics educators. This will help address the first research question, namely:

1. What are the physics pre-service teachers’ understandings about physics education?

The second major section of this chapter will focus on the second question and examine the physics pre-service teachers’ understanding (i.e. views) and development of understanding of STSE education. The second research questions is:

2. How do physics pre-service teachers understand STSE education in the context of physics curricula and in their physics curriculum and instruction course?

In order to address this question, initial definitions and transitions of understanding and acceptance as discussed by the pre-service teachers will be noted. Further, as the pre-service teachers moved through their curriculum and instruction course, their acknowledgement of certain cornerstones or currents of STSE developed and became refined. This progression will be analyzed.
5.1 Understandings and Insights about Physics Education

This section centers on the first research question: what are the physics pre-service teachers’ understandings about physics education? Their perceptions of and experiences as physics students in connection with their learning opportunities in the curriculum and instruction course during their B.Ed. program have helped shape their opinions of ‘physics education’. By understanding their views and what has shaped their views, identification of what makes a ‘good’ physics teacher from their perception can be formulated. This is important since as they move forward in becoming physics teachers with a curriculum that has an STSE focus, perhaps different from what they may have experienced as a student, they may either be supportive or find contradictions within this curriculum. From the pre-service teacher’s perspective, this ‘new’ curriculum may connect or be disconnected ideologically with sense of being a ‘good physics teacher’. In this section, I begin by examining what students identify and perceive as the features and/or characteristics of ‘good’ physics teaching.

5.1.1 Characteristics of ‘Good’ Physics Teaching

Pre-service teachers identified different strategies from their own past experiences that would help physics students learn physics and make the learning of physics meaningful and long-lasting. These strategies were considered to be the foundational characteristics of ‘good’ physics teaching from their various experiences at both the high school and university level. These characteristics of ‘good’ physics teaching included: active engagement, application to the real world, hands-on experiences, and calculations and computations in physics. Each of these will be described and analyzed below.
Active engagement

The pre-service physics teachers drew upon a wealth of experiences as they considered their own learning styles and preferred practices which led to a feeling of active engagement within the physics classroom and therefore a deeper understanding of the physics being taught. Each had experienced (a) physics classrooms at the high school level, and (b) a variety of teaching/learning opportunities at the university level as students. From this collection, and in reflection of what “worked best” for each of them as individuals, summaries and conclusions were made individually and as a collective during focus group sessions. Overwhelmingly, they self-identified and described active engagement with content to be the most important aspect of their learning in physics education. For example, Ben commented during the focus group sessions that:

Yeah, I get the numbers and I can do the calculations no problem, but if I can actually see the physics and play with the equipment – I get it. It makes more sense…Sometimes it doesn’t even feel like you are doing physics because you can get into it – it’s real stuff – every day stuff that’s not out of a book!

Ben was not the only student to comment on his desire for active engagement, all pre-service teachers made comments about moving theory or ‘textbook stuff’ into practice whereby they could manipulate or think through problems which combined the physics expectations with their own contexts. For example, Robert commented that:

I think I’m more of a hands-on. Like you can throw numbers at me and I get it, I get the numbers but to actually see them at work is probably the most important part for me…ummm being able to do the experiments and laboratories and stuff like that seeing the actual waves move and stuff like that…that’s real physics!
The notion of being actively engaged was important to all pre-service teachers as they felt that if students can see, touch, feel physics then the subject might be less ‘scarry’ or be seen as ‘more than just a math course’.

Teacher candidates identified active engagement as including lessons that were seen to be applicable to the real world, or laboratory experiences/hands-on activities (which could be considered a form of guided discovery) or discovery learning. Only one pre-service teacher cited that he enjoyed working more with numbers and equations (more traditional problem solving and traditional physics styles) rather than the hands-on types of experiences.

*Applications to the real world*

Pre-service teachers indicated that applying physics to real world problems was their most preferred learning strategy and this led to being activity engaged in the physics classroom. The connection to using applications or situations from the real world then examining the physics behind the scenario was traced back to when the pre-service teachers were in high school. Examples of their high school experience which used this strategy and that were communicated during the research included:

a) the balancing of buckets of water to examine torque (MJ and Diana),
b) understanding the motion of a projectile fired from a potato gun (Adam),
c) building bridges to determine the best design for maximum load (Ben),
d) a fieldtrip to better understand the ‘thrill’ of roller coasters at a local roller coaster park (Robert and Jesse),
e) viewing part of Apollo 13 and then trying to determine a viable solution to get the men back to Earth (Jeremy) and
f) analyzing the physics used in other movies and television programs to determine it’s ‘correctness’ (Seamus, Colin and Patrick).

Each pre-service teacher could remember their physics teacher connecting the physics they were learning to a real world application showing the relevancy of the concept being taught. Further, each commented that it was not only themselves that found this useful, but that (in their
opinion) their fellow classmates also benefited from these lessons where real world situations were examined to show the physics being used in context. However, from discussions with the pre-service teachers it should be noted that this did not occur everyday in the high school physics classroom, and in Ben’s case, it was rather infrequent for the teacher to include ‘real world applications’ and even more unlikely at the university level.

What is important to note here is that although there were differences in the extent to which preservice teachers actually experienced an “applications to the real world” emphases in their prior schooling, it was identified as central to effective and engaging physics education. For example, Ben commented:

Well, grade 11 we didn’t get taught much, that’s the honest truth, he did not teach us much at all …so I didn’t learn nothing. But the next year, the teacher we had in grade 12 had an understanding that we did not have the best teacher the year before so we actually got taught. It was, I would say about 80% content driven, where we were given problems on the boards and we would be given mathematical problems to solve and we did have some experiments – we did have the optical light one where light refracts and we did waves – so we did some experiments but it was content driven because we were in a smaller school so the funding wasn’t there so we couldn’t do exciting labs – it was more like a math class…. [In university], I only had one physics course that I had first year that had a lab component to it – otherwise they were content driven. They tell you it was like this and you think, ok, memorize this or know what this formula means so it was not too exciting. Probably the most exciting physics course that I did take was “sports physics” was probably not a ‘real physics’ course but you learned how a baseball curves and a lot of sports aspects – how a slap shot works and a lot of cool things and I think if you bring that into a grade 12 curriculum, I think kids would be real interested in that.

Interesting points from Ben’s response include the high percentage of his grade 12 physics course that was content based, possibly due to the fact that the grade 12 teacher was attempting to ‘catch up’ from content not covered in the previous year. It is unknown why the school was poorly equipped, as Ben suggested, resulting in fewer laboratory sessions being conducted or it may have been due to feeling that with limited time, more content could be covered through direct instruction. These two aspects discussed by Ben turned a physics class into a mathematics
class in Ben’s opinion. Therefore, when Ben went to university, physics courses without laboratory components were completely normal. In his discussion concerning “sport physics”, it is interesting to note that he did not view this as a “real physics course” as it deviated from his previous learning experiences. However, he found it very interesting and thought points from the course could be integrated into the grade 12 curriculum and be of interest to the students, i.e. “kids would be real interested in that”.

Jesse’s experiences in high school physics and university physics was not as “mathematically based” when compared to Ben’s. Jesse described a high school physics classroom that included ‘traditional’ teaching styles, laboratory work, and applications to the real world. Jesse describes his teacher:

…he would describe concepts, he would ask a lot of questions like ‘what does that mean’, ‘why are we doing this’ … you had to think about the problems and labs in real terms and he stress that a lot – understanding the concepts and for him, the math was important.

Here, the meaning of the physics was important along with how the physics related to the context. This ‘meaning’ would venture into the notion of the application of physics to the real world as seen by the students. When Jesse continued his studies at university, it was a very different experience:

Yeah, it was awful … it was absolutely awful so the fact that there was so much hands on in high school versus in university where it was complete theory – even when it was review and I knew what he was trying to say… yeah, it was very boring. I regret that I didn’t just stay home and read the textbook and do it on my own instead of going to class everyday… that’s what my friends did… and they got better marks.

An important point should be noted in Jesse’s comment – the acknowledgement that his high school experience was ‘hands-on’ and used real world application yet his university experience was not – it was “boring” and class time seemed to be “a waste of time”. Jesse was able to
overcome this shift in teaching style through his knowledge and understanding and his own work ethic, but how many would not be able to overcome such a transition? This discontinuity between high school and university teaching styles could impact high school students who are doing well and who want to take physics at university. How can the university inspire them to continue their study? This point will be revisited later in the section on the goals of physics education.

In Patrick’s high school experience, the inclusion of history was used to help place the content in perspective, i.e., real world applications from a historical perspective, during his high school physics courses.

Patrick:…our teacher saying ‘ok this is what we are going to learn about today’, he gave maybe a little bit of a history or background or story then he essentially derived the equations on the board based on what we had already learned in the previous classes – take what we had – formulas – derived new ones from that, do a few examples and then generally we would be given some questions from the text book that we would spend the rest of the class doing. But, when I got to university it was pretty much all derivation as far as I remember… a few examples… but we would spend entire classes sometimes just deriving formulas – very little history – which is something we did talk about occasionally in high school which I found very interesting too because it puts everything in perspective, I found.

Again, adding a historical component to lessons was another way to engage students in learning about the physics, similar to the experiences of Ben and Jesse in that physics was applied to real world events or situations. Yet, as in the previous quotes, the teaching styles at the high school level varied from those at the university level. For Patrick, not including historical elements as was done at the high school level, Patrick felt less engaged in the university physics setting.

In Robert’s situation, the content at the high school level was being covered using both traditional teaching methods and through ‘doing science’ whereby content (theory) was
transferred into practice (laboratory or demonstrations) with application to the real world. As Robert describes:

…Like in university but obviously university is very lecture style like there wasn’t really very much experimentation. In high school in grade 11 and 12 was a lot of hands on. Both teachers I had were very good at being hands on umm. Bringing manipulatives in… like I don’t think there was more than 2 days in a row where there wasn’t a manipulative in the classroom like air tracks, ripple tanks and all that stuff… ever day we were doing something hands on that applied to the real world. I loved it! That’s why I took physics at university!

His university experience was similar to Ben’s, Jesse’s, and Patrick’s experiences and somewhat disappointing in that classes followed the traditional lecture style, with little applications to the real world.

Moving from the examination of the pre-service teachers’ high school experience into their university experience, typically they found that less active engagement activities were experienced and, for them, the physics classroom became more of a ‘mathematics class’. The pre-service teachers did not seem to fully enjoy this change of pedagogy yet they knew that this was the norm for university physics and did not question it.

Pre-service physics teachers’ felt that their engagement within a physics classroom did not stop at the end of their undergraduate experience but rather continued into their bachelor of education program through the following lessons: building a water pump, investigating a carousel, experiencing a hovercraft lesson, participating in a Rueben’s tube and sound activity, investigating the muzzle velocity of a watergun, and engaging in a pulleys and levers lesson. The following table lists the pre-service teachers and the lessons they felt were to be ‘real world applications’.
Table 5.1 : Activities considered to be ‘applicable to the real world’.

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<thead>
<tr>
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<th>Building a water pump</th>
<th>Carousel physics</th>
<th>Hovercraft lesson</th>
<th>Rueben’s tube and sound</th>
<th>Watergun &amp; Momentum</th>
<th>Pulleys &amp; Levers</th>
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<tbody>
<tr>
<td>Ben</td>
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<td>Robert</td>
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<td>Jesse</td>
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<td>Colin</td>
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<td>Adam</td>
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<td>Jeremy</td>
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<td>Seamus</td>
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</table>

These lessons connected to the ‘real world applications’ – seeing physics in the world around them. The pre-service teachers’ cited the above lessons as, in their opinions, being highly applicable to the real world. These comments were made early on in the research, prior to any consideration that these lessons might be more than just real world applications.

Each of the lessons (from my view as the instructor) was rooted in the application of physics to the real world. These lessons (again from my perspective) were also STSE orientated. For example, the building of a water pump was an examination of hydraulics and pressures to move water via the pre-service teacher built hand-driven water pump. Here the history of water pumps was examined and discussed along with the need of fresh drinking water and the ramifications which occur when access is limited or denied (political and societal impacts).

Carousel physics was a field trip to the local carousel where the motion and electrical systems of the device were investigated along with the historical significance and technological advancements made to the device. In this lesson there was an examination of the historical
component of the carousel, the societal component, and the necessary community involvement to
restore the carousel.

The hovercraft lesson dealt with the notion of flight and experiencing ‘frictionless’
motion. This lesson focused on the historical perspective, the technological advancement, and
societal impact of this technology. It was based on previous research and classroom activities
discussed in Laronde and MacLeod (2012). The Ruben’s tube lesson examined how and why
sound waves generated from a computer can be visualized using the Rueben’s tube with
applications to compressions, rarefractions and wave patterns of gases.

The water gun and momentum lesson required the pre-service teachers to calculate the
muzzle velocity of a water gun as described in (MacLeod, 2007) and connect this value to their
sense of toys being safe. Here ethics and personal values were discussed along with consumer
product information and child safety regulations – for example, who decides what is ‘safe’?

The levers and pulleys lesson concentrated on understanding the 3 classes of levers and
then performing experiments and calculations with various orientations of pulleys to determine
the work relationship a well known mathematical relationship but not extensively ‘experienced’
or applied to the real world by this group of pre-service physics teachers. The role of pulleys and
levers in the development of civilization was discussed.

It was interesting as the instructor to listen to the pre-service teachers comment during
classstime about what constituted a ‘real world’ problem and application – where was the STSE?
How much of a role it needed to play in the lesson for it to be labeled as an STSE lesson. The
conversations and debates allowed me (as the observer and instructor) to see first hand that the
pre-service teachers were beginning to formulate their own ideas and perceptions of STSE and
real world applications concepts along with revisiting some of the physics content they would eventually be teaching.

The majority of comments regarding why these lessons were singled out centered on the idea of being able to ‘see’ the physics in action – having the content placed in context. Further, these lessons went beyond the notion of showing or getting the pre-service teachers to see how the content could be taught using an application to the real world. The pre-service teachers were encouraged to examine and question how ethics, values, history, role of technology, and impact/benefit on and for society, (i.e. safety standards for children’s toys when considering the water gun lab, or the implications of helping villages have town water pumps and a discussion of the notion that if access to clean water is controlled then a village can be controlled).

These discussions took the average physics lesson from being content driven to providing a connection between content and context, and provided a scaffolding for students to engage in the content in a way that STSE literature suggests (Pedretti & Little, 2008; Aikenhead, 1994; Aikenhead, 2005; Sadler, 2006; Hodson, 2006; Ratcliff, 1997; Roth, 2004). This led to pre-service teachers questioning if, as teachers, teaching the physics concepts and subsequent equations is where our role (as teachers) should end or do we have a responsibility as science and physics educators to engage and push our students further than the ‘status quo’? These issues and lessons will be discussed further in section 5.2, which focuses on STSE education in the context of physics.

**Hands-On**

Similar to the notion of applications to the real world which was just discussed to understand physics concepts, pre-service physics teachers also found that ‘doing physics’ (an extension of what Hodson (2000) described as ‘doing science’), i.e., being able to make
something and then complete measurements with it, was also an important part of “good” physics teaching. It seemed to be, for them, one way to successfully achieve active engagement with the content. As part of their high school experience, many noted that their high school physics teacher attempted to include hands-on activities and/or laboratory sessions. The pre-service teachers also commented about how they enjoyed this ‘hands-on’ type of learning strategy. For example, although Ben did not experience a great deal of hands-on learning he comments:

… you still have to do some obviously mathematical and knowledge work to make up the contents of the part course, I believe, but I really enjoy the application/hands-on part because I believe that students learn through actually designing experiments or even like coming up with their own ideas and clarifying with us because it makes physics a little more exciting. Because, I know when everyone looks at physics they think \( E=mc^2 \) and ‘you guys are the geeks and even more than the math students’ and so it’s not like that and I think that there are actually a lot of interesting concepts in physics but I just think it’s just be taught so dry over the years and that maybe the curriculum has made it this way. So I think that if we could do some really neat things like more experiments with kids in physics it would be something they would really enjoy definitely down the road. We did have the optical light one where light refracts and we did waves – so we did some experiments but it was content driven…

Ben comments that in his opinion, “students learn through actually designing experiments” and “they would really enjoy”, this would be in keeping with Hodson’s notion of “doing science” (Hodson, 2000). Ben also comments that public perception of physics (i.e, hard, boring, only for ‘smart’ people) does not help the cause of learning physics. This echoes Aikenhead’s (2005) analysis of students being indoctrinated into a subject area that is considered ‘hard’ and ‘unattainable’ and therefore the expectations of that subject area are limited. Aikenhead (2005) also suggests that physics has been made so ‘dry’ and that by doing ‘neat experiments the kids would really enjoy doing it.’ Why is this significant? Consider Ben’s experiences during his high school education where there was predominantly little to no active
engagement with the content – the content was taught in a very traditional manner. Yet, despite his own indoctrination into the field of physics, he notes that the dominant pedagogy he experienced was dry and not engaging and that something could be done to change this. In these comments, ‘dry’ meant deriving formulae and applying formulae to the specific problem in the form of pure calculations to solve word problems. The phase ‘neat experiments’ means doing hands-on type activities and applications perhaps related to the real world but certainly with the purpose of engaging students with the physics content and providing a possible context where the physics can have meaning and be used.

In Robert’s case, he experienced a very ‘hands-on’/‘application’ type of high school experience. Recall his earlier words:

In high school in grade 11 and 12 was a lot of hands on. Both teachers I had were very good at being hands on umm. Bringing manipulatives in… like I don’t think there was more than 2 days in a row where there wasn’t a manipulative in the classroom like air tracks, ripple tanks and all that stuff… ever day we were doing something hands on

In Diana’s case, she also enjoyed hands-on type of activities and identifies this as part of “good” physics teaching and learning. Here she equates hands-on with experiments “I like to try things like experiments I think it’s the best way for learning physics, definitely.”

Patrick also agrees with a hands-on learning emphasis for physics teaching. However, for him he would rather do this ‘at home’ so that he can ‘experiment’ on his own – perhaps where he is free from comments made by others and where he is free to think and explore on his own:

I really appreciate the whole conceptual, practical aspects of physics and it’s those things that I like exploring on my own time at home and that I get the most out of it.

When the pre-service teachers were asked about the hands-on components they experienced during their undergraduate degrees, for the most part, they laughed. As with real
world applications being discussed at the university level, hands-on/experiments were not something that was incorporated in the B.Sc. programs for the pre-service teachers. Class time was lecture time and ‘doing physics’ was left to fourth year projects.

Pre-service physics teachers felt that there were a number of ‘hands-on’ activities during their curriculum and instruction course and often commented during class that “This doesn’t feel like ‘doing physics’ even though I know I’ll be teaching this stuff to real kids and I can use this in my classroom.”. This is interesting in that the activities the pre-service teachers completed during their curriculum and instruction course were rooted in the curriculum and STSE ideas, yet they were ‘non-traditional’. Could it be that the pre-service teachers are equating ‘doing physics’ with only what are considered traditional physics experiments? Are they able to go beyond the ‘known’? This course, for many of the pre-service teachers was a return to what they experienced during their high school years and they often chatted about the similarities, yet wondered how they would be able to do the ‘hands-on’ and still get through the curriculum as required. This is reminiscent of the concerns of pre-service teachers given by Aikenhead (2005) concerning purpose in the classroom, pressure to prepare students for university and possible lack of resources including time.

Calculations and Computations in Physics

Hands-on activities and laboratories are interesting but the mathematical aspect of the physics is also a key component of “good” physics teaching. Indeed, not all pre-service physics teachers felt comfortable with either applications to real world problems or completing hands-on activities or experiments. A few felt more at ease when examining physics word problems and determining the outcome from the purely mathematical perspective. For example, pre-service teachers Colin and Adam commented:
Colin: I have to say probably going through the math and seeing how it all falls out…like I like the experiments too but I really like going through the math and seeing how everything fits together yeah and seeing how the physics and the math work out at the end.

Adam: The labs were more memorable but I’m not the best hands on person – I’m not good at learning it that way. I’m fine the other way [theoretical].

