Pre-Service Teachers' Perceptions Of Teaching STSE-Based High School Physics: Implications For Post-Secondary Studies

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Abstract
Science, Technology, Society and Environment (STSE) education has received attention in educational research, policy, and science curricula development, yet less advancement has been made in moving theory into practice. There are many examples of STSE-based teaching in science at the elementary and secondary levels, yet little has focused specifically on the area of physics education. This research examined pre-service physics teachers' views and perceptions, challenges and tensions which influenced their adoption of the required STSE educational expectations found within secondary school physics curriculum of Ontario, Canada, in the context of a pre-service physics education course. The researcher employed an interpretive case study design. The pre-service physics teachers' evolution of perceptions and attitudes demonstrate 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 faced when teaching physics through an STSE lens, provides implications for teacher education and physics education at the undergraduate level.
Keywords: STSE education, Pre-service physics teachers, interpretive case study

Introduction

This article describes the research conducted by a physics teacher working within a faculty of education in the province of Ontario, Canada. Its purpose was to examine the understandings and perceptions of pre-service physics teachers as they began their teaching journey with a physics curriculum, which challenged them to teach physics through a Science, Technology, Society and Environment (STSE) lens. This research describes how these pre-service teachers came to understand the scope of teaching physics through an STSE lens, and the possible challenges and benefits for the various stakeholders if physics content is taught in this way. The research questions emerged as a result of the province repositioning STSE expectations within the curriculum documents and wanting to know how this change in curriculum was going to be perceived by those in a pre-service education program. The research questions were:

1. What are the initial understandings held by the pre-service physics teachers' about physics education and does their position change or evolve?
2. How do pre-service physics teachers define STSE education in general, in the context of the physics curriculum that they will teach, and in their physics curriculum and instruction course?
3. What do the pre-service physics teachers perceive to be the challenges and tensions of teaching physics at the high school level through an STSE lens? And,
4. What are the implications for the future of physics education and STSE education as perceived by these pre-service physics teachers?

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It explored how pre-service physics teachers came to understand the integration of required science, technology, society and environment (STSE) educational expectations into the high school physics curriculum (University Prep 11 Physics and University Prep 12 Physics). 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 connection to STSE, and pre-service teacher views about physics education and STSE education. Through investigation of the intersection of these research areas, insight and awareness of issues in the preparation of pre-service physics and science teachers emerged leading to recommendations in pre-service physics and science education, secondary student engagement levels within the physics classroom and during physics units in general 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 different from those of general science teachers. Finally, there is little data on pre-service physics teachers' attitudinal changes concerning STSE.

Literature Review

Science Education for Scientific Literacy

Our understanding of science varies—whether it is the diversity 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). The goals of science education can include preparing today's students to become future scientists or science teachers, or rendering them capable of responsible decision-making in terms of economic, social, and environmental concerns (Pedretti & Little, 2008). Over the past 30 years, science education and research examining the purpose of science education have adopted the term "scientific literacy," defined by Pedretti and Little (2008) as "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). As well, The Council of Ministers of Education (CMEC, 1997) set out four components of scientific literacy; the first encourages students "to develop a critical sense of wonder and curiosity about scientific and technological endeavour" (p. 5). The second component suggests that teachers need to enable 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" (p.5). The third component focuses on "preparing students to critically address science-related societal, economic, ethical, and environmental events and issues" (p.5). The final component is that teachers need to provide a solid science education foundation for students so that they will be able to "pursue progressively higher levels of study, science-related occupations or science-related hobbies" (p. 5).

Adopting a broad definition of scientific literacy, science education, has concentrated on making science accessible and meaningful for all students, since "traditional school science attempts to socialize students into a scientific way of thinking and believing . . .. Other students who do not see themselves as future scientists and engineers are screened out"(Aikenhead, 2005, p. 384). The goal is "to develop students' capacities to function as responsible, savvy citizens in a world increasingly affected by science and technology"(Aikenhead, p. 384). Further, Hodson

(1998) 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). 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 learning goals for learning about science are:

> *"To learn much more about the phenomena and concepts they are investigating, . . . 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, pp. 139–140)*

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)*

From this understanding of scientific literacy as well as the notion of learning science, learning about science and learning to do science, it is clear that these goals are broad, diverse, and challenging. STSE offers one way of achieving these goals (Pedretti, 2005).

