Pre-Service Physics Teacher STSE Education: Learning through Conversations Between Brazilian And Canadian Scholars

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ABSTRACT

Science, technology, society, and environment (STSE) education is a focus of the public education system of both Canada and Brazil and therefore should translate into the teaching and learning that occurs within their respective Bachelor of Education programs when addressing Science education, and specifically the connections between STSE and Physics Education within the curriculums of both countries. This research is based on the experiences that took place during a 20-day scholarly visit to St. Francis Xavier University with Dr. MacLeod by Dr. Roehrig, a Physic Education scholar from Brazil. Using the technique of comparative study, the authors agreed upon three areas of comparison to be considered: the performance of teacher educators, the curriculum structure of the B.Ed. programs, and university–school interaction. Each of these three areas drew attention and are discussed within. This work points to possibilities for strengthening the insertion of STSE pre-service education with the aim to exchange best practices. As this collaboration evolves, this work is expected to expand with discussions leading to both breadth and depth of improvements within course offerings, overall education of pre-service and in-service physics teachers, and faculty who enact the premises of STSE physics education in their daily practice and profession.

Keywords: Physics; Physics Pedagogy, Pre-Service Teacher Education, STSE Education.

INTRODUCTION

Science education with a technology, society, and environment (STSE) focus has been considered one of the major strands of the science curricula of both Canada and Brazil, yet both countries approach STSE education very differently. In Canada, the education system is held under provincial jurisdiction; therefore, each province and territory has their own, sometimes unique Science curriculum. As a result, STSE content appears differently in each of the provincial and territorial curriculum documents. Further, how teachers enact STSE education within their own science classrooms depends on a myriad of factors including their own understanding of science and STSE, resources, time, and perceived value of STSE content to the student (Aikenhead, 2005). Unlike the Canadian system, in Brazil, the education system is nationally-based system and the Science curriculum and STSE outcomes are found in the National Curriculum Guidelines (Brazil, 2006), and are based on the National Curriculum Parameters (PCN), which was the current curriculum document in the first two decades of the 2000s. The *National Pact for the Strengthening of High School* was an in-service teachers training initiative that occurred between 2014 and 2015, and a dedicated chapter of the Natural Sciences Notebook (Brazil, 2014) specifically discussed various possibilities for teachers to develop STSE focused education (see Department of Basic Education. High School Teacher Training, Stage II - Notebook III: Natural Sciences. Ministry of Education, Department of Basic Education. Curitiba: UFPR/Sector of Education, 2014). The most recent Brazilian curriculum guidelines—the National Common Curricular Base (BNCC)—approached this perspective as it established interdisciplinary themes in Natural Sciences curriculum stating that "[STSE] constitute a basis that allows students to investigate, analyze and discuss problem situations that emerge from different socio-cultural contexts [...] applying them in the resolution of individual, social and environmental problems" (translated from Brasil, 2018)Although the discussions concerning STSE education in Brazil have gained strength in the last 20 years and the study of STSE education has consolidated itself as a line of research with an increasing number of studies published in journals and events, there is still great difficulty in implementing STSE education effectively in an ongoing, consistent basis in the Brazilian education system. This system is referred to as "basic education" and is equivalent to Grades 1–12 in Canada.

The infusion of STSE education or lack thereof is especially concerning in physics and in physics teaching. The occurrences of STSE teaching in Brazilian classrooms are still sparse and occur in isolation in that they are a "one-of-lesson." Many teachers have commented that they do not know what or how to organize their lessons so that STSE and the physics content are harmoniously covered within physics classes in a way that STSE is embedded within the course and not a stand-alone or considered as an "after-thought." Thus, there are strong indications that physics continues to be taught in a decontextualized, highly fragmented way and with a strict focus on pure mathematics, a teaching model that perpetuates inexorably traditionalist views, when we, as researchers and teachers, as discussed in the literature know better (Aikenhead, 2005; Forbes,

2008; MacLeod 2012, 2013; Novodvorsky, 2006; Schwartz, 2002). The driver for this work is our collaborative frustration with the systemic status quo, and examining our own teacher education science programs, and questioning if and how we as individual science professors can create greater ripples that lead to shifts in pedagogy whereby STSE education will be recognized and used by pre-service and in-service teachers as a mechanism though which to teach content rather than be seen as an add-on as it currently is in both countries. In other words, our hope is, as Erickson (2006) alluded, to "use" topics to teach and assess deeper, conceptual understanding rather than just showing or talking about the topics. This idea also resonates with the notion first introduced by Hodson (1998) then adopted by MacLeod (2012) of learning physics, learning about physics, and learning to do physics while making it personally meaningful, that is, to contextualize the content. This is where STSE enters the picture.

In this work, we present reflections resulting from a process that aimed to understand the possibilities of how to implement STSE education effectively into the physics degree course of the Federal Technological University of Paraná (UNIV A). A philosophical movement that has taken place within the undergraduate programs of this institution has pointed to the need to strengthen the technological dimension of teacher training courses. Specifically, STSE education has been configured as the main guiding element that should be considered by the collegiate of each undergraduate course for their curricular organization. At UNIV A, students can enter directly from their basic education and complete their teacher training alongside their physics education training concurrently. Therefore, it is possible during some semesters or terms that students are simultaneously experiencing their pedagogical courses (courses focused on education), their physics content courses, and their pedagogical content knowledge courses (which fuse both their educational knowledge and their physics knowledge to assist them in becoming physics teachers). In contrast, at St. Francis Xavier University (UNIV B), students are required to complete a degree in science (biology, chemistry, physics, or other) prior to enrolling in their education degree. The education degree is considered an "after degree," which combines courses on pedagogy both broadly as well as specifically in the area of science education (pedagogical content knowledge courses) where time is spent on each of the disciplines separately and in combinations via STSE initiatives.