In summary, it appears that these pre-service teachers do prefer applications of physics to the real world and hands-on/discovery types of learning situations; however, these experiences seem to be located primarily at the high school level. Further, understanding the content and meaning of concepts as they related to the student’s surroundings was an important part of the high school experience either using it in the ‘here and now’ or placing it in a more historical context.

At the university level, this particular group of pre-service teachers indicated being indoctrinated into the traditional physics realm (as Aikenhead, 2005, described) and although the pre-service teachers were successful at the university level, they did not find this traditional teaching style to be overly engaging. One could describe their university experience as very much pre-PER or rather traditional teaching methods as described by McDermott (1998), Beichner (2009), Harrison (2010), Knight (2004), and Redish (2003) as being ineffective. The reaction to this type of physics teaching may not be surprising since traditional science teaching (at the secondary school level), according to Aikenhead, has three major evidence-based failures, one being, “an ubiquitous failure of school science content to have meaning for most students, especially outside of school” (Aikenhead, 2005, p. 385).

The critical point here is that, specifically physics, have meaning both inside and outside of the classroom, and that students understand the content as well as the application of the content to the context. For the student, it is imperative that the teacher provide context as it is a
highly important and an effective way to engage in higher order thinking. Further, by allowing students, regardless of the educational level, to participate in the act of ‘doing science’ (Hodson, 2000) or in this particular case ‘doing physics’ along with what Hodson described as ‘learning science’ (Hodson, 2000) (here it would be ‘learning physics’) and finally ‘learning about science’ (Hodson, 2000) (for this particular research, learning about physics would be precise), students will be encouraged to make a personal connection to the content through context. Thereby slowly dispelling the notion that physics is hard and unattainable and only for the elite whereby indoctrination is required (Aikenhead, 2005).

5.1.2 Goals of Physics Education

From these glimpses of the teaching strategies and pedagogical practices the pre-service physics teachers experienced in their own high school and university education, it is of interest to understand what these individuals perceive as the aim of high school physics. This is important because if we consider what is being asked of these pre-service teachers as they become physics teachers using a physics curriculum with an STSE focus, how do they reconcile physics and physics teaching (as traditionally taught or experienced) with an STSE lens that includes NOS, decision-making, action and agency – a subject that is no longer as objective as they once thought. As they become teachers, their views and perceptions will undoubtedly inform their own teaching practices. Initially, six main ‘ideas’ or ‘reasons’ for taking high school physics were raised by the pre-service teachers. These are summarized below in Table 5.2.
Table 5.2: Perceived reasons for taking high school.

<table>
<thead>
<tr>
<th></th>
<th>Prepare for University</th>
<th>Understand basic concepts</th>
<th>Create Interest</th>
<th>Not prepare for University</th>
<th>Relevant to everyday lives</th>
<th>Think like scientists &amp; learn to problem solve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ben</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Robert</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jesse</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patrick</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adam</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dianna</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jeremy</td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Seamus</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>MJ</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>5</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

If the frequency of responses is examined, this group would say that the top three reasons for high school physics teachers in teaching physics to students is to (in rank order):

a)  have their students understand the basic concepts,

b)  prepare their physics students for university physics courses,

c)  create student interest and make physics relevant to the students’ everyday lives,

These are understandable goals for physics teachers to have i.e., for students to understand the content, to be well prepared to go to the next educational level and to make the topics interesting and relevant. This is in keeping with Aikenhead’s (2005) and Ziman’s (1980) comments about evidence-based failures in the traditional science classroom. As so eloquently written by Aikenhead, 2005, they are “crises in student enrolment, myths conveyed to students, and a ubiquitous failure of school science content to have meaning for most students, especially outside of school” (385). These pre-service teachers have the same ‘end’ in mind when
considering why students would want to take physics in high school – to try and find ways of increasing students’ level of scientific literacy (as they commented ‘understanding the content’) so that they may be better prepared citizens; having a deeper understanding and appreciation of the intricacies of the world in which they are a member and contributor. However, it should also be noted that the pre-service teachers are also aware that many of the students within their classes will be moving on to university and as Aikenhead (2005) described this is a pressure that may move the pre-service teacher away from STSE initiatives.

Pre-service teachers were asked to describe the goals of physics education at the high school level at different points throughout the entire research project. The reasoning behind asking this question so frequently was to determine if and how the pre-service teachers’ views of physics education were changing as they became more familiar with teaching physics, STSE perspectives in the new curriculum; and their ongoing reflection on their own experiences and students’ needs. At the beginning of the research, pre-service teachers were of the opinion that the perceived intent or purpose of teaching physics should be to teach the concepts and laws of physics (to teach the content), to create a passion or increase interest in physics, to better understand how things work in the natural/real world, and to remove or diminish the misconception that physics is ‘hard’. When comparing the ‘reasons’ and ‘purpose’ for teaching physics, the pre-service teachers gave very similar responses this helps validate their views of the purpose of teaching physics and what the possible goals can be of the physics teacher.

Pre-service teachers were also asked their perceived reason for high school students taking physics to see if there is any connection between what they think the purpose of teaching physics ‘is’ and why the students are in the classroom. It seems that there is some correlation between the two in that they believe that the main reason students would take a physics course is
to ‘understand the basic concepts’ and the intent of teaching a physics course is to ‘teach the content’. The second reason given in respect to why students would take the course is to prepare for university – understandable since these students will be coming to the end of their high school program, and this point also arises in the purpose of teaching physics as the second entry. Preparation also arises later when discussing the implications of using an STSE orientated curriculum and the possible difficulties students might encounter as they move from the high school setting into a university atmosphere, but it was not noted here in an early snapshot of their views.

As the pre-service teachers moved through the course and the research stages, discussion and opinions for the reason/purpose for including physics education at the high school level did not change significantly. What did change was their level of understanding and acknowledgement of possible benefits and challenges of teaching physics courses with an STSE-orientated curriculum and that one of the goals of physics education could be to include more STSE. As Diana commented:

just working with the students and realizing that that [STSE] is the best way to engage them – thinking about real world and real issues and people have opinions and want to share them and then they talk and get engaged.

So, in answering the first research question: What are the physics pre-service teachers’ understandings about physics education? For this particular group of pre-service physics teachers, physics education is about (as Seamus, a pre-service teacher, describes) “connecting the content to the student’s context – the importance, relevancy and implications – a more engaging physics classroom” and that being his goal as a physics teacher and echoed by the others in the class. From here, acknowledging that using active engagement within the class and hands-on type activities whereby students can ‘see’ and ‘experience’ the physics works well and benefits
most students and this is in keeping with the literature (Bloom 2006; Chiappetta, 2006; Kragh, 1998; Redish, 2003; Knight, 2004; McDermott, 1998; 2006; McDermott, Heron, Shaffer & Stetzer, 2006). Physics teachers also need to keep in mind that most students will be going on to university and so they need to consider the possible impact of the high school experience as students continue with their physics learning.

5.2 Understandings and Insights about STSE Education

This section will focus on the second research question, ‘how do physics pre-service teachers understand STSE education in the context of physics curricula and what are the shifts in pre-service teachers’ understandings about STSE education while enrolled in a physics curriculum and instruction course?’. This question is answered at two levels. First, a discussion of STSE at the macro perspective is provided, whereby the notion of understanding STSE and possible goals of an STSE orientated physics curriculum as perceived by the pre-service teachers are discussed. Within this, a clear metamorphosis of meaning and appreciation of the scope of STSE education is evident from the multiple data sources that were collected over time. Following this, STSE education is discussed at the micro perspective whereby connections will be made between the pre-service teacher’s understandings of STSE and the research literature on STSE ‘cornerstones’ and ‘currents’. Here, understandings of how, why and if each of the acknowledged ‘cornerstones’ or ‘currents’ can or should come into play when teaching physics with the possible implications of each. It should be noted that due to the timing of the ‘currents’ paper by Pedretti and Nazir (2011), the majority of the analysis of the data was completed with the notion of ‘cornerstones’ of STSE (as described earlier in chapter 2) and found within the writings of various authors including Hodson, Aikenhead, Pedretti, Lederman, etc. and later the idea of ‘currents’ (Pedretti & Nazir, 2011) was applied.
5.2.1 STSE: A Macro Perspective

Coming to understand STSE and what an STSE-orientated curriculum means is not an easy task when coming directly from a physics or science degree, which was very traditional in nature, i.e., in regards to content covered, teaching styles, and teaching strategies used. Therefore, during the research stages, pre-service teachers were frequently asked about their working definition of STSE and what they felt the goals of an STSE-orientated physics curriculum could and should be. The data for this particular section is discussed in chronological order since it was found that the more the pre-service teachers engaged in discussions concerning the meaning of STSE, learnt about strategies of teaching physics, general pedagogy, pedagogical content knowledge and had opportunities to reflect on lessons that explicitly modeled STSE-orientated physics lessons (from the instructor’s point of view), a deeper, more elaborate understanding of the scope of STSE was gained. It is not surprising that there would be a shift. However, my emphasis is on trying to understand teacher candidates perspectives on STSE and how they begin to reconcile physics education and STSE. It is important to note that not all pre-service teachers were at the same place on this continuum at the same time. This led to passionate discussions concerning what STSE is, could be, should be, and what implications this might trigger.

STSE: A description

One of the first questions pre-service teachers were asked when this research project began was, “In your own words, can you please define or describe STSE education?” To place this in context, pre-service teachers had only been enrolled in the B.Ed program for a few weeks and were just beginning to understand some of the terms/language commonly used in education. After being asked the question, most asked for clarification on what STSE stood for. They were
then told ‘science, technology, society and environment’. At this point, one of two responses was given:

Response A: “I have no sweet clue! Does this mean I fail?”, or

Response B: “Right, it has to do with how physics relates to science, to technology, to society and to the environment.”

When asked to elaborate on response B, the answer was simply restated with the same meaning. It was clear that the pre-service teachers did not have the term STSE in their vocabulary explicitly. Yet, this is not to imply that the pre-service teachers did not have some understanding of STSE. When asked to describe (from either their high school experiences and/or their university experiences) times when the teacher/professor gave them ‘real world problems’ to solve or discuss, each of the pre-service teachers could recall instances whereby they were given the opportunity to deconstruct situations that occur in the ‘real world’ and examined the physics behind the situations. These instances were discussed in the previous section under the label of ‘applications to the real world’. For these pre-service teachers, it seemed that they had experienced STSE-orientated lessons to a varying degree and gave the lessons the label of ‘real world applications’ rather than STSE-orientated lessons. This seems to reflect the application current noted by Pedretti & Nazir (2011).

Another interesting point to consider is that most of the pre-service teachers did not know what STSE meant or it’s implications to teaching in a non-traditional manner. It should be of little surprise that they did not know of STSE as they are new to the teaching profession and may not have examined the curriculum documents prior to entering the bachelor of education program. However, the pre-service teachers do perceive STSE as being important. Why? Is it because it is in the curriculum documents and teachers are expected to teach what is within the
documents? Or is the term STSE just another label for ‘real world problems’ or ‘applications’ – meaning that the label becomes less important then the notion of illustrating to students how to place the physics content into context – by whatever label is ‘in fashion’.

As the research proceeded and the pre-service teachers had an opportunity to examine the ‘new curriculum documents,’ which placed STSE expectations, i.e., “Relating science to technology, society, and the environment” at the forefront of each unit, they started to understand the scope of STSE as was presented by the Ministry of Education of Ontario. They began to make further connections between what they experienced as students to what was being asked of them by the curriculum document. One focus group’s discussion described the new curriculum as:

Robert: Well, it’s gearing towards what I actually started learning in high school which I’m glad they started a bit earlier was just getting us involved… and involving the environment around you. Like doing things like wonderland physics like seeing actually physics and how centripetal force… like seeing stuff in real life applications and seeing the technologies that are coming out because of what you are learning in class. So one thing – in grade 12 we looked at how CDs actually work with the laser and that with all the bumps and grooves so, something like that where it actually relates things back to what we see as students an not just numbers on a blackboard which I understand but doesn’t help me.

Jesse: STSE means to me that the world is not compartmentalized – everything is integrated with everything else so all this pristine physics we are learning must somehow correlate and affect other aspects of society, environment.

Colin: From my understanding, the ministry wants to put more of a focus on how science relates to society, how it influences technology – just what it stands for, it’s not just different things – it’s not just taking science and learning it but put it into context of different things.

Seamus: It seems to me that that is part where we take the physics concepts – just the theory behind it and apply it to real life. I think if kids in high schools have more of a hands-on ‘this is how this applies to real life’ then it would be more interesting for them, easier to stay in it… I think there comes a point where if something is over your head it’s easy to shut it off and stop trying to learn about it if you don’t really understand it or if you don’t see why you wouldn’t understand it… If you, if you know why you are learning about something in physics it makes it easier for you to continue to try to figure
out what is going on. If you are learning about different theories and you don’t know how they apply to anything why bother – why bother learning it. So I think it’s important to apply what you are learning to something so that it has relevancy.

When examining these responses, predominant phrases include:

a) seeing actual physics,

b) real life applications/practical applications – not just numbers,

c) physics is not compartmentalized therefore must correlate, integrate, and affect other aspects of society and the environment,

d) science relates to society and influences technology, and

e) placing physics into context/apply to real life and relevancy.

These are of interest for two reasons: first, a connection can be made between the experiences the majority of the pre-service teachers had during their high school physics courses and STSE education. From their explanations of their high school experiences, they did experience a degree of an STSE-orientated physics course, even if not explicitly referred to as STSE. Secondly, the descriptors used by the pre-service teachers to explain their understandings of STSE touch upon many of the ‘cornerstones’ or ‘currents’. For example, real-life applications, affecting society and the environment, influencing technology, and relevancy. This is in keeping with the various definitions in the literature concerning STSE (Aikenhead, 1994; Hodson, 1993; Pedretti, 2005; Ratcliffe, 1997; Rubba, 1991; Sadler, 2006; Solomon, 1994; Verma, 2008; Pedretti & Little, 2008) to name a few, and parallels can be seen between this and Pedretti and Nazir (2011) discussion of ‘currents’ when examining the application/design, socio-cultural, and socio-ecojustice currents. Similarly, what is not said is also of interest – there is no mention of values or agency or sociopolitical action. In considering values, agency, or sociopolitical action, these ideas reflect a more post-positive vision of science – a shift from transmission to
transformational learning experience. Are these pre-service teachers ready for this shift or is the indoctrination they experienced as students holding them back?

As their views and understanding of an STSE-orientated curricula matured, pre-service physics teachers were able to begin to question the larger scope of this curricula change and the goals of STSE education. For instance, the awareness of a connection between STSE and scientific literacy was cultivated and the cornerstones and currents (Pedretti & Nazir, 2011) of STSE were examined through the focus groups and discussed in class. The following table (Table 5.3) illustrates how their view of STSE shifted as they proceeded through their C&I course. It also speaks of the goals of STSE education from their perspective.

Points of interest from the focus group sessions include connections to society and the ability to “make informed decisions as citizens” similar to the notion put forth by Sadler (2006) (value centred/socio-cultural and perhaps socio-ecojustice current (Pedretti & Nazir, 2011)); the idea of broadening perspectives and discovering new connections, real world applications reminiscent of Future studies (Bell, 1996; Lloyd & Wallace, 2004; Pedretti, 2005) (application/design current (Pedretti & Nazir, 2011)); issue-based – looking at the entire issue (Hodson, 2006; Ratcliffe, 1997; Roth, 2004; Sadler, 2006) (socio-cultural and socio-ecojustice (Pedretti & Nazir, 2011)); and more than just ‘hands-on’ (eluding to all the other currents and not just application/design).
Table 5.3: Responses concerning the participant’s understanding of the scope of STSE.

<table>
<thead>
<tr>
<th>Research Stage</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Beginning of research</strong></td>
<td>STSE allows you…</td>
</tr>
<tr>
<td></td>
<td>• To be able to make informed decisions as citizens</td>
</tr>
<tr>
<td></td>
<td>• Opens doors to career paths</td>
</tr>
<tr>
<td></td>
<td>• Good basic understanding of physics</td>
</tr>
<tr>
<td></td>
<td>• Lets you continue to be a little kid, discovering new connections</td>
</tr>
<tr>
<td></td>
<td>• Broadens perspective – interrelated physics and applying the knowledge/content</td>
</tr>
<tr>
<td><strong>Towards the middle of the research</strong></td>
<td>• Curriculum has some good ideas as to how to incorporate STSE into lessons</td>
</tr>
<tr>
<td></td>
<td>• Science applications that go to other areas of science and sometimes to real world applications</td>
</tr>
<tr>
<td><strong>At the end of the research</strong></td>
<td>• STSE is more than just ‘hands-on’ physics</td>
</tr>
<tr>
<td></td>
<td>• Now I understand the link between physics and society better</td>
</tr>
<tr>
<td></td>
<td>• This seems to be how most teachers taught us but we didn’t have a label for it – we just thought it was good teaching.</td>
</tr>
</tbody>
</table>

Pre-service teachers commented at the end of the course on the following views they have of teaching an STSE based physics course and/or teaching physics through an STSE lens:

MJ: My belief is that the best way to teach is the hardest way to teach but it’s also the funnest way to teach. It’s going to take a lot of work and imagination but it’s more enjoyable for everyone involved and you just have to stay on top of kids who need help with the math part because you’re going to have to take away from that a little bit to do the STSE stuff so you’re going to have to be on your p’s and q’s in terms of assessment and getting on top of stuff like that but it’s the best way to do it.

Here, MJ is noting the future challenges he will face with an STSE based physics course. And, although there will be challenges, he still feels as if it is the best way to teach the content.
Seamus: I think it’s absolutely essential. If you compare any of my comments from previous interviews I’ve always been a proponent of the STSE approach to teaching physics and I feel it would be really redundant to just keep repeating what I have said all along but just the application of it – just tying it to something that the students will actually experience after they leave class and they stop taking physics or if they continue on in university. It’s things that they’re going to see and experience in the world and without making the connection just giving them theories and giving them formulas to use it just a math class. So in physics I think what changes… what separates physics from mathematics is that you’re actually applying it to things and I think STSE is the probably the best and hopefully most efficient way to do that, to incorporate or I guess make the association between the laws of physics and what you actually observe. I think it’s important to use technology, society and environment and it’s important to relate those three, I think that’s a nice kind of way to break it down to what you’re actually applying the science to.

Seamus alludes to the application current as discussed by Pedretti and Nazir (2011).

Jeremy: …I’m very keen on STSE. I’m very keen on maybe bringing in some of the intrinsic curriculum into science so core values about society so respecting society, respecting the environment, respecting energy respecting… You know just the world around us and you can actually incorporate that into the physics classroom courtesy of STSE.

In this comment by Jeremy, he discusses ‘core values about science’. This is in keeping with the values current of Pedretti and Nazir (2011). Jeremy discusses the ‘what’ of STSE.

Robert: I believe that it’s [STSE] the best way to teach physics. …It says something about STSE based physics because it keeps your interest in physics. Like if I just had a dry physics course where it was just equations and math I never would have taken it beyond first year physics in university but I enjoyed it and kept going through it because I got to see some of the practical side – almost STSE like.

Ben: …So you have to be careful with the STSE approach too we’ve got to teach it such that the kids have the capability of explaining how that mechanism works or how the structure works and can relate it to what they’ve learned in the content. They can relate to notes you’ve taught them, the content you taught. I think sometimes what happens, STSE right away I think some teachers might thing ‘oh it’s a period you can throw away and give them popsicle sticks and be like here ‘build a structure’ and have fun’ and you can do that some periods once and a while but there’s got to be a goal at the end for them to understand. They just can’t build a bridge today and now we broke it. If that’s all they learn then that’s not really an STSE to me it just seems like a fun period of arts and crafts for a physics class.
It is clear, as the pre-service teacher’s experienced, interacted with, discussed, and reflected on their understanding of STSE their perceptions of STSE matured. They acknowledged that this type of teaching is going to take work and imagination on their part. Careful attention will need to be given to certain content areas that, although extremely important, may not be the central focus of the ‘new’ physics courses, for example will students still focus on understanding and mathematical problem solving techniques to complete calculations (the mathematical part of physics). Will this be compromised with an STSE-orientated physics curriculum? This is an important question and one that has been discussed in the literature whereby some would argue that an STSE-orientated curriculum is ‘watered-down’ yet STSE supports such as Aikenhead and Solomon would argue that no content is being taught but (perhaps) unlike the traditional method it is being taught in context – benefiting the student and moving the abstract into familiar territory.