The Nature of STSE Education

STSE education is 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. Science environmentalists and sociologists who focused on integrating "values" and "social responsibility" in science education have supported STSE education. Over time, STSE has evolved, as Aikenhead (2005) explained, STSE was formed by amalgamating broad academic fields which included elements of science, scientists, social issues external and internal to these communities whereby relationships would probe communal, epistemic and ontological values. STSE education also seeks to develop an understanding of the nature of science (NOS), i.e.,

> *"It is 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)*

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

Some have criticized STSE and wondered whether it really improves students' understanding of science. Aikenhead (1994) suggested that STSE requires a deep understanding of science, and that students learn concepts, theories, and laws when science content is embedded in a meaningful and relevant context. In addition, other studies (Bennett et. al., 2007; Aikenhead, 2003, 2005, 2006) have shown that students in STSE courses demonstrate improved attitudes towards science. Bennett et al. (2007) reviewed a number of studies that examined the effect of implementing context-based/STSE, and found that these approaches did result in improvements of attitudes and understanding of scientific ideas. Further, it has been noted that, “significant increases in numbers choosing physics and biology in students taking the STS [E] program, with numbers doubling in both subjects” (Smith & Matthews, 2000, as quoted in Bennett et al., p. 363). STSE seems to holds promise for keeping students interested in pursuing studies in science, including physics.

History and philosophy of science (HPS) is a component of STSE, “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 times, this allows the teacher to set up a paradox for the student to work through. With the use of HPS and setting up paradoxes that students can explore, greater emphasis can be placed on conceptual learning thereby allowing students with ‘math phobia’ greater access to physics courses at the secondary level (Nashon et al., 2008).

As STSE continued to gain strength from worldwide research initiatives and innovative curriculum development, could McFadden’s (1980) comment, that “the majority of Canada’s youth never receive a systematic course of instruction in physics, the science which embodies the main ideas propelling the scientific-technological revolution” (p. 49) still hold true? Could this STSE-oriented physics curricula be perceived as more student-friendly and help demystify and quell fears about learning physics? Furthermore, could science teachers who teach physics embrace an STSE-oriented curriculum where students are learning physics, learning about physics, and learning to do physics as was described by Hodson (2000) concerning science and scientific literacy?

Development of Physics Education Research (PER) and Connections to STSE

Physics 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). As frequently indicated in the literature, physics enrolment at the secondary school level continues to decline (Brickhouse, 2001; DeBoer, 1991; Hart 2001). Research into why physics enrolments are declining has been undertaken both by physicists and by science education researchers. As McDermott (1998) stated:

> *“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 type of research has come to be known as physics education research (PER), is primarily conducted by physicists, and has been conducted worldwide (McDermott & Redish, 1999; MacLeod, in review). They 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 (Akarsu; 2010; Leonard, 1996; McDermott, 1991, 1998, 2001; McDermott & Redish, 1999; Redish, 2003). Researchers have also engaged students in dialogue, examined homework and written reports, conducted classroom observations, and used pre- and post-testing of students. The results have been used to guide the development of curriculum at the university level. 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). 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 (by Redish; see van Aalst, 2000).

Teaching strategies have also undergone scrutiny, studies have illustrated that traditional teaching methods are ineffective. 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). When students' beliefs about physics and problem-solving were examined, "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, p. 37). How can physics teachers enhance student learning in physics? The "better approach" suggested by many authors is to use a variety of teaching strategies that encourage students to participate in lectures, and to talk about methods and the meaning of problem-solving tasks—that is, students learning about physics while learning to do physics – a slight twist on Hodson (2000) and advocated by many (Akarsu, 2010; Beichner, 2009; Bloom, 2006; Harrison, 2010; Redish, 2003; Wieman 2005); and to contextualize physics (Kortland, 2005). And, as McDermott commented, "To make science meaningful to young students, teachers need to know how we know as well as what we know" (2006, p. 760). STSE could be a key teaching method to implement this suggestion and making science and, more specifically, physics meaningful and valued by students. As discussed by Knight,