Pre-service teachers are acknowledging that there is more to STSE than just an application/design current (Pedretti & Nazir, 2011) and although this is an important current in physics, other currents are also applicable and valued. For example, the values current is discussed here. Later, in the next chapter, the historical, logical reasoning and socio-cultural currents (Pedretti & Nazir, 2011) are acknowledged and discussed by the pre-service teachers under challenges and tensions.

*STSE Education and Scientific Literacy*

As discussed in the literature review, scientific literacy plays a critical role in any science curriculum. Researchers have been asking for some time if an STSE-orientated science curriculum can help promote the level of scientific literacy of all students. The views of the pre-service teachers as they pertained to the role of scientific literacy within the physics classroom
were explored. Further, the pre-service teachers were asked in focus group sessions to discuss how, in their opinion, scientific literacy could be related to STSE:

**MJ:** I think they’re definitely related because STSE is all about what is going on in society and to know that you need to be literate and be able to figure out stuff that’s going on in the world and they are directly related in that sense.

**Seamus:** I think they are directly related. It would be hard for first year physics teachers to make that connection right away because there isn’t a lot out there [curriculum is heavy in terms of number of expectations] and it’s just kind of coming together so I think they are definitely related but it would be hard for teachers to make that connection just because it is a new issue [STSE and scientific literacy] to worry about.

**Dianna and Colin:** Agree.

This group seems to feel that a connection exists between STSE and scientific literacy – a student needs to be able to understand the issues that are brought up in an STSE lesson and in order to do that, they must have some level of literacy in science. Another group of pre-service teachers who met to discuss the same issue took a different stance on any connection between STSE and scientific literacy:

**Jeremy:** I don’t think STSE and scientific literacy are related. I think scientific literacy maybe relates more to being able to problem-solve and understand problems themselves whereas STSE just relates to students’ understanding of science and the world around them. I think they’re two separate ideas/concepts.

**Ben:** …I think there’s some overlap. You have to learn a little scientific literacy to understand the world problems. I think you have to learn some of the concepts before you can actually do some of these labs themselves or create something. So I think there’s a little bit of overlap but at the same time they’re totally different concepts one is just theory-based and the other is more about understanding. I probably contradict myself but they do have to overlap a little bit to understand. So you have to learn a little scientific literacy to understand STSE I think before you can actually do the problems. I think there’s a little bit of overlap.

**Robert:** It’s all about relating science to technology, society and the environment so you need that scientific literacy to be able to actually have that relationship. So you can show a video or something that’s STSE-based to show that there’s real life examples but if you can’t tie that back with at least some of the key terms and show that the Tacoma Bridge
like resonance frequency you do have to know some of the basic terms. So scientific literacy and STSE are linked loosely, but they are.

Jeremy: Well, ok there is some connection but they are not the same thing.

Here, Jeremy, a well respected member of the curriculum and instruction class, and the oldest member of the class, expressed his opinion of no connection first. From here, other members of the group were hesitant to disagree with Jeremy, however Ben eventually did express his opinion of an overlap existing between the two concepts. From here, Robert conveyed his ideas. These two individuals held opinions congruent to those of the first group who met. Jeremy eventually did agree to a point yet stood firm in his stance of the concepts not being the same.

This loose connection between scientific literacy and STSE may give rise to some concern, yet this was not the end of the discussion as the research progressed. In another focus group session:

Dianna: Bringing STSE into the classroom, it will really help with their problem solving techniques and it helps them integrate a whole bunch of different ideas and that goes towards scientific literacy.

Ben: I think STSE and scientific literacy combined will engage the students more. I think scientific literacy itself is not really engaging but when you bring in the STSE, it makes the students more engaged where the students might want to think ‘literacy’.

Dianna: It gives them a theme.

Ben: Yeah.

Another group’s discussion of STSE and scientific literacy included:

MJ: I think scientific literacy is just picking up things that you hear and thinking about them in a scientific context and I think they are directly related as such they are just going from opposite ends one is introducing the concept and tying it back into science and then the other, scientific literacy, is seeing an applied thing and then converting it back to science so they’re definitely related just going through different pathways.
Adam: Scientific literacy does that mean that you can pull out a journal from some physics professor and some university and understand what he’s saying?

Jeremy: I think its understanding key terms and concepts and the fundamentals.

MJ: I think of it as if you hear a news story that involved all those words like you were saying, that you can infer it to the basic meaning and not get lost in the jargon

Jeremy: No, I think that you have to be scientifically literate to apply STSE. It’s the chicken and the egg right? Scientific literacy happens or develops and knowing those concepts and those core concepts you can actually use those to develop STSE through physics.

Colin: I disagree. I think that you can learn them both at the same time. To me I think scientific literacy means that you can read a story and you think critically about it and you think scientifically so you think does this number makes sense based on this information and you sort of interpret what the article is saying and I think you can learn that at the same time as STSE.

Jeremy: I think you need to know the basics before you can apply STSE. But it can be done in conjunction.

Adam: I think they are in a broad sense related. Because if you take the STSE approach you could basically do a whole lab with the students without actually explaining to them any of the properties of what you’re doing and then afterwards go and say okay what did we learn and apply that to definitions and the jargon.

The discussions of these two groups of pre-service teachers give voice to the connection they see between STSE and scientific literacy. Dianna indicates that through STSE, scientific literacy will be achievable since STSE acts as an integration agent between different ideas and skill sets (a very interesting point and in keeping with the notion that STSE can be used to teach content in context without it being ‘watered down’). In the same exchange, Ben sees STSE as a way to make scientific literacy more engaging as it helps give scientific literacy a theme. During this exchange, these pre-service teachers did not specifically define what was meant by scientific literacy.
Yet, the act of defining scientific literacy was a point of contention with the second group. What depth of scientific literacy are we referring to? In this instance, MJ sees the connection between scientific literacy and STSE as a symbiotic relationship – for example, being able to understand the ‘scientific jargon’ used in everyday speech. Adam brings up the idea that scientific literacy may mean the ability to read scientific journals. Jeremy questions which should come first STSE or scientific literacy (highly similar to some of the arguments found in the literature) – he suggests scientific literacy whereas Colin disagrees and feels both can be taught at the same time (possibly getting at the same point as MJ or those comments made by the pre-service teachers of the first exchange). It is encouraging to see that Jeremy has, in this second focus group discussion, acknowledged a connection between STSE and scientific literacy even if he is unsure of how to proceed.

From these conversations, the ideas of the first group could be classified as falling under Roberts (2007) second vision of scientific literacy where he stated that scientific literacy:

…derive its meaning from the character of situations with a scientific component, situations that students are likely to encounter as citizens. At the extreme, this vision can be called literacy (again, read thorough knowledgeability) about science-related situations in which considerations other than science have an important place at the table. (Roberts, 2007, p. 730)

Other authors who have furthered this view (Roth & Calabrese-Barton, 2004; Pedretti and Little, 2008) and even the CMEC in their 1997 report. Overall, then pre-service teachers acknowledge that scientific literacy can be achieved via STSE education, a view echoed by (Aikenhead, 2005) and Pedretti and Little (2008).

The second group of pre-service teachers questions of timing and depth of scientific literacy for physics students. This is a slight shift in thinking from the earlier discussions. It clearly shows that pre-service teachers see the importance of scientific literacy, the possibility of
engaging and enhancing the level of scientific literacy of their future students through the use of
STSE, but they question and are divided and hesitant to describe how and to what extent these
two ideas play out in the classroom setting – similar to their colleagues in academia where these
cconcerns are evident in the research literature.

This was not the end of the discussions concerning scientific literacy and STSE. In this
next exchange between pre-service teachers, they focused on the meaning of the term ‘scientific
literacy’ and to some extent ‘literacy’ in general and they attempted to distinguish between the
notion of ‘content knowledge’ and ‘literacy’.

Robert: Well literacy and STSE, literacy is part of society. You need to be literate. Being
literate gives you a better chance to succeed in society. So when we’re talking about
incorporating science and society….

Jesse: Okay, I think she means science literacy which means specifically in the
vocabulary of science reports and such which is not necessarily what you would need in
everyday society.

Robert: But it’s still literacy so if you’re getting into a science, if you’re going on into
education in science like if you’re going into post secondary education in science literacy
in science yes is important it’s part of the society of being in the scientific society.

Jesse: Would you agree that scientists are a very small niche in society?

Robert: Not really, everyone can be a scientist. Just because we’re not trained scientists if
you don’t have to have degrees, everyone is a scientist. Everyone thinks about things,
everybody does tests and applies the scientific method. The scientific method is applied
across the entire curriculum people just don’t realize that’s what it’s called.

Seamus: You could test somebody’s scientific knowledge just the basic knowledge - do
you understand concepts - you could do that and get a pretty good understanding of how
well they know the topic by giving them multiple choice or fill in the blank test. But the
literacy is more. The scientific literacy is so important because you have thousands of
people enrolled in universities all over the place where you have to write actual lab write
ups about your findings or you have to communicate what your findings are and its
important to be literate so that you can do that and so you can communicate your ideas
because in the classroom you’re being asked things that are already well known by
anyone teaching the subject and its pretty conventional knowledge but when you go
beyond high school, if you find something new for yourself you have to explain how it
works and literacy is very much a part of that because the ability to communicate and
express your findings are just as important as what the actual finding is itself because if
you understand it and nobody else does then it doesn’t do anybody any good. So the
literacy aspect is important because it’s not just filling in the right blanks and circling the
right questions on the test there comes a point where you have to communicate what your
understanding is and that’s where the literacy comes into play it’s very important I think.

From this exchange, Robert feels that being literate means that you will have a greater chance to
succeed in society. Jesse then attempts to define scientific literacy as the vocabulary of scientific
reports, which is not necessarily what everyday society requires. This could be seen as Roberts
(2007) vision 1 of scientific literacy and Aikenhead’s issue with traditional science being only
for those who see themselves as future scientists (2005). However, this idea is quickly refuted by
Robert indicating that we are all a part of a ‘scientific society’. Jesse argues that scientists are a
very small component of society again Robert refutes this in that people may not have the label
of ‘scientist’ but are still ‘doing science’ (as discussed by Hodson (2000)) on a daily basis, using
the scientific method, just not knowing what it is called.

An interesting parallel could be made at this point but was not discussed during the
exchange, using Robert’s insight (just as people may be using science and not know the proper
terminology), the pre-service teachers were exposed to STSE lessons during their high school
experiences but yet did not have a name for it. Seamus is also a supporter of scientific literacy
for all, citing that testing scientific knowledge is one aspect but being able to effectively
communicate scientific understanding is a much more cogitatively rigorous undertaking and
should be the focal point of scientific literacy. This is similar to the findings in the research
literature, for example work by Hodson (1998), Aikenhead (2006), Pedretti & Little (2008), Roth
& Calabrese-Barton (2004), and CMEC (1997).
In the second part of this group’s exchange, there was an attempt to focus the group more on a possible connection between STSE and scientific literacy, if there is a connection, and to describe it:

Patrick: I think they want there to be a connection. The people who are implementing STSE want to have a connection but I think it’s more difficult than they might realize. Scientific literacy is very isolated, it’s concepts and knowing how to do certain procedures whereas STSE is a much broader category so by trying to combine the two you either have to reduce the one to fit in the other or blow one up to fit in the other to get them to match.

Seamus: I think he (Robert) was right talking about society part of it because bringing science as a part of our society that’s where the communication really lies. I would say that they’re related.

Jesse: I feel they’re rather disjointed, science, technology, society and the environment seems more like the broad casual science whereas scientific literacy is more of the specialized scientific career type knowledge of special scientific vocabulary.

Robert: It depends how you define scientific literacy. It depends how serious you take it.

Jesse: My idea of scientific literacy is a science journal or a research paper. Whereas STSE is more something like you might get on the quirks and quarks radio show where they put it in general terms where a lot of people can understand it. It’s more casual. Most people only need a casual understanding of scientific literature. If they can get the problem solving skills and the other general knowledge foundation then generally it’s enough for most people. STSE is more casual and the scientific literacy is for the scientific community.

Seamus: So do you think scientific literacy is only important to people who continue in the academic field? Do you think it’s not important to the 85% of your high school students that are not going to continue.

Jesse: Correct.

In this exchange, Patrick begins by raising an interesting point, ‘they want there to be a connection’, they meaning the Ministry of Education and academics who helped write the curriculum. He sees scientific literacy as isolate and small when compared to STSE education’s enormity. Some type of ‘resizing’ needs to occur if the two are to be combined else one will
overshadow the other. Seamus is still of the opinion STSE and scientific literacy are related – science as part of society. Jesse is of the same mindset from the first part of the exchange and in agreement with Patrick in that STSE is broad and scientific literacy is specialized. Robert attempts to defuse the situation by indicating that it depends on one’s definition of scientific literacy – again this is in keeping with the literature, see Roberts (2007).

Jesse goes on to explain his point that ‘most people will only need a casual understanding of science and STSE provides that whereas scientific literacy is for the scientific community’ almost questioning who science should be for? Seamus was annoyed by this comment and called Jesse on his comment – ‘that scientific literacy is NOT important for the 85% of your high school students who are not going to continue’, and Jesse agreed – this was his opinion. This exchange between Seamus and Jesse is the confirmation for Aikenhead’s (2005) comments regarding the screening out of students at the high school level from secondary science and the role of physics as a ‘gate-keeper’.

The term ‘scientific literacy’ is one that can hold different meanings for different individuals depending on their past experiences. As this group continued to discuss and formulate their own meaning of this term, key components were brought to light including (a) the issue of chosen pedagogy to cover the most content, (b) the meaning of literacy as a teacher, (c) the connection between scientific literacy and the role of terminology, (d) how the scientific method could be brought to the mix and (e) the realization that STSE and scientific literacy is not just for physics courses taught at the high school level but rather is a K-12 initiative.

Patrick: I don’t think the way STSE is being implemented right now will allow students to get that. I think by implementing STSE they’re missing out on some things that they need. There’s only so much material they can cover in a school year and by putting in this they’ve got to take something out or reduce something and I think that losing that is going to diminish their scientific literacy in the long run.
Jesse: When you say literacy are we referring to terminology because they may not be the same thing?

Patrick: Terminology, skills, problem solving abilities the whole package.


Jesse: To do that in science you need to have context you need to know the terminology.

Robert: But it’s more then terminology. It’s a wide range of things.

Seamus: But you can model literacy to your students and you can do STSE-based experiments and labs and you can run through all that and give them a completely based STSE experience with the course and then you can expect them to write a formal lab write-up using scientific convention to make sure that it is an academic paper at the end of the day. You can do both. I really think you can.

Jesse: It obviously depends on the level of the course like college level or university level.

Robert: I think you teach them right away in grade 7. I remember my labs in grade 7 my teacher had us write our hypothesis, our materials, our procedure, our observations, our conclusion. We did actual lab write-ups in grade 7. I mean it wasn’t formal or the best way to do it but we were taught early on that this was the scientific method and you will do this for every experiment you do and I think that falls into the category of scientific literacy.

Patrick: Okay then if we’re following that procedure then we’re assuming that STSE is implemented at a very early age.

Seamus: Which it is now. It’s like kindergarten or grade 1.

Patrick: Ok then if it was gradually begun like from the very beginning.

Seamus: Yes, it [STSE] has to be built on. It’s not just something you can’t just start it in grade 11. It’s not something you can do overnight but it’s something that should be modeled all the way through the education system.

Patrick: Ok I could see that working.

Patrick begins this exchange with the concern of time to cover curriculum. He feels that both STSE and scientific literacy will not be able to be covered and something will have to be left out.

With his concern, a discussion follows, again attempting to define what is meant by the term
‘scientific literacy’. Robert brings up the definition of literacy from language arts. Jesse feels that in order to do that in a science classroom you would need to have context and terminology (perhaps through STSE?). Robert is again frustrated since he sees scientific literacy more than just terminology. Seamus suggests that you can achieve scientific literacy through STSE-based experiments and labs. Jesse brings up the level of the course – college versus university. Robert explains that STSE and scientific literacy is not just something that happens in grade 11 but can be at all grade levels, explaining his grade 7 experiences. Patrick and Seamus then realize that since STSE is brought in at the elementary level, perhaps STSE can be used to model scientific literacy and be used as a method to achieve scientific literacy. This was a clear moment of realization that the student that they will be teaching in their physics courses will have had 10 years of science education prior to their course.

As the teacher, I was surprised that they were of the opinion that STSE had only been introduced in the grade 11 and 12 science courses and up until that moment they had never considered the experiences of the students who they would be teaching. The discussion brought up many of the issues discussed in chapter 2 with respect to scientific literacy, it’s complexity, lack of clear and agreed upon definition and need for discussion to clarify ideas and meanings. Further, it appears that this group of pre-service teachers generally agree that STSE is a way of achieving scientific literacy for their students, regardless of their career paths and that scientific literacy is necessary for a scientific society. This is in keeping with the literature of Aikenhead (2005), Pedretti and Little (2008), Hodson(1998; 2000), Roth and Calabrese-Barton (2006) and the Council of Ministers of Education (1997).

5.2.2 STSE: A Micro Perspective - Cornerstones and Currents
In the previous section, the macro perspective of STSE held by the pre-service teachers was discussed. In this section, I turn to some of the particular components of an STSE-orientated physics curriculum that were specifically mentioned by the pre-service teachers, what these components mean to the pre-service teachers, if and how they should be considered when teaching physics and what possible implications might occur due to examining components, cornerstones (Aikenhead, 1994; Hodson, 1993; Pedretti, 2005; Ratcliffe, 1997; Rubba, 1991; Sadler, 2006; Solomon, 1994; Verma, 2008; Pedretti & Little, 2008) or currents (Pedretti & Nazir, 2011) of STSE within a physics classroom.

*Real World Problems and Issue-based Tasks*

The concepts and content taught in physics are often transferred into what ‘old school’ physics teachers and physicists label as ‘real world problems’. This term is not frequently found in the STSE literature, rather these types of problems are known as “application/design currents” (Pedretti & Nazir, 2011), and the notion of ‘problem solving’, i.e., computational problems which examine content into context, which could include real world problems is discussed in PER literature but the depth of problem is often not well defined. Since the idea of using STSE to teach the content was equated to solving ‘real world problems’ when teaching physics by the pre-service physics teachers, a good starting point was to determine the meaning of this term for pre-service physics teachers.

Pre-service teachers discussed the ‘real world problems’ they experienced while in high school. These problems included: kinetic and potential energy problems applied to roller coasters and the building of a roller coaster; the friction between car tires and the road; shockwaves breaking windows in war zones; elevator problems; Doppler effect applied to planets to show the direction of their movement; car accidents using inertia, moment, elastic collisions to determine
who was at fault (similar to the police); atomic weapons and fission; physics of toys and TV shows; using light to understand how a CD and UPC codes work; and bridge designing and testing. Each of these ‘real world problems’ can be classified under at least one of the STSE currents, and predominantly the application/design current. Could it be that the term ‘real world problems’ from a physics teacher’s perspective is a synonym for an STSE-orientated lesson? And, depending on the extent to which the ‘real world problem’ is discussed and evaluated more then one current (Pedretti & Nazir, 2011) could be present? It could be possible that the issue or stumbling point here is simply that of a difference in terminology between disciplines, i.e., physics and education?

Typically when a physics teacher or professor speaks of a ‘real world’ problem they are referring to taking the concept in question and finding or applying it to a natural setting so that the physics can be seen ‘in real life’ or ‘in action’ so that the students can understand the relevancy of concept – measure its value to them as learners and users of that information. This is as described under ‘aims of science education’ highly similar to that of the application/design current proposed by Pedretti and Nazir (2011) where by they state “practical problem solving, transmission of disciplinary knowledge and technical skills” (p. 35). According to Pedretti and Nazir (2011), one of the shortcomings of this current is its lack of attention to question ‘why’. Perhaps the ideas of ‘real world applications’ and ‘application/design’ are the same but the language used to describe them is different as they arise from different academic areas.

Given that real-world applications/problems are fundamental to physics education, and issue-based to STSE, how did pre-service teachers identify with and understand these ideas? Pre-service teachers were asked early on in the research if they would include issue-based tasks in their physics classes and if so to give an example. This was done prior to any class discussion
concerning issue-based tasks, STSE education, or real-world applications/problems. Therefore, this provided a snapshot of where the pre-service teachers began in their journey of understanding this concept in connection to STSE education. Some did not understand what ‘issue-based tasks’ meant. They thought it was a synonym for classical physics laboratory work, others knew that it was important and somehow related to STSE, but not sure how. These individuals indicated that they would include it, but did not give a reason – only that if it was part of the curriculum then it should be included. Very few attempted to discuss why they would include issue-based tasks. For example:

Robert: I think it’s just important to show students that physics isn’t stuff that is just made up 100’s of years ago its stuff that is happening today. It’s all very real, it’s all stuff you can take a part in right now. There are jobs out there for it.

Colin: I like the idea of letting them know where we use it, how what we learn is applicable and doing that as much as I can so I would definitely do it and as often as I can.

Patrick: It is always good to have practical applications and like I said before – giving a little bit of history kind of puts things in perspective for some of the students. Whether I go full that way, I’m not sure. I have to kind of just try it out and see how it works.

At this very early stage in the research, it was clear that the pre-service teachers did not have a full understanding of what was meant by the term ‘issue-based tasks’ even though, in some of their high school experiences they shared (as was discussed in section 5.1), they had experienced this style of teaching. A common term used by the pre-service teachers at this early stage was the notion of ‘application’ of the physics. Again, we are reminded of the Application/Design current (Pedretti & Nazir, 2011) where the notion of practical problem solving using the transmission of the discipline (physics) knowledge. This is common in physics classrooms especially when examining Classical Physics. Unfortunately, the teacher’s ability to have direct applications and allow students to design and investigate becomes limited as the
course moves into or has topics like Quantum Mechanics and Modern Physics concepts. There are ways around this – especially with the use of technology and access to the Internet in most schools. For example, when considering applications being used to discuss and explore Classical Physics, Patrick brought up the point that history could also be included as an entryway into the physics – this could be considered a fusion between application/design current (Pedretti & Nazir, 2011) and NOS (Lederman & Lederman, 2004). This idea will be revisited in the discussion of NOS.

The combination of real world problems and issue based tasks reappeared as the research continued.

Seamus: I’m having a hard time thinking about what the difference between issued based and real world …

Dianna: Real world you have to take in so many more variables. I think if you were doing an issue it’s just hypothetical but in real world you have to take into account so many more variables and that is really tough at grade 11 and 12.

Colin: I agree.

From this short focus group exchange, it was evident that the term ‘issue-based tasks’ was still confusing in meaning for some pre-service teachers.

However, in other exchanges between other pre-service teachers, different levels of understanding emerged, one in which content and context are distinguished and ideas of activism and integration surface:

Jeremy: I don’t think I can differentiate between them…the similarities are mathematical and probably problem solving. The differences are obviously the content so with real world problems students are engaged in everyday life whereas on the other side we’re maybe looking at social activism and trying to incorporate that into a physics environment. So we’re not only asking kids to think about the world around them but maybe their impact on the world around them and what factors are affecting them other then physical factors and physics itself.
Ben: I’m in agreement with that and I think definitely if you can bring some of these other issues I think you could probably get more student interest…like cancer research that somehow relates to a physics content and other problems that are going on in the world right now…Both will engage the student in the same way but the real world problems students enjoy them but you have to create that little bit of culture into the problem and have it relevant to actual material out in the real world then they can learn some of that integration between a different subject and also solve a problem in physics and I think they’ll actually enjoy the subject a little more instead of doing a straight up calculation problem…The difference is that issue based is a lot harder then a normal real world problem to create because you have to think a little more, actually do a little research and try to create a problem to make it relevant. So that’s probably the difference, it’d be a lot harder to make a problem.

Robert:…It basically comes down to trying to show the students that there is a great world around us and kind of find as many issues that you can that are actually better that you can bring them into the classroom but that’s maybe the hard part.

For this group of pre-service teachers society and social activism emerged as part of an ‘issue-based task/approach’ this would be in keeping with Aikenhead’s (1994) comments concerning STSE filling a “critical void in the traditional curriculum – the social responsibility in collective decision making on issues related to science and technology (p. 49). Further from the literature, we are reminded of Roth’s (2009) comment “we found that knowing more…would expand our power to act, and our endeavor in learning more was inherently motivated in the process (p. 210)

Comments from the pre-service teachers during focus group sessions that centered on issue-based and ‘real-world problems’ included:

Dianna: …Just working with the students and realizing that that is the best way to engage them – thinking about real world and real issues and people have opinions and want to share them and then they talk and get engaged. I’ve seen that on placements.

Ben: And, I think this helped – these focus groups – I first thought it was just all the old labs but you think of the water gun experiment – I’ve never thought of that – so it was revamping a lab that was boring and kids didn’t know what they were doing… I can test out the muzzle velocity of a water gun and then relate it to something – dangers of “toys” and what risks we are willing to accept as a society – what’s acceptable.
Jeremy: …As much as I say it’s bad that we’d be taking away from the analytical side or from the mathematical side I would like to spend more time making physics interesting for kids and I do really like the notion that we could spend more time on STSE and issues.

Adam: I know from my perspective, I’m more interested in showing the kids why the formulas exist and where and how they are useful to the real world.

Seamus: No, my ideas haven’t changed they have only been solidified – I always thought both were important, now I’ve read and understood a bit more and know why they are important to include.

From the comments made by the pre-service teachers, it seems that the notion of getting students to think about the real world and real issues is one way to encourage engagement – to get students talking so that they can share their opinions. Also, having extensions to laboratory findings is a second way to engage students into thinking about issues they may encounter in society – what do the numbers which are generated from experiments mean, i.e., the calculation of a water gun’s muzzle velocity and the consequence of a projectile traveling at such high speeds. Are toys really safe and what do we consider ‘reasonable’ for a toy?

The course readings (as found in the appendices) were also beneficial to some pre-service teachers in better understanding and seeing the scope of issue-based tasks and approaches. Other ideas and reasons for including issue-based tasks and approaches included: making physics more interesting and showing the students ‘why’, ‘where’ and ‘how’ formulas are useful in the real world. It seems that using an issue-based approach, according to these pre-service teachers, provides a useful way to help students see the relevancy and connection between what they are learning (the content) and their every day lives (the context). This is in keeping with the literature concerning SSI, for example when Sadler (2006) discusses how SSI is the bridge between science and society usually examining controversial issues. As discussed by Aikenhead (2006) and Pedretti and Little (2008) values based – an important point as these students take the
next step towards independence and needing to understand science as it affects and effects society and its coupling to values which is discussed later in this chapter.

Pre-service teacher’s perceptions of connections and limitations of real-world problems, issues-based problems, and their understanding of STSE is another interesting aspect. The following comments shed some light on their views:

Dianna: I would say they are a bit related but real world problems are still very over simplified they don’t take into account many of the other issues, whereas STSE, when you are looking at something like hydro electricity the real world problem would be what is the GPE how much is converted into electricity and calculate the efficiencies. STSE would look at the overall impact of having this type of energy production – so it takes into account – really its multi-disciplinary as opposed to just looking at the physics of it…The funny part is – in my class – on my last placement my [associate teacher] told the kids at the beginning of the semester – this class is going to ruin your everyday life because you are going to be walking down the street and you are going to be seeing things and think completely in physics class – how would you describe that motion, what is causing this to happen and it’s true… and that is kind of where I’m at now and you think of everything in terms of physics – really STSE physics - it ruins your life – it’s funny and it’s ok…then the students will be questioning things in a whole new way!

MJ: I think if they’re taught the right way originally then they’re the same but STSE just says give them a real world problem and then make the direct connection between science, society, technology and environment but make the direct connection. If it’s just a word problem and they have to answer it and they don’t make the direct connection then that’s lower on the continuum base then it otherwise would be if you said this is related to the environment.

Adam: …I think in the STSE we’re actually looking more at the problem itself rather then just grabbing those number from the problem and throwing them in the formula.

Jeremy: Word problems are very narrow, STSE problems are much more broad – for example, scientific advancement in x-ray and in MRI. We never would have talked about before we would have said yes we would have said yes this applies to MRI or x-ray but the curriculum actually asks you to go in and talk about what MRI is and talk about x-ray and talk about the impact those inventions had on society. Now we’re talking about how they originated and how they tie into physics and how we and our families are getting benefit from them every day. I think that’s a very different perspective from the traditional word problem.

Seamus: …When you talk about real world issues they’re dealt with in a world issues class in a social science setting so they typically say down with science, down with
progress – a very one sided view because everyone who has education in a world issues class is opposed to these scientific progress so I think science students should be exposed to it on the other side so they also have that education and have debated world issues so when the two sides come together they have some common ground to stand on…I think world issues are definitely related to an STSE-based science class…many of our world issues stem from bio, chem or physics situations.

Jesse: I think STSE is broader then just real world applications would because real world problems generally work in a small closed system and looking at one small event. STSE can be that but it’s also more, it’s the impact on society it’s the impact on the environment which you can’t really quantify in a simple math/physics problem so it’s beyond that there’s more shady areas… so I think they are on a continuum but I’m not sure where to make the dividing line.

Robert: Typically physics class has very clean and simple problems (the students don’t have the math background to handle the real situations). STSE has more to do with wider range of parameters and how it affects society and the environment but then real world problems consider every aspect instead of the overlying feature.

Jesse: If the students can do the math that is involved in the more complex real world problems/STSE types then we could get them to qualitatively answer the questions – that might bridge the gap.

How do real-world problems relate to STSE and issues-based education? Most agree that real world problems exist on an STSE type continuum and where they are on that continuum is dependent on their degree of sophistication in examining issues beyond the physics calculation and making the direct connection to society, technology or the environment. STSE is multi-disciplinary and goes beyond looking at just the physics of the situation - it is more then a word problem which requires a formula, numbers, and basic calculation. Word problems can be very narrow, yet STSE is broad as was discussed previously by Aikenhead (1994) in chapter 2. This multi-disciplinary approach will most likely lead to an increase in student interest (as discussed by Bennett, Lubben & Hogarth, 2007).

It was thought by one pre-service teacher that (as suggested above) STSE-based physics courses could see enrollments surpass traditional biology and chemistry classes as students
would see the connections between content and context. This would mean that physics could go from being viewed as a ‘gate-keeper’ to being an accessible subject with relevancy to all.

Further, issues come into play in most social science streams, yet those students who take physics are often not able to take world issues classes (from the perspectives of the pre-service teachers) therefore, including STSE into physics is highly important, so that (the secondary students) can participate in and debate relevant current issues with their social science peers.

Finally, in returning to the issue of the level of mathematics needed in order to complete STSE based physics problems, the suggestion of providing qualitative instead of quantitative responses was suggested and echoing an idea posited by Nashon, Nielsen and Petrina (2008). This is noteworthy since the physics the pre-service teachers were exposed to as high school students and during their university courses were calculation based. A shift in pedagogy is detected.

**Values**

When examining the pre-service teachers’ understandings and views of STSE the idea of values education emerged. Comments made through the research indicate their support for values education and shed light on the relationship across STSE, physics education, and values education. Comments also reflect some of the challenges, which will be discussed later.

Dianna: You need to be literate in the ethics of science.

Ben: You still have to include the ethics and students have their own beliefs – student opinion and what they think or how they can explain a problem and sometimes everyone sees it from a different point of view – where you might explain something to some one and they might be like ‘oh I didn’t really see it as that’. Like something where …like evolution would be an example in biology – that would be a big example but in physics we don’t cross those barriers as much – but kids might have their own ideas…Like the atomic bomb. I might have my opinion on it and they might have their own opinion so you have to be careful with how you bring that topic up – and that can lead to debates
sometimes if you want to – if that is what your purpose is to get across – else just touch on it and try and stay neutral.

Ben brings up important points concerning values education, i.e., both students and teacher will have their own opinions – their own values and this can lead to debates therefore, sensitivity is required. This was acknowledged in the literature by Aikenhead (2006).

However, Ben does not seem to think the issues of physics are as controversial as those in biology. This is an interesting point as it reflects an understanding of physics as being ‘clean’ and very objective – as Redish (2003) explains “Science must build a clear and coherent picture of what is happening at the same time as it continually confirms and calibrates that picture against the real world” (p.15). Further Ben made no connections between our present day understanding of physics and physics concepts and modern day technologies that can be used for both society’s benefit and society’s demise. Ben’s explanation of ‘values’ is highly similar to how Aspin described values, yet there was no mention of values tied to different cultures nor a clear connection to decision making (Aikenhead, 2006; Pedretti & Little, 2008). Similar points were acknowledged by others, but the conversation went further.

Jeremy: I think we as teachers are supposed to be the moral compass for our students and we should be putting some type of activism or social morality into all of our classes that ties into science and physics in a big way. So absolutely, let’s teach kids to be responsible with everyone especially the energy unit. Conservation of energy needs to be a conversation when learning about electricity and how it’s generated.

Colin: I agree, it has to be cross curriculum in terms of teaching values to students. It shouldn’t just be in a religion class or in just one specific class.

Jeremy: It’s like taking driver’s ed without learning defensive driving.

MJ: STSE by nature has to get back to ethics as such.

Adam: There’s certainly that saying ‘in the name of science’ where we can do all sorts of tests and what other people may consider immoral things in order to advance technology
in science and I think it’s important that students are aware of the effects that technology has on everybody else. So I think it is important.

Jeremy feels that teachers need to be the moral compass for their students and encourage activism or social morality, yet he makes no comment concerning the possibility of a difference in values and/or the possibility of pushing an agenda. Colin indicates that values education should not be limited to just science but it should and could be across the entire curricula so that all students could benefit. Adam brings up the notion that the effect of technology on society is a point that students need to be made aware of and may play a part of values education. These pre-service teachers are also in agreement with the notion of coupling values education and the science curriculum (Pedretti et al., 2008) via STSE (Pedretti, 2005). Interestingly, the pre-service teachers did not vocalize a connection between values education and socio-scientific issues just broad unit topics where values might fit in. Nor did they give examples of teaching strategies, which could be used within the classroom to incorporate values (Pedretti & Little, 2008; Zeidler, 2005). It really reflects the current push to include ideas that teaching is a moral profession and as teachers we have a social responsibility to raise ‘values’ questions.

In another focus group, conversation was passionate and descriptive with the purpose of attempting to situate where and why values education should be taught within the educational system.

Robert: I came through in the Roman Catholic school, the separate school board and I plan on teaching there if I get a chance to down the road. Ethics and morals have a huge part as a whole so whether it be physics or English I believe that values play a key role in all education. I think it should.

Jesse: I’m just going to try not to rant. I very strongly believe if we do not include values in our education we are being irresponsible. However, I feel society today is kind of tying teachers’ hands behind their backs not really letting them teach values. It’s like we’re trying to teach in a moral vacuum and it is a very difficult challenging thing. It is part of the reason that I believe that our society is in decline because of the moral vacuum.
Patrick: I don’t think there’s anything in specific sciences or physics that’s inherently evil so how do you pass these value judgments on to them? You can’t tie it directly to the material you have to tie it to what’s moral.

Here, Patrick is referring to the content directly, i.e., F = ma is “not inherently evil”.

Jesse: Yeah but there are moral consequences to certain actions. Einstein, when people use Einstein’s theories to make the atomic bomb, he said, ‘Wow I should have become a watchmaker’.

Patrick: So do you tell your students okay we’re going to learn about atomic theory but don’t do anything stupid like try to blow up nations with the knowledge I’m going to give you. Is that what you mean?

Jesse: That’s a very flippant way of putting it but essentially they have to think of the moral consequences to their actions.

Although the conversation was heated this is a wonderful example of pre-service teachers exploring the connections between content, values education and STSE. It is an example of the pre-service teachers ‘talking it through’ to come to some common ground on understanding what the curriculum is now asking physics teachers to teach and the implications of this as citizens.

The conversation continued:

Seamus: When I was in OAC and it was time to apply to different programs everyone told me to go into engineering because ‘you like math and science you should be an engineer’ and I’m sitting there in February of my fifth year of high school [Seamus’ fifth year would have been his OAC year] not having any idea what an engineer was. Now I’m not saying you should bring engineering into high school but there should be education on “this is what scientists/engineers do once they finish school” - they build this. How about the environmental impacts of what we do as engineers or as scientists when we decide okay we have to build this or the technological advancements that result because of physics and all the sciences, they have consequences for the rest of the world. They have environmental factors, social factors. The science classroom may not be the best venue for that but it should be taught somewhere in high school …there should be that discussion of “this is science, this is what we do and we always want to strive for progress in society but we should weigh it with the impact with what will happen when we do that”. I never took any classes about the consequence of progress or dealing with the impact of building and engineering. I don’t know where it fits in but I think that values should be connected to physics education for sure I just don’t know where it should happen or when.
From Seamus’ comment above, this is very insightful as he acknowledges that as a high school student, he did not learn about the ‘consequences of progress or dealing with the impact of building and engineering’ yet, as was seen earlier, he along with the other pre-service teachers felt that they did experience a form of STSE education within their physics classroom. Could it be that only certain currents (Pedretti & Nazir, 2011) or cornerstones were discussed in physics? The STSE issues and items which were easy for the teacher to relate to the content, applications and the problems in the text instead of moving discussion beyond the obvious?

Jesse: I remember taking stuff like that in my geography classes and that was completely separate from that. It was a completely different mindset in the geography class than it would be in a physics class.

Seamus: You have all the ‘tree-huggers’ in one class who are learning about this and then you have all the people who are going into science and actually making these changes who don’t know anything about it. It becomes a giant ethics thing and you get people protesting in university and all these science people are thinking ‘what’s their problem’ and they’ve never had a chance to actually consider what the impact of scientific discovery can be.

Patrick: By introducing morals and values into our science classes doesn’t that turn the material into more of a subjective knowledge?

The notion of having ‘subjective knowledge’ within a physics classroom is one that was very disconcerting to the pre-service teachers. By acknowledging ‘subjective knowledge’, physics was moving from a very ‘objective’, black and white, right or wrong type of subject to one whereby opinion and values needed to be considered. This led to working from the known (subjective knowledge and opinion in biology) to the unknown (how to possibly deal with subjective knowledge in a physics classroom as the ‘teacher’) and the responsibilities of dealing with the unknown.
Seamus: It doesn’t turn the material itself, I mean the laws of physics are concrete. You aren’t going to argue with that but you’re going to say “this is what we can do with the laws of physics” but it raises the question of “should we do it?” It’s an ethics part of science I mean in biology class you talk about genetics but where do you ever talk about and have that debate of should we use genetic technology that might happen in a biology class but physics has the same impact on a different level of the world and that’s not addressed anywhere in the curriculum as far as I know.

Jesse: It’s [values education is] more obvious in biology classes

Seamus: It sure is because people have more of an objection to when you’re dealing with human life as opposed to the physical environment

Robert: In chemistry too, they talk about chemicals but never talk about how they affect the environment.

Jesse: I worked at a company that produced methyl amines so just a pure chemical company and it was near a town in southern Ontario so you can just imagine the kind of gross chemicals. The river south of the town, the bed used to be coated with mercury; they had to suck that out. People there have the highest rates of cancer than anywhere else in the country and you have to wonder why? Well, it’s because in the fifties when people wanted to get rid of pollution they pumped it into the ground water then people 50 miles downstream were suddenly getting ovarian cancer in vast numbers.

Seamus: People are more aware of these things now but I don’t think it would hurt to address these things in high school. They do it in biology, they do it in chemistry and I think it could come into play in physics as well.

Overall, the physics pre-service teachers believe that values education is important to physics education and they have positioned this relationship as examining the possible moral, ethical, environmental and societal consequence when applying the laws of physics to different situations. This definition and discussion reflects the value centered, socio-cultural and perhaps the socio-ecojustice currents (depending on the context) discussed by Pedretti & Nazir (2011). Again, ways to include values education pedagogically were not specifically mentioned however there was general agreement that values education might help students become more knowledgeable and able to participate in ‘decision making’ and ‘civic responsibility’.