> *"Physics education research has brought out the need for instruction to be student-centered, explicitly recognizing the knowledge state of the students and the activities that will transform them to the desired state. In this view of instruction, the teacher is less an authoritative source of knowledge and more a facilitator; providing opportunities and feedback through which the students can develop correct knowledge structures and mental models. Implicit in this view is that students construct their mental models from their experience; we cannot hand them an already built, fully operational mental model. This model of instruction is called scientific constructivism." (Knight, 2004, p. 41)*

In examining Physics Education Research, there are few studies that connect physics teaching and learning to STSE education. How might physics education consider learning physics, learning about physics, and learning to do physics? Unfortunately, little PER has been conducted by trained physicists in secondary school physics classrooms, or with secondary school physics teachers in the area of STSE. Furthermore, there has been very little examination or focus on physics teachers' or pre-service teachers' perceptions of an STSE-oriented physics curriculum in the literature (Nashon, 2008; Pedretti, Bencze, Hewitt, Romkey, & Jivraj, 2008).

Pre-service teachers' views about physics and STSE

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" (p. 144). Other authors have agreed: "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). 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 adapt 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; Rubba, 1991). When 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; Forbes, 2008; Novodvorsky, 2006; Schwartz, 2002).

According to the literature, a teacher's self-identity and self-efficacy play an important part in determining which of Aikenhead's three categories a teacher gravitates towards (Pedretti et al., 2008). Part of this self-identity is a professional self-identity, developed during the undergraduate years when students were socialized into a particular scientific discipline (Aikenhead, 1994). A determining factor, according to Aikenhead is if the person can move beyond the previous 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).

Examining teachers and pre-service teachers' self-efficacy was 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 favour academic self-directedness and open-ended problem solving." (Yoon, 2006, p. 15)*

Ways of increasing pre-service teachers' self-efficacy included using cases and case methods that allowed for multiple points of entry, through the use of scaffolding (Yoon, 2006). Implementing an integrated module during the pre-service education program which combined 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, 2007). The three types of knowledge a teacher must possess and that need to be discussed in a curriculum and instruction course are: content knowledge, pedagogical knowledge, 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, pp. 831–832)*

Yet, 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 and does suffer. To what extent do these factors affect physics teachers and pre-service physics teachers specifically? The answer to this question is complex and vague, with little clarification in the research literature.

Methodology

This research is rooted in qualitative case study 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 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. In this research, I employed an interpretive case study design in my research (Novodvorsky, 2006). The specific phenomenon this case study examined and explored the views, adoption issues and challenges, and perception and attitudinal changes physics pre-service teachers faced as they consider a physics curriculum that explicitly emphasizes an STSE orientation to physics education at the secondary level. The constant comparative method for data analysis was used on all data collected and grounded theory methodology as discussed by Glaser (1956) and later Charmaz (2006) applied to the findings.

Overview of the case

The participants for this research were enrolled in a Curriculum and Instruction Physics Course (bachelor of education) within a Faculty of Education at a small Ontario university in Canada. This was a one-year program whereby upon graduation the participants would be licensed to teach within the province and abroad. There were 11 pre-service teachers enrolled in the course and 10 participated. The participants all had an undergraduate degree (bachelor of science or bachelor of applied science) and were required to have a minimum of 15 credits in physics in order to be in the course. I was both the instructor and the researcher; therefore I kept my own research journal and employed a research assistant to conduct various aspects of data collection to reduce power struggle issues.

There were five stages to the data collection process: initial online survey and individual interviews, three rounds of focus group discussions, final online survey and individual interviews. The online surveys were a mixture of qualitative, open-ended questions and quantitative questions were scored on an even based Likert-scale. Interview and focus groups were conducted with pre-determined semi-structured questions, which allowed for participants flexibility in their responses. Participants were asked if they would like to share artifacts with the researcher at the end of the research. All interviews and focus group sessions were recorded, transcribed and member checked prior to data analysis being completed. Data collected by the research assistant was turned over to me after final grades for the course had been submitted.