NOS
When considering the Nature of Science and if STSE is able to engage students’ understanding of NOS, the pre-service teachers made interesting comments throughout the research period, which eluded to their own understanding of NOS and what their expectation might be for their future students. For example, earlier in this chapter, pre-service teachers commented on who scientific writing should be for and if it is appropriate for and reasonable for high school students to understand technical scientific writing or if scientific writing is meant for a larger, broader audience which alludes to a broader understanding of scientific literacy. The question of ‘who is science for’ was discussed. This gets to the heart of who should value scientific knowledge and the development of knowledge (Lederman & Lederman, 2004).

Another example connecting scientific literacy and NOS was during an exchange between pre-service teachers whereby they were discussing the notion of having essay questions on physics tests and how one could mark an essay which might be subjective in nature:

Patrick: Yeah, but even just in marking – so you don’t have teachers taking on a different subjective ideas …

Jesse: But they do that in English every day!

Patrick: But that is the whole thing about sciences is that we are suppose to be objective and so even if we are talking about subjective material there should be a certain amount of objectivity to what we are saying – maybe just stick to the facts kind of thing…

Jesse: As opposed to marking for style…

Patrick: Yeah, because then you can start to have compare/contrast questions. Like write an essay on your physics exam on whether or not Galileo was a hero…

Jesse: *laugh*

Patrick: Do you agree with what the Church did to him at the time or what not… Because then you could start having these huge debates and yeah, they are interesting but I don’t know if they would help advance your physics lesson very far.
In this short exchange, there are many ideas and opinions being voiced. For example, there is the traditional approach of physics teaching being suggested as well as a more progressive approach being voiced. Underlying this exchange is that the pre-service teachers are alluding to the challenges and tensions of going beyond the content, for example in their consideration of ‘marking’ and assessment of students. This challenge will be discussed in the next chapter.

However, returning to another point in this exchange, the notion of an essay concerning Galileo - this is an example of NOS (as well as incorporating historical perspectives). Giving students an opportunity to express what they know of Galileo and how scientific knowledge was generated and then validated is significant. What scientists go through in order to advance science – who is in the ‘right’ and how Galileo’s work impacted science as we know it today – all very relevant and connected to the content of the curriculum.

Further to this, is the question of how to mark or evaluate a question when the answer is subjective? For the most part, these pre-service teachers have only experienced or believed they experienced ‘objective’ types of questions where the answer is either correct or incorrect with little in between reflecting again, the ‘clean’ or ‘objective’ view of science in which they experienced during their ‘indoctrination period’. Yet, with a question as was suggested by the pre-service teacher, ethics, values, strength of argument comes into play – this is now a ‘subjective’ piece which must be evaluated. An uncharted territory for many of these pre-service teachers (which is probably why Jesse laughed), yet subjectivity plays a huge role in how scientists operate on a day-to-day basis and more will be said about this later under ‘tensions’.

Finally, there is the notion of including history in the study of physics. This was a commonly made point for Patrick who indicated on numerous occasions that he enjoyed learning physics and seeing it placed in some form of historical context. Including this is of particular
interest since the study of history, itself, is subjective, further with the development of scientific knowledge and the work of numerous scientists – the knowledge that is generated has affected every aspect of our known world, and history is the record of these occurrences.

5.3 Summary

The focus of this chapter was two-fold. First, it was to discuss the pre-service teachers’ understanding of physics education. In brief, they are of the opinion that active engagement of students within the physics classroom and with the content is the best way for students to achieve success. This active engagement can be through the use of applications to the real world, hands-on activities or through the use of calculations and computations. The main goal of physics education should be to help students understand the basic concepts so that they can better understand the world around them.

With respect to STSE education, I addressed both macro and micro perspectives. At the macro level I found that over time pre-service teachers became aware of the possible scope of STSE education; however, this awareness came after much discussion, reflection and reading. As the pre-service teachers became familiar with the notion of teaching physics using an STSE lens they became much more confident and had greater comfort with the idea of what was now expected of them as ‘physics teachers’ with an STSE-orientated physics curriculum with a design/application (Pedretti & Nazir, 2011) emphasis. There was very little of a transformative or agency emphasis although they did appear to be moving in that direction which given where they were in their teaching career could be seen as very hopeful. At the micro perspective, pre-service teachers were working towards understanding the scope of scientific literacy and the connections between it and STSE education – how the two can be combined or viewed separately. The question of real world problems being issue-based tasks was another obstacle
which pre-service teachers discussed, reflected on and read about before coming to a thoughtful understanding of ‘the continuum’. Pre-service teachers were keen on the notion of teaching values education in physics yet were unsure of how to assess work that is subjective. They all agreed that application/design activities fit very easily into any physics course and openly discussed a variety of times that they had personally experienced activities of this nature.

The pre-service teachers’ understanding of application and design as it pertains to STSE (Pedretti & Nazir, 2011) is quite strong in that there was a great deal mentioned that has been discussed previously in section 5.1 and to an extent in 5.2. Pre-service teachers see the need for including problem based learning under their terminology of ‘real world problems’ and in designing or building artifacts as described by ‘hands-on’ physics which were discussed in great detail earlier in this chapter. Both of these components of this current have been a part of the pre-service teachers’ own high school experiences and in some cases university experiences. Quotes from the participants have been given earlier concerning their enjoyment of completing application and design type activities. Also, they have commented that it is important for students to not only do the calculations but also to see the physics in action.

From my own perspective, and watching the pre-service teachers in class completing various application/design type activities, I would say that the majority of them enjoyed and found the activities to be highly engaging. And, although one would think that after a four year undergraduate degree, any activities based on the high school physics curriculum would be dull or boring – one would be mistaken. There were times of pre-service teachers experiencing the ‘A-HA’ moment where they connected the content into a relevant context. They indicated they supported these types of activities as it gives students a chance to “see physics in action”. There is no question that the pre-service teachers see application and design as a component of STSE-
orientated physics curriculum, as commented by the pre-service teachers in their most memorable physics moments. For example: the balancing of buckets of water to examine torque (MJ and Diana), understanding the motion of a projectile fired from a potato gun (Adam), building bridges to determine the best design for maximum load (Ben), a fieldtrip to better understand the ‘thrill’ of roller coasters at a local roller coaster park (Robert and Jesse), and viewing part of Apollo 13 and then trying to determine a viable solution to get the men back to Earth (Jeremy). Perhaps it is the most recognizable and familiar current as they themselves move into an STSE-orientated physics curriculum.

However, different currents or cornerstones were more problematic as they were more of a stretch from the ‘norm’ experienced by the pre-service teachers and so less talked about. Finally, their understanding of NOS is ‘in progress’ again considering that questions dealing with NOS can be subjective and the issue of assessment arose again. In summary, pre-service teachers seem to be in the ‘developmental’ stages of understanding STSE and the possibilities of moving physics content into context and seeing it through an STSE lens. For example, at times the pre-service teachers have a very good understanding of STSE ideas while at other times there were contradictions. This is consistent with that found within the literature, however, getting to their level of understanding has taken time and has not occurred without heated debate and reflection.

In the next chapter, chapter 6, the focus is on the challenges, tensions and implications for STSE and physics education as perceived by the physics pre-service teachers thereby addressing the third and fourth research questions, namely:

3. What do the physics pre-service teachers perceive to be the challenges and tensions of teaching physics education through an STSE lens?, and
4. What are the implications for the future of physics education and STSE education?

This chapter will also provide conclusions to the research and possible next steps.
CHAPTER 6: Challenges, Tensions, Implications and Conclusions

This is the second of the data analysis and discussion chapters. It focuses specifically on the challenges, tensions, and implications of an STSE-orientated physics curriculum as perceived by the physics pre-service teachers. During the course of this research, pre-service teachers identified a number of challenges and tensions associated with the implementation of an STSE-orientated physics curriculum. The possible implications of these voiced challenges and tensions are also speculated upon, along with suggested strategies to assist in meeting the perceived challenges and tensions. As a result of the challenges, tensions and implications, it then examines how these insights could inform university practice at both the undergraduate level and in bachelor of education programs in the area of science education for pre-service teachers. The first section of this chapter will address the challenges, tensions, and implications as perceived by the physics pre-service teachers as they came to understand an STSE-orientated physics curriculum. It discusses recurring themes acknowledged by the pre-service teachers, namely: resources, assessment and evaluation techniques, and values education. This section will help address the third research question:

3. What do the physics pre-service teachers perceive to be the challenges, tensions of teaching physics education through an STSE lens?

The second major section of this chapter is focused on the fourth research question and discusses how the findings from this research could be used in both undergraduate physics programs and in bachelor of education programs, in particular, addressing the question:

4. What are the implications for the future of physics education and STSE education?

Acknowledgement of the challenges, tensions, and implications of an STSE-orientated science curriculum, specifically a physics curriculum, as perceived by the pre-service teachers is
important as it gives those of us who are either teaching in an undergraduate physics program or a bachelor of education program a sense of the scope this type of change in the orientation of curriculum can have on the entire education system as voiced by the pre-service teacher perspective.

6.1 An STSE-orientated physics curriculum: Challenges, tensions, and implications

There is no question in the pre-service teachers’ minds that an STSE-orientated physics curriculum is ‘good’ for high school physics students. As they moved through their B.Ed experience they commented about the perceived advantages/strengths of teaching STSE-based physics. At the beginning of the research, the pre-service teachers noted that the advantages they saw in teaching an STSE-based physics curriculum were things such as watching students discover new concepts and showing students that physics is practical – doing applications of the content to show the relevancy of physics to the real world. By the end of the Curriculum and Instruction course, the pre-service teachers commented that the advantages included seeing a glimmer of understanding in the student, putting the content into context for the student via application of content and that STSE helps to spark the student’s curiosity thereby taking the content beyond the text and/or the traditional considerations.

As can be seen from the pre-service teachers comments, the shift in the perceived strengths of teaching STSE-based physics was very slight as the pre-service teachers moved through their B.Ed experience. Again, it is important to note what is not mentioned or is lacking in their comments concerning the ‘advantages of an STSE-based physics course’. There is little to no mention of citizenship or responsible action as part of the STSE approach to physics education. In some ways, it appears, as was discussed in chapter 5, that pre-service teachers are holding onto somewhat of a traditionalist view of physics – perhaps due to their indoctrination
(Aikenhead, 2005), yet they know they must come to understand and rationalize what is being asked of them with this ‘new’ curriculum.

However, with change, comes both ‘advantages’ and ‘challenges and tensions’. The main challenge of an STSE-orientated physics curriculum, which was voiced by the pre-service teachers was primarily logistical in nature and resources were their main concern, i.e., the preparation time for lessons, having adequate resources. They also commented on the stigma attached to teaching physics (that it was all formulas and textbook problems to solve) so they felt that others (staff, administration, parents, and students) might have a difficult time understanding why physics was no longer being taught ‘traditionally’. For example:

Robert: It’s more of a resource thing now. You can show all the videos you want but having more hands on resources is great but there’s just no money at this point.

Jesse: I guess it will mostly be up to us to kind of invent material.

Seamus: You want to feed on that [student] interest so that when you get to the next topic and they [students] say well what can you teach us about that topic because there’s got to be something interesting about that. So I think if you kill the interest [meaning not explore a topic via STSE] and just move on [due to time constraints and a huge curriculum]….I think that’s an unfortunate part of that system. In terms of the challenges that you face, if time constraint is not a challenge then just the resources like you said. It’s kind of a new thing and the textbooks aren’t updated. People [teachers] are going to have to share information on the web and share ideas of how to teach certain topics - that may be a challenge. The creativity, trying to figure how to incorporate STSE into every lesson, every day might be a challenge. It’s one that I’m looking forward to that’s definitely going to be a challenge – the time since we’re new teachers and we don’t have a foundation to build on. Most physics teachers are already in service for 5-10 years and they have their lessons and they just have to add another application to it. For us we have to develop the lessons from scratch….

Patrick: Also, how up to date is the material too? I mean if you’re trying to teach a bunch of teenagers about physics and you’re trying to tell them how it impacts the society and you’re making reference to things that are 20-30 years old…some of that not as applicable to them. So making sure your material is up to date or relevant for example you may have just heard on the news last night about this - let’s talk about that – that gets them much more interested I find.
Robert: Now we’re back to talking about the whole Ben Johnson/Donovan Bailey thing. We’re getting to the generation now where these kids didn’t remember but they were very young. In about 5-10 years they’re going to be like “who?” and have no idea who I’m talking about? So yeah it’s about being current and staying up to date with new stuff.

Patrick: Some things are very important like historical things. But when you’re trying to get every single day something STSE. You have to make sure at least some of it is current.

Jesse: The flip side of that. Some of the things that make it actually easier teaching this way is the internet. It’s like a teaching miracle like youtube and things like that.

Here, the exchange focused on resources for the class, which are up to date and relevant along with the time consideration for getting through all the curriculum and the time it will take for preparing lessons. These were common concerns among all pre-service teachers and these will be further discussed in the next sub-sections.

Other challenges and tensions became more refined and more specific. For example, this main challenge was still referred to as ‘resources’, however it now encompassed much more then previously described. It was defined to include all texts (teacher’s resource books and supplements), student resources, on-line materials, prep time, and classroom instruction time which would be needed to implement an STSE-orientated physics curriculum and assessment and evaluation materials.

As the pre-service teachers moved through the course, other challenges and tensions arose as their understanding of the curriculum deepened and their sense of ‘teaching’ developed. Their perceptions of the challenges and tensions became more ‘student’ centered, i.e., they began to question what would be in the best interest of their physics students – what would contribute to their (the student’s) success? The pre-service teachers were concerned for the high school students’ and the need to identify their level of understanding entering the physics course (this would fall under the assessment and evaluation challenge), next was the high school students
behavior and ability to understand the content given the breadth, depth, and time restraints of the physics courses (this is a combination of the challenges of resources and ethics). They speculated what this type of ‘curriculum change’ (as they perceived it as a curriculum change and not as a reorientation of the previous curriculum) could mean in the longer term as students entered into post-secondary education institutions to possibly study physics and/or become physics teachers – giving a glimpse at their own levels of comfort and confidence as beginning teachers (this is also in connection to assessment and evaluation as well as values education).

These challenges and tensions have been separated into those that focus on resources, as discussed above, assessment and evaluation techniques (diagnostic assessment techniques, questioning the authenticity of subjective assessment and evaluation techniques within a physics classroom and if/how these types of assignments would be ‘useful’ for students going on into university), values education, comfort and confidence.

6.1.1 Resources

A pervasive theme that emerged was pre-service teachers comments on their concern for not having enough ‘resources’ too adequately and properly (in their mind) teach the high school physics curriculum. The term ‘resources’ has been defined to mean both tangible items, i.e., laboratory equipment, classroom equipment, technology, and in-print materials, while the intangible item identified was mainly time. For the pre-service teachers, they envisioned this ‘change in curriculum’ as going from a physics curriculum with very little emphases on STSE (even though it was within the curriculum document) to one that is now STSE-orientated. This could be due to their limited experience with the previous science curriculum as they were focused on becoming familiar with the ‘new’ science curriculum as that would be the one to be implemented and used when they became certified.
When considering ‘resources’ the pre-service teachers would like to have as they try and determine how to implement this revised curriculum, the following was expressed:

MJ: Just …like … are they ever going to come out with a bit STSE document – this is what we do, this was successful, do it. We’ve all seen that teaching isn’t a challenge in how much you can come up with …but everyone has done it before so making the best things your own in your own unique way. So whether or not the STSE committee or the government is going to come up with STSE resources or just rely on physics teacher to pop things out of their brain.

Seamus: There comes a point where you have to be careful with copyright and laws because you are using everybody else’s stuff…do we need to worry about that too?

These are just two examples of comments made by pre-service teachers concerning resources. The first indicates that pre-service teachers are looking to the government to help supply the resources and teaching materials to infuse STSE ideas into their physics lessons and the second recognizes the importance of sharing resources and still making sure that credit is given where credit is due. In terms of the ‘scope’ of resources, little was said concerning on-line resources, however the use of on-line resources was certainly implied during class, the focus group sessions, and by the pre-service teachers themselves as they worked through the curriculum and instruction course. The fear of not having adequate resources is congruent with comments made in the literature by Aikenhead (2005), Pedretti et al.(2008), and Hughes (2000) for example. As the literature suggests, the lack of apparent resources is sometimes why pre-service teachers and in-service teachers move away from or refuse to consider an STSE approach in their science teaching.

It is interesting to note in the comment made above by MJ and echoed by others during class time is that it was assumed by the pre-service teachers that since the curriculum documents were ‘re-published’ there must be huge changes in the content of the curriculum whereby curriculum content itself was changed not a ‘refocusing’ of the curriculum. Although they were
given both the ‘old’ and ‘new’ curriculums, it took considerable time for them to realize that much of what is in the new curriculum existed in the old curriculum and the ‘change’ was in the focus of the document. Therefore, due to this restructuring of the science curriculum additional resources beyond the curriculum document (although nice) have not been produced by the Ministry of Education, rather teachers need to make their own connections between content and a relevant contextual nature for their students. On first glance, this notion of needing tangible resources is understandable, yet when reconsidered, perhaps a different view could be applicable, i.e., “instead of needing new stuff, maybe a new mindset – something that cannot be purchased and is much more difficult in ‘acquiring’…pivoting ones centre to view from a different direction” (instructor’s journal).

Understanding the possible scope of STSE is more then just using a formula or a new piece of equipment or a new lesson plan, it is about highlighting the science (in this case the physics) in situations that students can relate to and learn from – coming to a better understanding of the physics content along with any and all other aspects of the problem as it has been presented in its context. This requires ‘thinking beyond the box’, beyond the content, and beyond the prescribed text.

6.1.2 Content and Context

Pre-service teachers were concerned about how all the content could be covered even when infused in STSE lessons since they believed that there would be content outside of ‘physics’, which would need to be discussed and learned by students to gain a full appreciation of the issue at hand. For example, when considering time, pre-service teachers commented:

Patrick: That is just like we were saying – time would be the major – my major question.

Jesse: What do we drop to incorporate this new area? I definitely would not drop motion – that is so important and a lot of the people who are taking physics – it’s probably most
applicable to what they are doing. How am I going to know the students have a solid base of content if all or most is taught through STSE lessons?

The ‘concern for a solid base of content’ as Jesse mentions is important. We are reminded of arguments expressed by Steven Turner in his keynote address to the CRYSTAL Atlantique Annual Colloquium whereby he commented:

Enticing as the STSE option is, it faces serious problems of implementation and delivery in the real world of schools and students. …More complex civic controversies about technoscientific issues quickly turn out on close examination to hinge far more on the political and ethical beliefs of the antagonists than about factual questions of science and technology themselves. This unexpected fact reduces their potential as vehicles for introducing scientific principles per se. … But as every experienced teacher will attest, in the classrooms of Atlantic Canada [and perhaps in all regions of Canada], where ‘enacted curriculum’ is realized, and the only General Outcome that really matters and is consistently assessed is “Knowledge”, meaning “science content”. The curriculum materials supplied to teachers reinforce the implicit message that “Knowledge” is the outcome to which most if not all teaching should be oriented. In the “attained curriculum” – what students take away from their school experience – the resulting message all too often is that school science is de-personalized, irrelevant, fragmented, and something no cool kid pursues. (Turner, 2008, p. 10-11)

This concern that STSE is more than just ‘science’ content curriculum is also voiced by May (1992) where she challenges “…If I were a social studies educator, then, I would want to reexamine the defensibility of this model and where/if it fits in STS[E], not only to the benefit of my field but to those who mimic social studies uncritically”(3). She challenges STS[E] having science as its focus since it also “deals with political activism, ethics, human imagination, its products, processes, contributions, …critical, social and historical context beyond the ‘quick fix’”(3).

Supporters of STSE, such as Aikenhead (1994; 2005), Pedretti (2005) and others argue that content is not compromised, but rather acquired in a different way, through context. This also raises the interesting point about subject discipline – and that physics represents a particular
corpus of knowledge, which (from the perceptions of these pre-service teachers) was very content driven vice contextually driven.