Results

Pre-Service Physics Teachers' Understanding Of Physics Education

Findings indicate that these pre-service physics teachers believe that "active engagement of students within the physics classroom and with the content"(various participants during data collection) is the best way for students to achieve success. According to the pre-service teachers, "active engagement can be through the use of applications to the real world, hands-on activities or through the use of calculations and computations". This implies that a physics teacher needs to understand and apply many different teaching strategies within the classroom and that 'direct instruction' is not the only method to teach physics. This theme voiced by many of the participants seems to indicate that either the undergraduate experience is changing or that a shift is occurring whereby pre-service physics teachers realize that they can not repeat their undergraduate educational experiences in the secondary school classrooms (Aikenhead, 2005; Knight 2004; Redish, 2003; Wieman, 2005).

The main goal of physics education according to the pre-service physics teachers "should be to help students understand the basic concepts so that they can better understand the world around them". This is highly similar to the essence of physics given by Hart (2001). The main challenge pre-service physics teachers noted was that of "having adequate resources to teach physics through an STSE lens". The question and challenge of resources is discussed extensively in the work by Aikenhead (2005).

Understanding STSE Education In The Context Of Physics Curricula And Their Physics Curriculum And Instruction Course

Pre-service teachers show a steady and progressive understanding of STSE education. In the beginning of the course, as the research got underway, the candidates commented that in their own high school experiences they had experienced physics placed in context but did not refer to this as STSE education. For example, as high school students the candidates experienced:

a) Balancing 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 field trip 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 its 'correctness' (Seamus, Colin and Patrick)

In addition to these examples of classroom learning, candidates commented that their teachers would do more then just lecture:

> *"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." (Jesse)*

> *"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…I found [the history] very interesting because it puts everything in perspective." (Patrick)*

In each of these comments by the participants, it is clear that they had opportunities to learn physics in a way that went beyond the traditional Socratic, direct instruction, mathematical based physics lectures. Yet, when asked to describe STSE, their comments reflected no understanding of the term. For example, one participant responded, "I have no clue as to what STSE is…". It is interesting to note that although they did not know the term STSE, they had (to varying degrees) experienced STSE within their high school physics courses – perhaps an indicator of pedagogical science literacy of pre-service teachers? As the curriculum and instruction course continued whereby candidates had multiple opportunities to participate in and deconstruct STSE and non-STSE lessons, STSE was equated to 'hands-on' activities or 'real world problems'. From here, questions began to be asked during class time and focus group sessions concerning *how* connected 'real world problems' needed to be connected to the real world. Questions, which were raised, included:

> *"How are 'real world problems' connected to issue based tasks? What about ethics? Is values education part of teaching physics? How can and should history be included? How do we deal with a difference of opinion – subjectivity in physics? How can we assess accurately if subjectivity is involved?"*

"These discussions took the average physics lesson from being content driven to providing a connection between content and context, and providing a scaffolding for pre-service teachers 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)" (MacLeod, 2012).

As their awareness grew, confidence and comfort with the idea of STSE and what was now expected of them as 'physics teachers' with an STSE-orientated physics curriculum with a design/application (Pedretti & Nazir, 2011) emphasis was acknowledged. There was very little of a transformative or agency emphasis although they did appear to be moving in that direction. They were moving towards understanding the scope of scientific literacy and the connections between it and STSE education. After much deliberation, the pre-service teachers felt that real-world problems and issue-based tasks were on a 'continuum'. They were also keen on the notion of teaching values education in physics yet were unsure of how to assess work that is subjective.

Perceived challenges and tensions

The pre-service physics teachers echo the research findings from Aikenhead (2005) and Pedretti et al. (2005) and gave reasons why teachers may not be able to or unwilling to adopt STSE. Here, pre-service teachers commented that challenges to including STSE into their teaching of physics would include finding resources, time to complete the course and doing it "well", questions concerning assessing subjective material and if that material is actually "physics", wondering if it is ethical to judge a student's values, not knowing how to explain the changes within the physics course to parents who might have a very different view of what a high school physics course should be and content it contains. Finally, they voiced the concern of enrollment exceeding the allowed classroom size, i.e., classes larger than the maximum allowed – how do you teach physics to such a large class?

The pre-service teachers also discussed tensions. They commented that not all physics teachers would be at the same place in their understanding of STSE and questioned how that would impact their own personal teaching – would they be accepted and act as a mentor to other physics teachers or be outcast since they were not following the status quo (a tangent of the work by Akarsu & Kaya (2012)). The participants were happy that STSE could open up physics courses to those who are less 'mathematically' inclined but were wary of if the courses would then lose their rigor. Pre-service teachers commented that they did not know how an STSE orientated physics course would prepare students who were graduating and going into a bachelor of science degree to complete an honors in physics – would it be beneficial or place the students at a disadvantage (again the question of rigor was raised). They also asked if the professors of undergraduate science programs were aware that the science curriculum had changed and wondered about their reaction. These tensions are not uncommon as they have been voiced within the literature (Aikenhead, 1994; Bennett et. al., 2007; Aikenhead, 2005, 2006; Rubba, 1991; Forbes, 2008; Novodvorsky, 2006; Schwartz, 2002).

Implications

The implications for the future of physics education and STSE education can be further broken into the various perspectives: pre-service teacher, faculty of education, and faculty of science. For the pre-service teachers, there is little question as to 'why' one would teach an STSE-orientated physics curriculum, rather the question left in their minds was 'how do I do this well and consistently?'. They seemed cautiously optimistic about teaching STSE-orientated physics in that they knew it was a good idea but apprehensive of the reaction of their more experienced peers. 'Full' implementation will take time as they themselves feel it is a 'work in progress'. Further, they indicated a possible need within the school system to develop Professional Learning Community (PLCs), which would focus on physics teachers collaborating, and sharing ideas of how to infuse more STSE orientated lessons and activities into their everyday teaching. Another implication from the pre-service teachers point of view was that enrollment of students in physics courses could increase; this was seen as both a positive in that more students would have the opportunity to learn physics and also as a challenge in that the physics students would have less individual attention by the physics teacher if they were having difficulties. With teaching an STSE-infused physics course, physics teaching and learning could become less rigorous as was discussed earlier. Finally, the pre-service teachers felt that STSE could be used as a way to connect social and physical sciences within a school setting – obtaining both perspectives when attempting to understand a specific societal issue and the ramifications of political, economical, environmental and societal decisions made by governments or other organizations.

The implications from the faculty of Education perspective include the importance of explicit modeling for pre-service teachers so that they have the opportunity to (a) experience the lesson as students might and (b) have a chance to understand the planning and preparation that goes into such a lesson. By doing this, the pre-service teachers see the scope of STSE in the subject area (pedagogical content knowledge as discussed by Wenning (2007)) and see that STSE means more then just 'application' of physics. A second important point that was raised is the power of semi-structured small group discussions concerning the course content. Pre-service teachers felt that it was through 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 classroom. It was a non-threatening environment whereby no assessment or evaluation was tied to the conversation, rather it was learning for the sake of learning. Some might consider these discussions to fall under the 'professional learning community' design.

Faculties of Science, specifically physics departments, may want to consider examining the high school physics curriculum and discuss the contents with local high school physics teachers to better understand the high school physics learning experience. 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 as is inferred within the PER literature without specifically using the term STSE.

Summary

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 (MacLeod, 2012). It is the role of the teacher to help students make sense of the content and it is through the pre-service teachers' experiences in their bachelor of education program that they undergo their own transition from student to teacher. Their perceptions and views are important as these will eventually play out within the science and physics classrooms around the world. As physics and education faculty members, we are to assist our students on their own learning journey, showing relevancy and context of content and assist in their transformation from student to an actively engaged member of society.

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