6.1.3 Assessment and evaluation techniques

Earlier, in chapter 5, the components of STSE were discussed as pre-service teachers attempted to come to understand the scope of teaching an STSE-orientated curriculum. It was noted here that the assessment and evaluation of students would be a perceived challenge and tension of the pre-service teachers.

Tensions or challenges emerged as they considered how they would ‘evaluate’ students’ work. “How does one ‘mark’ objectively when the content could be very subjective in nature?” was a very common question during class time – pre-service teachers wanted to make sure they were assessing and evaluating their students correctly, ethically, honestly – but the question remained, “How can a subjective question be marked fairly when science is considered to be objective in nature?” This comment by Patrick indicates that there is still some hesitation towards the general impression of the subjectivity of science and NOS understandings. As discussed by Deboer (1991) and Aikenhead (2006), this view of science being ‘objective, linear and perhaps devoid of context’ is in keeping with the view of ‘traditional science’. It also points to the fact that the pre-service teachers had very little opportunity to experience these types of assignments within their own physics educational experiences and to have them valued (whether at the high school level or at the university level – questions which were subjective in nature were ‘not asked’ and ‘not part of the course’ or ‘not counted’). Therefore, they have indicated their lack of personal experience in this area and (from their conversations) a gap in their current B.Ed program to address their concerns on ‘proper’ assessment and evaluation techniques when considering a “subjective in nature” assignment to be assessed or evaluated.
Within the curriculum and instruction course we did discuss assessment and evaluation in terms of developing assignments, projects, tests, etc. from the curriculum expectations. We also discussed the importance of students knowing how they were going to be assessed, giving multiple chances at completing and trying new work, and the ‘acceptable’ level of mathematical manipulation and notion which physics courses should/could require. In terms of ‘English answers’ to questions, we discussed the importance of answers being clear and well written – the pre-service teachers felt that it was important for students to be able to understand and communicate via ‘English’ what was happening – what they observed. However, at no time in the assessment and evaluation conversations did they raise the point of assessing and evaluating ‘subjective’ material – feelings, perceptions, attitudes, etc. as they pertain to physics concepts.

This concern of properly assessing ‘subjective’ material will need to be addressed and will have implications at the faculty of education level in terms of making sure this point is addressed in programming. It may also find its way into a faculty of science if, as part of course work, students are encouraged and allowed to express their own personal attitudes, beliefs, values, feelings and perceptions as they pertain to issues within the specific area of science being studied. This will be further discussed in this chapter under implications of findings.

6.1.4 Values education

The question of values education is another challenge and tension for pre-service teachers. These individuals want to do the ‘right’ thing and teach their students how to be critical thinkers and responsible citizens along with required physics content – but whose values should be ‘correct’? What do you do as a teacher when you have a difference of opinion in your class? How do you approach the possibility that a difference in values can come from a host of sources – cultural, religious, sexual orientation to name a few. How can one manage and still be
equitable to all students given the diversity of the students we teach? How do you explain that you are including values education into a physics class when a parent asks? These were questions, which were asked during the course of the research within the classroom setting. This implies that these pre-service teachers do not see science as being ‘value-free’ as is the case of a more traditional view of science and as described by Deboer (1991) and Aikenhead (2006), although they struggle with the ‘how’ question of infusing values into science and specifically physics.

Pre-service teachers did not have a clear, straightforward answer about ‘how’ to infuse values education, but stood firm in their opinion that values need to be a part of physics learning. They also stood firm in their belief that it was up to each of them to address values education – it was (as some described) their civic duty. Here, values education according to the pre-service teachers deals with the ethics surrounding physics discoveries, use of physics knowledge, and the physicist’s responsibility and accountability to society and the environment as it would pertain to the content of STSE-orientated curriculum. It also encompasses the ‘ethics of teaching’ an STSE-orientated physics curriculum realizing that few universities use this approach in their undergraduate programs.

Another example of ‘values education’ being discussed was between Jeremy, Colin, MJ, and Adam whereby they feel ‘values’ need to find a place in science and physics education as the teacher is seen to be the ‘moral compass’. These are two wonderful examples of pre-service teachers exploring the connections between content, values education, and STSE. It also points to the question of pushing one’s own agenda and if a teacher was pro-nuclear weapons (for example) that this could easy become part of the classroom discussion. Since the teacher is in an ‘authoritative’ position, does this imply that students would feel compelled to hold the same
views as the teacher? In research presented by Cooper and Corrigan (2011) at ESERA, they commented:

Additionally, we have identified links between teachers’ values, their interpretation of curriculum, teaching practices and assessment practices (especially at the senior level.) Teachers’ values of science appear to be central here. A valuable Scientific literacy and socio scientific issues professional learning experience is found in teachers making explicit their values of science education to generate meaning around scientific literacy and make more informed decisions about how scientific literacy can be promoted in their classroom. (p. 29)

If these pre-service teachers acknowledge their own values and why they hold their values then this could help ‘unpack’ why they have their values and what the impact could be on their students as well as the connection between values and scientific literacy. This in turn can be connected to the decision making process where by Pedretti and Little commented:

Decision making involves identifying and analyzing an issue and selecting from alternative solutions. Decision making, however, is a complex process, encumbered by multiple possibilities, values, and agendas. In trying to manage the complexity, decision makers rely on criteria to distinguish among the possible solutions. This involves understanding the underlying the criteria, and analyzing the advantages and disadvantages of the various alternatives. (p. 45)

The role of the teacher in this situation should not be to push his/her own agenda but rather to shift from a transmissive orientation (as described by Miller, 1993) to a more transformational orientation where an emphasis is placed on the student’s own personal growth and social change within a student’s milieu and not the teacher’s own personal agenda.

As the focus group discussions continued, Patrick came back to the notion of subjective verse objective knowledge within the physics classroom and what that would mean for a physics teacher. It seems that although valued by these pre-service teachers, teaching and incorporating values into physics classrooms will need to be done with great care and consideration.
And, perhaps unlike their colleagues who teach chemistry and biology, the ethics and values associated with physics are not as well recognized by the general population and (in some cases) the physics pre-service teachers themselves this gives rise to acknowledging that the pre-service teacher’s level of comfort and confidence with values education is still developing.

6.1.5 Considering solutions: Professional growth aspirations

First and foremost, giving voice to the challenges and tensions as perceived by the pre-service teachers allows for a discussion to occur which by itself can give rise to possible solutions. Giving voice to these concerns is one thing, then examining the confidence levels when considering teaching an STSE based physics course and noting the perceived strengths and challenges of teaching such courses is important, but what action will be taken at the end of the curriculum and instruction course? Do the pre-service teachers have a plan to help them continue to learn and share resources and to continue to advance in their own practice? Or, is this where their learning stops? Which of Aikenhead’s (2005) orientations will they gravitate towards, i.e., those who will be supportive; those committed to pre-professional training who resist or even undermine STSE; or those who can be persuaded to adopt STSE? Although it is beyond the scope of this research to know what actions they will take, it is helpful to have the pre-service teachers consider what their actions might be – the possibilities after graduation.

When examining their professional growth aspirations and plans, none of the pre-service teachers were members of any professional teaching organizations at the time of the research. However, many indicated that they would like to join various organizations as a way to help support their classroom practice. For example, all planned on becoming members of the Ontario Association of Physics Teachers and five planned on attending the associated conferences. There were ten individuals who planned on joining the Science Teachers Association of Ontario.
and four planned on attending the associated conferences. Some pre-service teachers had already begun to read and participate in other activities, which would help develop their physics/science content knowledge and perhaps professional practice. These included reading science magazines and journals, attending teacher conferences, participating in science blogs and chat rooms, taking additional physics courses and their honours specialist in physics, and reflecting on their daily practice. These are possible ways that pre-service teachers could assist themselves as they move forward into their teaching career, yet when asked if they think they will ever be ‘satisfied’ with their understanding of an STSE-orientated physics curriculum, they replied:

Dianna: I don’t know if I ever will, actually.

Ben: I think just personal experience – once you start teaching – you might get some help from the teachers but I think it [STSE focused physics curriculum] will be so new that not even the teachers will know.

Dianna: Yeah, that is true.

This could be considered part of the pre-service teachers recognition that learning does not stop at the end of a degree – rather it is a life-long learning journey and that all teachers will be somewhere along the continuum.

Another suggestion put forward by the pre-service teachers was to ask their students for feedback. This is something that is often done informally, but perhaps this could take on a more formal part of in-service teaching. Ironically, this also indicates the possible level of indoctrination of the pre-service teachers since they would have been completing course evaluations for professors for a number of years and consider it simply part of the regular routine.

The group suggests that through personal experience and working with other teachers in their schools, they may find the answers they have to their questions. Yet, they also have
acknowledged that not all in-service teachers might be in the same place with their understanding and implementation of an STSE-orientated curriculum as the pre-service teachers. This could lead to tension between teachers, i.e., younger teachers may feel pressure to follow in the footsteps of more senior teachers who may or may not be moving towards infusion of STSE within their science courses.

Pre-service teachers suggested that a way to determine if ‘STSE is working’ meaning ways to explore the effectiveness of an STSE-orientated physics curriculum would be to survey the students at the end of the physics courses (and possibly science courses at the grade 9 and 10 level), thereby allowing the students to voice what worked and what did not work for them. Did the infusion of STSE help the students better understand and solidify the content they were required to learn? Or, did it leave the students more confused? As an extension to this notion of surveying students, it was also suggested that surveying graduates a few years after they finished high school would also be beneficial. By surveying past students, identifying what they are currently doing and how their physics/science courses assisted them, one might be able to speculate if and how an STSE based physics/science curriculum was advantageous to their learning and understanding of the discipline and with their current endeavors.

In addition to surveying students to obtain their perspectives and opinions of an STSE-orientated physics and science curriculum, pre-service teachers also came to the understanding that developing a good and trusting rapport with their students would also help them to determine their own success in teaching an STSE-orientated physics curriculum – what was working and what needed more work. This notion came from the comments of surveying their own students about transitioning from high school to university, but rather just asking the
students what worked within their high school physics classes and what didn’t. If and how STSE-orientated physics helped with their understanding of the content.

Similar to the ideas presented above, other members of the class hoped for Ministry developed resources. It seems that the pre-service teachers, as their classmates have indicated, will have to rely on personal experience and peer learning to help bring about a science class that is STSE-orientated.

However, these particular pre-service teachers still feel strongly that the government should assist with teacher ready resources. It was interesting (from the instructor’s perspective) that the pre-service teachers felt that all resources should come from the Ministry of Education (“the government”) but they did not in this conversation consider the possibility of sharing resources between teachers as is common practice in most schools, school boards, and with teacher organizations. Perhaps this is because they did not have experience with these bodies at the time of data collection. The reservation presented and where answers may be found are completely logical and do loosely connect with Aikenhead’s (2005) view of concerns pre-service teachers may have about STSE and adopting STSE. For example, the three possible orientations for teachers – those who will be supportive, those who will commit to pre-professional training but resist or undermine STSE and those who can be persuaded to adopt STSE.

In summary, these physics pre-service teacher tensions echo similar research findings from Aikenhead (2005) and Pedretti (2005) and give reasons why teachers may not be able to or unwilling to adopt STSE, including lack of resources (the government should provide a teacher’s resource book), frustration with combining everyday and scientific language, lack of confidence with an integrated content and its assessment and evaluation (subjective vs. objective types of questions), uncertainty about the teacher’s purpose in the classroom (teach values – but evaluate
them as well?), lack of support from both inside (in-service, senior teachers) and outside the school (government not providing resources), pressure to prepare students for university (from their own indoctrination) and general survival mode. These are the very challenges and tensions voiced by the pre-service teachers.

### 6.2 Implications for the future of physics education and STSE education

In this section, the focus will be on the fourth and final research question, “What are the implications for the future of physics education and STSE education?” Here the question that needs to be address is what can we do with this information at the pre-service level (what can we learn from this research to make better physics teachers) and what insights do the pre-service teachers have about suggested changes to the undergraduate programs to help the transition of physics students from high school to first year so as to make physics more accessible to all students.

#### 6.2.1 Implications: Pre-service teachers perspective

Pre-service physics teachers are a select group of soon-to-be science teachers. They arrive, eager to being the process of ‘becoming a physics teacher’ with a number of pre-set ideas about their subject area (content knowledge), physics, how to teach (pedagogical knowledge), how they would like to improve from their own experiences of being a physics student to make the learning environment of their physics classroom the best it can be (pedagogical content knowledge) (Wenning, 2007). They are of the opinion that physics and physics education is important and is given a ‘bad rap’ by society (Redish, 2003). In their opinion, physics can be a very difficult subject but it doesn’t have to be seen that way at the high school level. There is a sense that more students should take physics – or at least be encouraged to do so. This would give students, i.e., our future society a better sense of how the world works and why we see the
phenomena we do, according to the pre-service teachers discussions. And, this, in their opinion would get to the root of both STSE education and scientific literacy, at least as a first attempt.

They are, as in this particular case, each unique individuals who have had a unique path and it is this individuality that brings richness to our or any pre-service education classroom. There are many ideas, perceptions, challenges and tensions that these pre-service teachers have voiced concerning an STSE-orientated physics curriculum and these have been discussed earlier in this and the previous chapter. In all, there are a number of similarities between what these pre-service teachers have said and what can be found within the literature from Aikenhead, Pedretti, Hodson, Bybee along with many others. What is also important to note is that, as with high school students learning physics, pre-service physics teachers learning about STSE orientated physics takes time, resources, opportunities to explore, discussion and dialogue, examples, modeling of STSE lessons, opportunities to create their own STSE lessons and desire to ‘try them on real high school students’. STSE-orientated physics is not ‘exactly’ a new concept for the pre-service physics teachers, however, the scope of STSE is new and with any new idea, understanding the idea takes time.

These pre-service teachers want to teach an STSE-orientated physics course. They have some ideas from the Curriculum and Instruction course, the curriculum documents, and have formulated some ideas through discussions with their peers as to how to carry out this ‘new’ type of teaching. There is little question as to ‘why’ one would teach an STSE-orientated physics curriculum, rather the question left in their minds is ‘how do I do this well and consistently?’.

The pre-service teachers seemed cautiously optimistic about teaching STSE-orientated physics in that they ‘know’ it is a good idea yet they are unsure of the reaction of their more experienced
peers, the resources available to them, and feel that ‘full’ implementation will take time as they themselves feel it is a ‘work in progress’.

6.2.2 Implications: Faculties of Education and pre-service programs

There are two main points, which can be drawn from this research concerning what is done within a faculty of education to assist pre-service physics teachers engagement with an STSE-orientated physics curriculum. The first point is the notion of explicitly modeling STSE-orientated and non STSE-orientated lessons so that pre-service teachers are able to identify with both. This type of explicit modeling will support their pedagogical content knowledge and address Aikenhead’s (2005) concerns of lack of knowledge (content) and lack of experience with STSE-orientated lessons. It echoes Pedretti and Little’s (2008) recommendation that it be infused across all areas of science and explicitly attended to. As Bybee (1993) commented “The decisive component in reforming science education is the classroom teacher…Unless classroom teachers move beyond the status quo in science teaching, the reform will falter and eventually fail” (144). As science educators, this would also be true within a B.Ed program. Further, Yoon (2006) points out that increasing pre-service teachers’ self-efficacy could include using cases and case methods that allow for multiple points of entry, through the use of scaffolding. Finally, in order to feel confident teaching STSE-orientated lessons, pre-service teachers must possess the three knowledge bases (Wenning, 2007) being content knowledge, pedagogical knowledge, and pedagogical content knowledge. Therefore, in order to have pre-service teachers gravitate towards STSE-orientated lessons, they need to understand what they are, how they are different than non-STSE lessons and all that goes into the planning and implementation of an STSE-lesson.
The second point which has come from the research data is the notion of allowing pre-service teachers time to discuss in a semi-structured environment their own concerns and perceived tensions about teaching ‘differently’ from in-service teachers and differently from their experiences in an undergraduate program. These discussions allow pre-service teachers to understand, discuss, formulate and synthesize their own meanings of teaching through an STSE-orientated physics curriculum. The pre-service teachers found the focus group discussions to be a very useful ‘exercise’ where they could state their opinion or thoughts, not have them assessed or evaluated and come to an understanding while discussing and unpacking their views with their classmates in an environment that encouraged uninhibited conversation.

6.2.3 Implications: Faculties of Science and physics departments

The pre-service teachers in this study have some deep concerns pertaining to Faculties of Science and specifically university physics departments as they came to know and understand their function and purpose. In one exchange, Ben asks the question about the transition from high school to university and how students will make this transition. This is always a difficult transition. With a change in focus of teaching style at the high school level, students may have a better understanding of the content – a deeper understanding, but how will this play out at the next level for the student, will it help the student? In the end, will this shift in teaching at the high school level be advantageous to the students as they proceed on their learning journey wherever that might take them – university, college, directly to the workplace? This is also in keeping with the question ‘who is science for?’ are we teaching science to create scientists or to create a scientifically literate society? The Ontario curriculum document suggests the latter.

In the exchange between pre-service teachers, Adam suggests that a happy medium between the high school experience and the university requirements is what ‘should’ happen but
he does not give any further details. What are physics departments doing in light of this curriculum change? Can PER include STSE education? Are physics departments on side with PER? As we move forward in our understanding of teaching and learning as they pertain to science and physics specifically, more and more physics departments across Canada are becoming interested in PER.

PER suggests that professors should move away from pure lectures and utilize more inquiry within their classes (Shipman, 2006; Hawke, 1998). Physicists who engage in PER are primarily concerned with the conceptual understanding of the content by the students (Beichner, 2009; Leonard, 1996; McDermott, 1991, 1998, 2001; McDermott & Redish, 1999; Redish, 2003; Saul, 1998). The movement of PER towards STSE is slow. However, from the research by Harrison (2010) progress could be coming in that he commented that (a) most students learn best by interacting with peers, (b) peer interactions are most effective when they are based on conceptually based activities (could these be STSE-based?), and (c) activities are particularly effective when they involve real physical apparatus (2). The second and third points made by Harrison are loosely connected to Pedretti and Nazir (2011) current concerning application/design and possibly reasoning. Further, Knight (2004) suggests and supports the notion of using HPS as it can create a rich paradox for the students to navigate – this is in keeping with STSE ideals.

Universities and physics departments seem to be moving closer to accepting the possibility of teaching physics via an STSE lens; however, there is still a long way to go. To complicate matters further, little discussion occurs between those in physics departments and those who are members of education departments. Perhaps if the lines of communication were fostered, we could both benefit from the other’s insights.
Another interesting point from the pre-service teachers’ data is the idea that all physics students will go on to university. Do they make this assumption because that is their story or because they have not yet had significant time in a classroom setting as ‘teacher’? Further, the entire science curriculum now has STSE placed at the forefront of the guides – why do these pre-service teachers only focus on STSE in grade 11 and 12 physics classrooms? What about the physics units at other grade levels, this in consideration of the ‘science for all’ notion? These are unanswered questions, which will be revisited under the topic of future research possibilities.

**6.3 Conclusions and implications from the case study**

This research explored insights into the struggles, challenges, tensions, and hopes pre-service physics teachers have towards teaching physics, teaching an STSE-orientated physics curriculum, and wanting to create the best classroom experience possible for their future physics students. They have shared their views on what makes a ‘good physics teacher’ citing the need for active engagement, using applications to the real world when discussing content to help provide context for the students, the need for hands-on physics for students so that physics is not ‘just’ another mathematics course, yet also acknowledging the value and place of calculations and computations within physics – quantification of the phenomena is a huge component of the science of physics. The goals of physics education were also discussed, and included: generating students’ understanding the basic concepts, preparing physics students for university, and generating interest – making physics relevant. In terms of coming to understand an STSE-orientated physics curriculum, the first ‘obstacle’ was to form a description of what STSE could entail. Now, it is important to keep in mind that this was the pre-service teachers’ first encounter with the notion of STSE and as students of physics, they were unaware, in the beginning, that STSE defies a concrete, exact, definition. This is why their understanding of STSE was deemed a
‘work in progress’ in that as the course and research continued, their understanding of the scope of STSE became more extensive – it went beyond ‘real world applications’ to begin to included values, ethics, HPS, scientific literacy, decision making, action and agency, issue-based tasks, application and design, and NOS in varying degrees. Further, as the course and research progressed, pre-service teachers understandably grew in their confidence and comfort levels concerning STSE ideas and pedagogy, beginning to critically examine how they could reasonably and effectively integrate STSE into their daily physics lessons.

As mentioned above, this journey of the pre-service teachers came with acknowledged challenges and tensions. These included the challenge of appropriate resources – both tangible and non-tangible, questions, concerns, and frustrations over how to properly assess and evaluate students since STSE-orientated teaching allows for students to answer questions subjectively, and how can ‘those’ types of answers be accepted in an ‘objectively’ perceived physics class? A second challenge was the notion of values education and whose values should be taught within the physics classroom. Again, the concern for assessment and evaluation was raised as ‘how can one ‘mark’ a student’s values, is it acceptable to do so? Do we have a right to mark their values?’ This speaks to the pre-service teacher’s content challenge that teaching physics will mean more then just understanding the formulas, laws and principles. With these challenges and tensions in mind, pre-service teachers were asked how they would overcome hurtles? What possible solutions or strategies would help? Pre-service teachers acknowledged that they hoped answers and solutions could come from fellow teachers at their own schools as well as through teacher organizations such as the OAPT and STAO. They also indicated that being part of social networking groups may also be useful along with conducting their own ‘research’ via print and
on-line research. This echoes their level of confidence in implementing STSE-orientated physics and that this will also be a challenge as they move forward in their new career.

The implications of this research can reach into both faculties of education and science (specifically physics departments). For pre-service teachers examining what they considered to be a ‘new’ curriculum, the possibility of experiencing explicitly modeled STSE-lessons was highly important and influential. Faculty of Education professors and instructors need to remember that through explicit modeling pre-service teachers have an opportunity to (a) experience the lesson as students might and (b) have an chance to understand the planning and preparation that goes into such a lesson – the ‘behind the scene’s look’ at the teaching so that they can learn and adapt to meet their own teaching style and the learning styles of their own students. The second important point for Faculty of Education professors and instructors to draw from this research is the power of semi-structured small group discussions concerning the course content. The pre-service teachers felt that it was through these focus group discussions that they came to understand, appreciate, and critically analyze what they were learning and how they might come to implement it within their own classrooms. It was a non-threatening environment whereby no assessment or evaluation was tied to the conversations, rather it was learning for the sake of learning. Some might consider these focus group discussions to fall under the ‘professional learning community’ design.

Faculties of Science can also draw from the findings of this research, specifically physics departments in that those professors and instructors who teach first year physics courses may want to consult with the high school physics curriculum and local high school physics teachers to better understand the high school physics learning experience. The current experience may be very different than what the professor and/or instructor experienced when they went through
high school. From this information, a change in pedagogy may be in order to help first year students either transition from an STSE-orientated physics curriculum to a more lecture style, pure content driven course, or (perhaps) physics professors and instructors may see the value and importance of continuing with an STSE-orientated physics curriculum as a way to simulate students and intrigue them to continue on in physics past first year.

6.4 Limitations of the study

As with any study, there are limitations to this particular research. Firstly, I was limited to the class members of the Curriculum and Instruction course. These class members were asked to participate in this research. As can be seen from the data, there was an uneven gender split within this class and in the year that the research was conducted there was a smaller than usual number of pre-service teachers in the physics class which also limited the diversity of the class (gender as stated above, age, work experience, ethnicity, and sexual orientation). Secondly, as both the instructor and the researcher, I may have influenced the participants in their responses, i.e., they may have felt required to participate and/or give answer that I would be ‘looking for’ as the researcher. I attempted to avoid this limitation by hiring a research assistant to complete the data collection while pre-service teachers were enrolled in the course and prior to final grades being submitted, however, I can not be certain that these efforts were sufficient in their minds. Finally, as the instructor and classroom observer, I tried very hard to give pre-service teachers an opportunity to ‘talk through’ their questions and concerns about an STSE-orientated physics curriculum without giving my own perspective and views. This was, at times, very challenging as they would ask me direct questions connecting the theory they were learning in class to my previous experiences teaching high school physics.

6.5 Next steps for future research
The research and findings presented here can act as a base for at least three major new projects, which I hope to pursue in the future. The first would be to conduct a longitudinal study and revisit the participants of this particular study and find out ‘where they are now’ – are they teaching, if so where, what courses, etc. Then, examining their current understanding and use of STSE within their science classrooms (if they are teaching science), what challenges they have encountered, what have been their personal tensions with STSE, and where do they think they should go from here. It would also be very helpful to inquire about the effectiveness of explicitly modeled STSE lessons during the B.Ed experience. Was this useful? What advice would they give the professor when introducing STSE-orientated science or physics curriculums? Have they been able to receive the help and support in implementing STSE from the various groups and sources mentioned during their B.Ed experience or have they found support from other venues? Who and where has this support come from and “how” supportive has it been? Are they still supportive of an STSE-orientated physics curriculum? If so, why or why not?

A second aspect to this study could be in examining how, this group of pre-service physics teachers, have moved the theory they learned in the curriculum and instruction course into their own physics teaching. Or, this could be seen as a separate research project entirely, depending on the project’s scope. For example, if the pre-service teachers were willing to allow access to their own classrooms and interviews with students were permitted to obtain information and data on their perceptions of an STSE-orientated physics curriculum, then this would add a new dimension to the work. Questions for the now in-service teachers could include: What ‘cornerstones’ or ‘currents’ have they put into practice? What challenges have they experienced in the field? And, perhaps most importantly, what are the student’s views of an STSE-orientated physics class?
The third major research project that could be possible from this research base would be examining the ‘effectiveness’ of an STSE-orientated physics curriculum using a combination of PER and ‘educational’ qualitative research methods and literature. This would involve researchers from both education and physics departments working together to better understand the effectiveness of STSE pedagogy and question (perhaps pilot) the possibility of incorporating STSE-orientated lessons into undergraduate physics programs as an extension of current PER techniques and strategies. This could be very insightful for those in education as well as physics as to how to best teach content for retention and deep understanding along with critical analysis and decision making – all key learning outcomes at both the secondary and post secondary education levels. Further, this research could explore the transition for physics students from an STSE-orientated high school setting to either a non-STSE university physics setting and/or an STSE-orientated university physics setting. Helping to determine which is best for students and why – or does it matter?

Physics education is slowly moving away from the traditional view of science (Deboer, 1980) and the stereotype of being an elitist subject. Physics, as a subject, can be made accessible to any and everyone given the appropriate scaffolding. However, the age old question of ‘why do we need to learn this?’ may still arise. Teaching physics through an STSE lens is one way to increase the level of accessibility of physics, show relevancy of the content, place content into context for students, and increase the level of scientific literacy among all students so that, regardless of the path they choose after high school, they feel confident and competent. It is the role of the teacher to help students make sense of the content and it is through the teacher’s experiences in the B.Ed program when they are pre-service teachers that they undergo their own transition from student to teacher. Here, they have the opportunity to explore, question, and
challenge what they thought was teaching and what might be in the best interests of their future students. Perhaps, more importantly, by understanding their views about STSE and trying to see the scope of STSE education, they may identify how STSE was part of their own learning as well as how it can frame their future teaching. Their perceptions and views are important and need to be acknowledged and understood if we, as education faculty members, are to assist pre-service teachers on their own learning journey and their transformation from science student to science teacher.
References


APPENDIX A: PRE-SERVICE PHYSICS TEACHERS LETTER OF REQUEST

November 24, 2008

Dear Pre-service Physics teacher,

I am a PhD candidate at the Ontario Institute for Studies in Education, University of Toronto. As part of the doctoral research work that I am conducting, I am inviting pre-service physics teachers of a University in Ontario to participate in this study. Participation in the study is completely voluntary and will have no bearing on any course work completed at the University. This research will be conducted in 5 stages:

Stage 1: An on-line anonymous survey. This survey will ask basic demographical and about past teaching experience. It will also ask questions about your understanding of the relation between Physics and STSE and current and professional development you may find of interest. The survey has been designed to take approximately 20 minutes and can be completed anywhere on campus as it is on-line. It is completely anonymous as the software will generate an identification number for you that only you will know.

Stage 2: An Individual Interview. This is an interview conducted with my research assistant (RA). The RA will ask questions dealing with learning physics and teaching physics as well as your understanding of STSE. The interview has been designed to take approximately 30 minutes and will be conducted in H240 at a time that is convenient for both you and the RA. The RA will record the interview and later transcribe the interview removing your name. You may review the transcript to ensure validity.

Stage 3: Focus Group Discussions. These will be small group discussions between yourself and 3 other classmates. The discussions will be led by the RA in H207 at a time that is convenient for all group members. The RA will ask a series of questions for you and the group members to discuss which will be based on STSE education, physics education and the connections between these two areas. Each focus group meeting will take approximately 1 hour and you will meet 4 times during the semester for a total of 4 hours. Transcripts will be made of the meetings where all names will be replaced by pseudo names to protect your identity and so you may review the document to ensure validity. You will also be asked to honour the confidentiality of the group during this stage.

Stage 4: Exit on-line anonymous survey. This survey will be highly similar to that of stage 1 with similar questions and topics. It has been designed to take approximately 20 minutes and can be completed anywhere on campus. This survey will take place during the end of April 2009.

Stage 5: Exit Interview. This interview will be similar to that of stage 2 with similar questions and topics. It has been designed to take approximately 30 minutes and will be conducted in
H240 during the end of April 2009.

In all, the time commitment of this study is approximately 6 hours.

It is hoped that through this study a better understanding of the perceptions and challenges pre-service physics teachers have concerning the integration of STSE into Physics education in Ontario will be voiced. This will then assist in better pre-service teaching methods and translate into classroom related research to assist both students and teachers learning and studying in this subject area.

Because of the nature of this study, I am both the researcher and your instructor. Therefore, to remove power struggle issues, online surveys will be completed anonymously and interviews and focus groups will be completed by a research assistant. I will not have access to the data until after your final marks are submitted for EDUC 4506.

Basic Information

• If you agree to participate in this study, you will remain completely anonymous to the researcher, Katarin MacLeod, since you will be assigned an identification number for each of the surveys and your name will be removed from all transcribed interviews and focus group sessions by the research assistant. Your identity will be known to the research assistant who will respect and honour your confidentiality. Your identity will also be known to fellow classmates during the focus group sessions. Focus group members will be asked to honour the group’s confidentiality.

• Participant identity will remain completely anonymous and confidential, including in all reporting of results in scholarly publications and public presentations.

• You may refuse to participate or may withdraw at any time. A form will be provided for you to sign if you decide to withdrawal from the study so that your information can be removed from study.

• All data will be safely stored electronically or in locked filing cabinets and will be destroyed five years after the conclusion of this study.

• There are no reasonably foreseeable risks or harms to you. You may benefit from this study by reflecting on your experiences. You may find benefit to the reflective nature of the survey questions, interviews and process and focus group questions and interactions. There will be no promised significant benefit from this study. However, the potential benefits of this study include the scholarly and/or professional community better understanding the beliefs pre-service physics teachers have about teaching physics through an STSE approach, the factors which influence their adoption of an STSE approach into their teaching, and how their perceptions and attitudes change as they move through their B.ED. By better understanding the beliefs, factors, perceptions and attitude changes of pre-service physics teachers, the scholarly and professional community will be better able to address future issues and concerns and improve the experiences of current and future students and teachers in the area of STSE based physics education.
• Participation is purely voluntary. The instructor who is also the researcher will not have access to the data until final marks are submitted for EDUC 4506 therefore participation in the study will not affect the student-instructor relationship.

• By signing this letter, you will be providing consent to both participate and allow information from interviews and focus group meetings to be included in this study. You will be asked a second time for your consent at the beginning of each interview and focus group meeting. Again, you may decline to participate at any time.

If you have any questions, need further information or at a later time, please contact one of the following:
Katarin MacLeod, 705 474-3461 x4422 or by email at katarinm@gmail.com
Dr. Erminia Pedretti, 416-978-0080 or by email at epedretti@oise.utoronto.ca

A summary of the research results will be available in the fall of 2009. If you wish to receive a copy, please contact Katarin MacLeod at the following telephone number 705 474-3461 x4422 or by email katarinm@gmail.com

Thank you very much for considering this request. Your participation is very valuable and could help improve the experiences of current and future students and teachers.

Sincerely,
Katarin MacLeod

Name of Participant: ____________________________

Date: ______________________

Signature of Participant: _________________________

Email address: ____________________
November 24, 2008

Dear Pre-service Physics Teacher,

I am a PhD candidate at the Ontario Institute for Studies in Education, University of Toronto. This survey is part of the doctoral and research work that I am conducting. You are invited to participate in this online survey which will help examine integrating science, technology, society and environment (STSE) into Physics teachers’ education: Pre-service teachers’ perceptions and challenges. This survey will take approximately 20-30 minutes to complete.

It is hoped that through this study a better understanding of the perceptions and challenges for pre-service physics teachers can be identified and described when integrating STSE into physics curricula.

Information:

- All of the participants of the survey will remain anonymous. Once you launch the survey, the software will generate an identification number for you. This identification number will only be known by you. Only Katarin MacLeod will have access to the survey data once final marks have been submitted for EDUC 4506. You will remain anonymous with no way of identification.

- Your identification number will remain completely confidential, including in all reporting of results in scholarly publications and public presentations.

- You may refuse to participate or may withdraw at any time. Please contact the research assistant at 497-3413 if you wish to do so.

- All data will be safely stored electronically or in locked filing cabinets and will be destroyed five years after the conclusion of this study.

- There are no reasonably foreseeable risks or harms in completing the survey. You may benefit from this study by reflecting on your experience completing the online survey. However no direct benefits are promised.

- Participation in the online survey is purely voluntary and participation in the online survey will be deemed to constitute consent to allow that component to be included in this study once you have clicked on the ‘continue’ button at the bottom of the page.
Once you click continue, the survey will launch and you will click on the answer which best applies to you and your perceptions and type in answers to the free response questions. The bar at the top of the survey will indicate how much of the survey you have completed. When you have answered the last question, your data is then submitted to the survey software.

If you have any questions or need further information, please contact one of the following:
Katarin MacLeod, 705 474-3461 x4422 by email at katarinm@gmail.com
Dr. Erminia Pedretti, 416-978-0080 by email at epedretti@oise.utoronto.ca

A summary of the research results will be available in the fall of 2009. If you wish to receive a copy, please contact Katarin MacLeod at 705 474-3461 x4422 or by email at katarinm@gmail.com. Thank you very much for considering this request. Your participation is very valuable and could help improve the experiences of current and future students and teachers. Thank you in advance for your time and support. By continuing with this survey, you have provided consent. Please start with the survey now by clicking on the Continue button below.
APPENDIX C: PRE-SERVICE PHYSICS TEACHER INITIAL ON-LINE SURVEY

This survey has questions most of which you will click the response which best pertains to your situation and/or your perceptions. Thank you for taking the time to complete this survey!

A. Demographics

1. Are you Female or Male?

   ☐ F
   ☐ M

2. Which age group best describes you in years?

   ☐ 20 – 24
   ☐ 25 - 29
   ☐ 30 - 34
   ☐ 35 - 39
   ☐ 40 +

3. What is your highest degree?

   ☐ B.Sc.
   ☐ B.A.
   ☐ M.Sc
   ☐ M.Ed.
   ☐ Ph.D.
   ☐ B.Eng
   ☐ Other (please specify)

4. Is Physics your first or second teachable?

   ☐ First (5 full courses of physics)
   ☐ Second (3 full courses of physics)

5. What are your other teachable areas?

   ☐ Chemistry
   ☐ Biology
   ☐ Mathematics
   ☐ Science
   ☐ English
   ☐ History
   ☐ Geography
   ☐ Phys.Ed
   ☐ French
Other __________________

B. Practicum and past teaching information

6. What board/school division are you completing your practice teaching in?

(List boards)

7. Are your placements considered public, Catholic or private?

- Public
- Catholic
- Private

8. Do you have previous experience teaching children in a school setting?

(Blank box)

9. Have you taught Physics outside Ontario?

- Yes
- No

10. If YES, where else have you taught and for how long?

(Blank box)

11. What is the average number of students in your physics classes during your practicum placements?

- <15
- 15 – 20
- 21-25
- 26-30
- 31+
  - I do not have a physics placement.

12. Are there more boys or girls in your physics classes during practicum?

- Boys
- Girls
- Even
  - I do not have a physics placement

C. Relation between Physics and STSE
13. Prior to beginning your B.Ed, had you ever heard of STSE education?
   - Yes
   - No

14. How would you define or describe STSE education?
   (Text box)

15. From your perspective do you think physics and STSE are related?
   - Yes
   - No
   - Don’t know

16. From your perspective, do you think it is possible to teach high school physics from an STSE perspective?
   - Yes
   - No
   - Don’t know

17. What is the aim of teaching university preparatory or grade 11 and 12 level physics to high school students from your perspective?
   (Text box)

18. What challenges do you think you will face attempting to teach an STSE based physics curriculum?
   (Text box)

19. When you were a physics student in high school, did your teacher ever discuss ‘real world problems’?
   - Yes
   - No

20. Can you provide some examples:
   (text box)

21. Please rate the following statements:
<table>
<thead>
<tr>
<th>Strongly disagree</th>
<th>disagree</th>
<th>neutral</th>
<th>agree</th>
<th>strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A)</strong> I feel confident in my ability to teach STSE education</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><strong>B)</strong> Science and values education should not be coupled</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><strong>C)</strong> Decision-making skills are an important part of a science curriculum</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><strong>D)</strong> I am unlikely to teach STSE in my early years of teaching because of the planning and time demands</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><strong>E)</strong> I am worried about the lack of resources available</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><strong>F)</strong> STSE requires an interdisciplinary approach</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><strong>G)</strong> Promoting ‘action’ (i.e., personal, local) should not be the business of school science educators</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><strong>H)</strong> I feel adequately prepared to tackle STSE education</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><strong>I)</strong> STSE education is not as important as the rest of the science curriculum</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><strong>J)</strong> STSE teaching is not worth the effort and time</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

**D. Current/Future Professional Development**

22. Are you a member or do you plan on becoming a member of the following organizations and do you attend their conferences or plan on attending their conferences?

| Organization | Future Member | Member |
23. What other types of professional development activates do you take part or will you take part in that you feel help with your physics teaching?

Currently:
- I don’t
- I read science magazines
- I read science journals
- I attend other conferences (teaching related/student related)
- I develop new laboratory experiments
- I take part in on-line chat groups/blogs that focus on physics education.
- I take extra courses in physics at a university
- I take extra courses in mathematics at a university
- I reflect on my teaching
- Other (specify)

In the future:
- I won’t
- I will read science magazines
- I will read science journals
- I will attend other conferences (teaching related/student related)
- I will develop new laboratory experiments
- I will take part in on-line chat groups/blogs that focus on physics education.
- I will take extra courses in physics at a university
- I will take an honours specialist course in physics
- I will reflect on my teaching
- Other (specify)

E. Summary ideas

24. If you could change the physics curriculum, what would you change and why?

(Text box)
25. What changes would you make in the physics curriculum or in the education system in general to support STSE based science education?

(Text box)

26. Do you have any other comments that you would like to include in this survey?

(Blank box)

Thank you for completing the survey!
Results will be posted to:
A forwarded website
In
November 2012.

Note Question 21 was developed and reported on in the following reference:

APPENDIX D: PRE-SERVICE PHYSICS TEACHER INITIAL INTERVIEW GUIDING QUESTIONS

The following are guiding questions, which will be used during the pre-service physics teacher’s initial interview. They are meant to probe into the perceptions of the pre-service physics teacher with respect to the integration of STSE into physics teacher education, their perceptions and associated challenges.

Questions:

1. Please describe your most memorable physics learning moment. What made the moment so memorable? What was the role of the physics teacher in this moment?
2. Do you enjoy learning physics? What is your most favorite method of learning new physics concepts?
3. How would you define or describe the way you were taught physics?
4. Have you had the opportunity to observe a physics class on your practicum? If so, is it similar to what you experienced as a student or different? If it is different, how was it different?
5. What do you think science education should be about?
6. What is your understanding of STSE education?
7. What do you think physics education should be about?
8. What is your understanding of PER?
9. How would you describe your level of confidence in teaching physics?
10. How would you describe your level of confidence in teaching a physics curricula that is STSE based?
11. Do you think you will include STSE and issue-based tasks into your everyday physics lessons? Why or why not?

12. When you are teaching physics, what do you want your physics students to understand or gain from the course?

13. What is the best part or point about teaching physics?

14. What is the worst part or point about teaching physics?

15. Is there any other points or comments that you would like to add?

This concludes the interview. Thank you for participating. A transcript will be prepared for you to verify and clarify any information if necessary.
APPENDIX E: FOCUS GROUP GUIDING QUESTIONS

Focus group session 1:

1. In your view, what should physics education at the senior level be about? What are the goals for our students?

2. What does STSE education mean to you?

3. Do you think physics can be taught from an STSE perspective? What are the associated challenges and benefits from teaching physics from an STSE perspective?

4. What examples can you give from either EDUC 4506 or from previous physics courses that could be labeled as STSE lessons?

5. What questions do you have about STSE and incorporating it into the Ontario physics curricula?

6. When and where do you think you will find the answers to your questions?

Focus group session 2:

1. In reviewing your previous definition of STSE, has the definition changed, if so, how and why?

2. What units in the senior physics curriculum lend themselves to an STSE approach? What resources could you use for these units? What would you want your students to understand from these units other than the basic physics concepts?

3. What are the most important things for physics students to learn from the high school physics curricula? What should physics education be about?

4. How would you describe the similarities between real-world problems and an issue-based approach to teaching physics?
5. What challenges do you anticipate in teaching an STSE based physics curricula?

Focus group session 3:

1. In reviewing your previous definitions of STSE, has the definition changed, if so, how and why?
2. From your perspective, are the ideas of STSE and scientific literacy related to each other and to the physics curricula? If so, how? If not, why not?
3. Do you feel your ideas of STSE education as they pertain to the physics curriculum are changing? If so how?

Focus group session 4:

1. If asked during a teaching job interview to define and give an example of STSE education in a physics setting, how would you answer this question?
2. Do you think STSE can be successfully integrated into the physics curriculum?
3. What advice or insight could you give the researcher on this topic? What needs to change in the pre-service program, what should change in the curriculum?
4. What challenges will you face now that you are on the threshold of being physics teachers with an STSE orientated curriculum? What should teaching and learning physics be about?
5. If your perspectives have changed with regards to STSE, scientific literacy and/or issue-based approaches, how have your perceptions changed and what made them change?
6. What do you think will be your next steps after the B.Ed with respect to STSE education?
APPENDIX F: PRE-SERVICE PHYSICS TEACHER ON-LINE EXIT SURVEY

This survey has questions most of which you will click the response which best pertains to your situation and/or your perceptions. Thank you for taking the time to complete this survey!

A. Demographics

1. Are you Female or Male?
   - F
   - M

2. Which age group best describes you in years?
   - 20 – 24
   - 25 - 29
   - 30 - 34
   - 35 - 39
   - 40 +

3. What is your highest degree?
   - B.Sc.
   - B.A.
   - M.Sc
   - M.Ed.
   - Ph.D.
   - B.Eng
   - Other (please specify)

4. Is Physics your first or second teachable?
   - First (5 full courses of physics)
   - Second (3 full courses of physics)

5. What are your other teachable areas?
   - Chemistry
   - Biology
   - Mathematics
   - Science
   - English
   - History
   - Geography
   - Phys.Ed
B. Relation between Physics and STSE

6. How would you define or describe STSE education?

(Text box)

7. From your perspective do you think physics and STSE are related?

- Yes
- No
- Don’t know

8. From your perspective, do you think it is possible to teach high school physics from an STSE perspective?

- Yes
- No
- Don’t know

9. What is the aim of teaching university preparatory grade 11 and 12 physics to high school students from your perspective?

(Text box)

10. What challenges do you think you will face attempting to teach an STSE based physics curriculum?

(Text box)

11. When you were a physics student in high school, did your teacher ever discuss ‘real world problems’?

- Yes
- No

12. Please describe any ‘real world problems’ that were used/discussed when you were a student.

(Text box)

13. If your teacher did discuss ‘real world problems’, in your opinion, how does this idea compare to issue-based education?
14. Please rate the following statements:

<table>
<thead>
<tr>
<th>Strongly disagree</th>
<th>disagree</th>
<th>neutral</th>
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</tr>
<tr>
<td>F) STSE requires an interdisciplinary approach</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>G) Promoting ‘action’ (i.e., personal, local) should not be the business of school science educators</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>H) I feel adequately prepared to tackle STSE education</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I) STSE education is not as important as the rest of the science curriculum</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>J) STSE teaching is not worth the effort and time</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

E. Summary ideas
15. If you could change the physics curriculum, what would you change and why?

(Text box)

16. What changes would you make in the physics curriculum or in the education system in general to support STSE based science education?

(Text box)

17. Do you have any other comments that you would like to include in this survey?

(Blank box)

Thank you for completing the survey!
Results will be posted to:
A forwarded website
in
November 2012.

Note Question 13 was developed and reported on in the following reference:

APPENDIX G: PRE-SERVICE PHYSICS TEACHER FINAL INTERVIEW GUIDING QUESTIONS

The following are guiding questions which will be used during the pre-service physics teacher’s final interview. They are meant to probe into the perceptions of the pre-service physics teacher with respect to the integration of STSE into physics teacher education, their perceptions and associated challenges.

Questions:

1. Please describe your most memorable physics learning moment during EDUC 4506. What made the moment so memorable? What was the role of the physics teacher in this moment? Would you consider it an STSE lesson? Why?

2. What should science education be about?

3. What is your understanding of STSE education?

4. What should physics education be about?

5. What is your understanding of Physics Education Research?

6. How would you describe your level of confidence in teaching physics?

7. How would you describe your level of confidence in teaching a physics curricula that is STSE based?

8. Do you think you will include STSE and issue-based tasks into your everyday physics lessons? Why or why not?

9. When you are teaching physics, what do you want your physics students to understand or gain from the course? In your opinion, how do these ideas relate to STSE education?

10. What is the best part or point about teaching physics?

11. What is the worst part or point about teaching physics?
12. Would you be interested in submitting to the researcher any artifacts that you created during EDUC4506 which illustrates your journey from being a physics student to becoming a physics teacher?

13. Are there any final comments or suggestions that you would like to make to the researcher with regards to this thesis topic?

This concludes the interview. Thank you for participating. A transcript will be prepared for you to verify and clarify any information if necessary.
Dear Research Assistant,

Please withdrawal the information I provided to you on ________________ (date) during stage __ of the research project for Ms. MacLeod.

Thank you,

Print name: ____________________________

Signature: _____________________________

Date: __________________________________
Course Description
EDUC 4506 is a critical study of the aims, scope, and sequence of the Senior Physics curriculum. It includes analysis of Ministry guidelines, overcoming Physics anxiety of students and yourself, understanding the scientific and technological concepts presented in the curriculum documents. We will also discuss integration of Physics outcomes with other topics and strategies to promote and nurture interest in Physics as well as technology.

Learning Expectations
The standards of practice for the teaching profession and the ethical standards for the teacher have been embedded in the learning expectations for this course. This course has the following expectations for the candidates:

- Understand and implement Ministry of Education curriculum expectations and Ministry and district school board policies and guidelines related to senior learners.
- Identify, select, and plan Physics education programming specifically suited to the developmental needs of senior division learners.
- Demonstrate a level of competency in modeling the appropriate uses of classroom materials, laboratory materials, resources and experiences appropriate for Physics learners in the senior grades.
- Employ the most current and effective instructional methods related to Physics education to the senior division.
- Have opportunities to increase skills and effectiveness as Physics educators.

Instructional Practice
The importance of a physics, mathematics and technological education in the growth and development of senior students will be addressed. Current curriculum issues, trends, and lesson delivery techniques will be discussed and integrated into all components of the course via direct instruction, small group interaction, pair-share techniques, group brainstorming and problem solving, action research, co-operative learning and peer presentations. Tutorials and workshops focused on curriculum outcomes will augment course candidates’ prior scientific knowledge and respond to individual needs. Pre-service teachers will have opportunities to create supportive networks, receive feedback from peers and the instructor and, through readings and in class assignments show growth and professional development using the reflective process.

Course Content
Senior Physics course supports the Ontario Ministry of Education documents:

- *The Ontario Curriculum, Grades 11 and 12: Science, 2000 and 2008* (when published at the end of September)
- *The Ontario Curriculum, Grades 9 to 12: Program Planning and Assessment, 2000*
- *Ontario Curriculum Exemplars, Grade 11, 2003*

Successful candidates will demonstrate their understanding and ability to apply the following:

- Knowledge of Ontario Ministry of Education curriculum policies for Physics education
- Curricular implications of educational destinations – work, college and university
- Community, print, electronic and collegial resources that link closely to the Ontario curriculum
- A variety of assessment and evaluation instruments appropriate to the developmental stage of learners and the delivery of physics.
- Instructional strategies appropriate for senior learners for both individual and group learning experiences
- Effective classroom management strategies appropriate for senior learners in a physics classroom and laboratory.
- Theoretical foundations of elementary Physics
- Learning theories of elementary Physics

<table>
<thead>
<tr>
<th>Topics</th>
<th>Date</th>
<th>Topic</th>
<th>Homework</th>
</tr>
</thead>
</table>

219
<table>
<thead>
<tr>
<th>Date</th>
<th>Activity and Resources</th>
<th>Additional Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>September 9</td>
<td>Introduction, course outline, resources &amp; examine the curriculum</td>
<td>Read over the grade 11 curriculum</td>
</tr>
<tr>
<td>September 16</td>
<td>Goals of a physics teachers, work with LoggerPro 3</td>
<td>Complete analysis of motion using LoggerPro 3 &amp; Digital cameras</td>
</tr>
<tr>
<td></td>
<td><strong>Portfolio assignment – Type of physics teacher</strong></td>
<td></td>
</tr>
<tr>
<td>September 23</td>
<td>Fieldtrip to Carousel Bring laptops &amp; cameras</td>
<td>Work on the analysis of the data</td>
</tr>
<tr>
<td></td>
<td><strong>Portfolio assignment – Overview of PER</strong></td>
<td></td>
</tr>
<tr>
<td>October 21</td>
<td>What did we learned from the carousel?</td>
<td>Submit “Carousel Analysis” assignment for feedback see</td>
</tr>
<tr>
<td></td>
<td>Motion, forces and torque Ticker-tape, solar cars, H20 cars &amp; Rollercoasters</td>
<td><strong>Portfolio assignment</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Read over the grade 12 curriculum</td>
</tr>
<tr>
<td>October 28</td>
<td>Work, energy and power</td>
<td>Find a water gun</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Compare/Contrast Solar cars, battery cars, H20 car(s)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Physics lesson plan due</strong></td>
</tr>
<tr>
<td>November 4</td>
<td>Energy and Momentum – water gun experiment</td>
<td><strong>Portfolio assignment - Water gun lab</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Return Physics lesson</strong></td>
</tr>
<tr>
<td>December 2</td>
<td>Waves and sound</td>
<td>Ruben’s tube, music, easy demos</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Portfolio assignment – Overview of STSE</strong></td>
</tr>
<tr>
<td>December 9</td>
<td>Wave nature of light, optics</td>
<td>Thin lens and fish tank labs</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Portfolio assignment – Thin lens lab</strong></td>
</tr>
<tr>
<td>Christmas break</td>
<td></td>
<td><strong>Think about Physics unit due on February 3, 2009</strong></td>
</tr>
<tr>
<td>January 6</td>
<td>Electricity and Magnetism</td>
<td>Circuits, magnetism basics, bread boards and oscilloscopes</td>
</tr>
<tr>
<td>January 13</td>
<td>Pulleys &amp; Levers</td>
<td>Kinex kits, building and measuring</td>
</tr>
<tr>
<td></td>
<td>Pulleys and levers lab</td>
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<td>---------------------------</td>
<td>-----------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>January 20</td>
<td>Hydraulics Part 1</td>
<td>Examine college physics course and toy water pumps</td>
</tr>
<tr>
<td>January 27</td>
<td>Hydraulics Part 2</td>
<td>Creating your own pump with measurements &amp; write-up</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Portfolio assignment – Developing water pumps</td>
</tr>
<tr>
<td>February 3</td>
<td>Integration of Physics</td>
<td>Unit of study due</td>
</tr>
<tr>
<td>March 31</td>
<td>AP/IB Physics, OAPT, Science Fairs and more</td>
<td>Physics portfolio due</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Returning of Units</td>
</tr>
<tr>
<td>April 7</td>
<td>Unit presentations</td>
<td>Returning of Physics portfolios</td>
</tr>
<tr>
<td>April 14</td>
<td>Teaching Physics in today's classrooms</td>
<td>Last class and student evaluations</td>
</tr>
</tbody>
</table>

**Evaluation Procedures**

In order to be successful in this course, students must complete all assignments. The penalty for late submission of an assignment is 10% per calendar day. Exceptions will be made for special circumstances; however, students must request an extension by contacting the professor. Failure to complete or submit an assignment will result in an assigned grade of zero “0” for the assignment. If a candidate is absent for 20% or more of the course schedule, the I/S Division Chair will be contacted and the student will be in jeopardy of losing the course credit.

1. **Physics Portfolio = 40% (due March 31, 2009)**

Each course candidate will individually develop a physics portfolio. This portfolio is to include:

- ✓ A description of what type of physics teacher you would like to be giving examples from your past teachers and professors. (1 page max) **Complete by September 16**
- ✓ A brief overview of PER and what you think it means for your physics classroom (1 - 2 pages) **Complete by September 23**
- ✓ A brief overview of STSE and what you think it means for your physics classroom (1 – 2 pages) **Complete by December 2**

  Cont.

- ✓ An overview and write-up of any four of the in-class projects, these include:
  a) Carousel physics (**Submit Oct 21 for feedback**)
  b) Water guns and Momentum
  c) Thin lens lab
d) Pulleys and levers  
e) Developing water pumps

The write-up will include:
Part 1: Introduction/Description of the activity  
Part 2: Relevance to the curriculum (and expectations)  
Part 3: Detailed analysis of the ‘experiment’ with quantities to be calculated and the calculations along with observations and sources of error and drawings  
Part 4: How this activity could be used in a classroom and what modifications might be necessary  
Part 5: What did you learn from this activity?

✓ A summary of the portfolio including how the development of this project has affected your understanding of physics, physics teaching, physics and science research. Complete by March 31

More details on marking scheme will be provided in mid-September.

2. Lesson Plan = 20% (due October 28, 2008)

Each student will prepare a lesson plan from any Physics course. Lesson plans need to follow the required format as discussed within the Methods class. The submission should include the following:

- A title page with the title of the lesson, your name, the course you have selected and reference to specific expectations covered by the lesson.
- The lesson plan with all supporting documentation.
- All references used to create the lesson.
- Submit both a hard and electronic copy so that the information can be posted to the professor’s webpage and course CD as a resource for others.

Email to: sciencehook@gmail.com

Detailed marking scheme will be provided in Methods class.

3. Unit of Study = 40% (due February 3, 2009)

Each course candidate will find a partner and develop a unit of study which is STSE based from either SPH3U or SPH4U (new curriculum). This course of study must follow all the requirements as discussed within the Methods classes. The unit does not have to be generated by Curriculum Planner as this program will not have the
new curriculum expectations. Further detail on this assignment will be issued in October. You will need the course textbook to help you with this assignment.

Textbook & Resources

There is an official textbook for this course;


Readings and Resources:


http://umdperg.pbworks.com/Joe+Redish

http://ejse.southwestern.edu/volumes/volume_list.html

http://www.usask.ca/education/people/aikenhead/

http://phet.colorado.edu/index.php


http://www.phy.ilstu.edu/jpteo/

http://www.physics.org/

Plus, a CD of the various prepared documents at the end of the course will be made available. There will be a number of resources students can access at the Library which include the grade 11 and 12 student textbooks published by Nelson. Other resources will be made available by the professor and will be placed in the Library on an as needed basis.
APPENDIX J: A DESCRIPTION OF THE LESSONS GIVEN DURING THE CURRICULUM AND INSTRUCTION COURSE

A description of the various lessons taught during EDUC 4506 by the instructor and indication of if they were considered STSE or non-STSE based experiences for the pre-service teachers.

<table>
<thead>
<tr>
<th>Lesson Topic</th>
<th>Brief description</th>
<th>STSE</th>
<th>Non-STSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to the course</td>
<td>Introduction, course outline, distribution of resources and curriculum documents (information session)</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Introduction to Portfolio, data analysis software</td>
<td>Goals of a physics teachers, Work with LoggerPro 3 and complete analysis of linear motion with digital camera, Plan for fieldtrip</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Fieldtrip to Carousel</td>
<td>Analysis of the physics involved with the operation of a 1920s carousel, Technology requirements and changes, Impact on society</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Motion, forces and torque</td>
<td>Ticker-tape lab using motion carts to calculate velocity and acceleration,</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Ticker-tape lab using solar cars and H20 cars with comparisons how technology could affect performance</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Logger Pro 3 (velocity and acceleration) analysis of Rollercoasters</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Work, energy and power</td>
<td>Discussion of work, energy and power. Mathematics involved and problems associated with teaching these topics</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Energy and Momentum – water gun experiment</td>
<td>Using a watergun and an air-track determine the muzzle velocity of the watergun using the law of conservation of momentum, calculate the energy lost, and connect to paintball injuries/deaths of children and adults</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Waves and sound</td>
<td>Drawing and physical examples of waves</td>
<td></td>
<td>✓</td>
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<tr>
<td></td>
<td>Tuning Bagpipes (beat frequencies) and mechanical resonance (Tacoma Narrows bridge)</td>
<td>✓</td>
<td></td>
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<tr>
<td></td>
<td>Ruben’s tube</td>
<td>✓</td>
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<tr>
<td></td>
<td>Calculating the speed of sound with a hard surface</td>
<td>✓</td>
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</tr>
<tr>
<td>Topic</td>
<td>Content</td>
<td>Complete?</td>
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</tr>
<tr>
<td>Wave nature of light, optics</td>
<td>Thin lens lab (traditional with candle and metre stick light bench)</td>
<td>✓</td>
<td></td>
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<tr>
<td></td>
<td>Fish tank optics (TIR and critical angle calculations) connection to fibre optics</td>
<td>✓</td>
<td></td>
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<tr>
<td></td>
<td>Single slit diffraction and Young’s experiment</td>
<td>✓</td>
<td></td>
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<tr>
<td></td>
<td>Pinhole camera physics</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Electricity and Magnetism</td>
<td>Building basic circuits (parallel and series)</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Next steps: breadboards and circuits</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Basics of magnetism, duality</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Pulleys &amp; Levers</td>
<td>Kinex kits: Building pulley systems, measurements and connection to technology and societal uses</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kinex kits: Building lever systems, measurements, and connection to society</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Watching Obama’s inaugural speech</td>
<td>Class watched and discussed implications of Obama’s inaugural speech on the future of science</td>
<td>✓</td>
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</tr>
<tr>
<td></td>
<td>education in the US and Canada</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydraulics Part 1 and 2</td>
<td>Creating your own pump with measurements &amp; write-up</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Integration of Physics</td>
<td>Discussion of how physics can be integrated into other sciences and how other subject areas have</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>influenced physics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AP/IB Physics, OAPT, Science Fairs and more</td>
<td>Discussion of requirements for AP and IB physics programs, benefits of OAPT (conferences, contests,</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>etc.) and basics of science fairs (regionally, provincially, and national)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unit presentations</td>
<td>Pre-service teachers presented their units to the class.</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Teaching Physics in today’s classrooms</td>
<td>Last class: Discussion of ideas presented in the course. Impact on classroom activities. Where</td>
<td>Hints</td>
<td></td>
</tr>
<tr>
<td></td>
<td>science education and specifically physics education could be going</td>
<td>(nothing</td>
<td></td>
</tr>
</tbody>
</table>