The notion of this scholarly visit and study emerged from the desire to infuse a greater sense of STSE into both our own teaching practices and by extrapolation, explore and mentor other educators on how they can do the same specifically in courses where it has been perceived that almost zero insertion of STSE discussion or activities have occurred. For example, courses such as "Teaching Project STSE" and "Teaching Methodology" at UNIV A that are found within the curricular matrix of course offerings may lend easily to the insertion of STSE education via discussion or activities, while others may require more time and thought of how purposeful infusing STSE could be obtained. In fact, some of the professors and instructors of higher education themselves do not know when or how to conduct their activities to promote this approach

as being essential for the future physics teachers and herein lays part of the problem. It is perceived that the professors and instructors of UNIV A are on an STSE spectrum ranging from novice to expert when considering a pedagogically infused STSE physics education course. The question now is how to move participants along the spectrum to reach greater engagement in STSE infused lessons, building their capacity, self-identity, and competence and confidence.

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Theoretical Foundation

The problems related to the teaching of physics in either the basic education in Brazil or the secondary school systems in Canada mirror each other and are well known and exhaustively mentioned in the literature. In short, to highlight Bazzo et al. (2003), since the mid-20th century, the trend in science teaching has been content-centric, with a strong reductionist, technical, and universal focus. Within the educational research literature, it is well documented that as a traditional school subject, science education was to be objective, linear, and context-free (DeBoer, 1991). This was the state of school science until WWII, unfortunately post WWII advancement of school science was not as revolutionary as other subject areas yielding the reflective comments from Aikenhead (2005):

> *Traditional science teaching has had 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)*

One way for students to retain content, is to connect with it in some way, else it is quickly forgotten. This is the attraction of STSE, which provides contextualization for the student (MacLeod, 2012). Overcoming the lingering problems of the past, as discussed by Aikenhead, has been the objective of studying the area of research related to the teaching of physics. As educational researchers and former teachers, pedagogically the use of experimentation, information technologies, games, and simulations, among other strategies, as possible solutions to improve the level of engagement that students have in physics in basic education all provide entry

points for learning for students. Despite the potentiality of these resources, it is necessary to consider that there are fundamental methodological elements that must be present in educational practices that allow students to attribute meaning to physics in its historical and social context. In this sense, STSE education can offer a pathway to teachers that will bridge the science that students learn closer to the lives of students within the framework of the Brazilian Basic education system or the Canadian public school system.

One of the fundamentals of STSE education to be considered prior to stepping into the classroom is the contextualization of knowledge as/for/from the student perspective. This aspect, according to Aikenhead (1994), implies "teaching about natural phenomena in a manner that embeds science in the technological and social environments of the student" (p. 48); that is, it is a contextualization in which the scientific content is connected and integrates with the student's historical and social context, past, present, and future values. The content can connect culturally with the student. According to Acevedo et al. (2005), from the perspective of STSE education, scientific content becomes relevant to students to the extent that students will be shown how issues presented can be related in their social context, contributing to the notion of citizenship and civic duties concerning scientific and technological issues and their potential or possible consequences, and the impact STSE issues have on society and the environment.

According to Ziman (1994), though the power of STSE we can highlight the interdisciplinary, historical, philosophical, and sociological focus of how science can be used in problematization and solution finding. These aspects can help students construct a more coherent image of science, to the extent that an interdisciplinary model promotes the reduction of fragmentation of knowledge, connecting the historical, sociological and philosophical approaches while deconstructing the supposed neutrality attributed to science. The problematization contributes to the understanding and discussion of real-life and current issues of a scientific and technological nature, present in the social context of students and bringing value to the content and meaning which transcends the “test” that takes place at the end of the unit.

Educating science teachers, especially physics teachers, which have intention to work from the perspective of STSE education, has been a great challenge for teacher educators of both countries. This is what has led us to initiate this research and these discussions. It is our united quest that has led us to this collaboration with the intention of infusing STSE into science pedagogy, specifically physics pedagogy in such a way as for it to be unnoticed and done with ease.

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). In such an approach, it is understood that we, as researchers, have adhered to a subjectivist or transactional epistemology; moreover, we acknowledge a relativistic ontology where multiple realities exist, and understandings are co-created. We argue that the epistemology for this research is partially interpretive since the "knower and known interact and shape one another" (Denzin & Lincoln, 2005, p. 22). This research project can be characterized as interpretive research (Merriam, 1998) since we knew each other and through discussions were coming to an understanding about our shared and different situations. Further, multiple realities were voiced by both researchers since we were able to understand the need for STSE education and both were able to focus and re-focus our points of view to acknowledge the frustration of colleagues to "add in" STSE. This was a critical part in clearly identifying barriers to each of the above-named areas via qualitative data analysis to "understand and explain the meaning of the social phenomena with as little disruption of the natural setting as possible. …It is assumed that meaning is embedded in people's experiences and that this meaning is mediated through the investigator's own perceptions" (Merriam, 1998, pp. 5–6). If we accept Merriam's (1998) suggestion, then the experiences and opportunities we had to make connections with and voice concerns about imbedding STSE into these areas can be voiced and then could be unpacked and addressed.

To do this, we employed an interpretive case study design (Novodvorsky, 2006). The specific phenomenon explored in this case study was the infusion of STSE as it could be viewed, the issues and challenges of STSE, and the evolution of our perceptions and attitudes as we discussed, learned, and reflected on our three areas of study. The areas of study were identified to be the performance of teacher educators within the classroom, the curriculum structure of the B.Ed. programs, and university–school interaction. Elements of the comparative study were used (Silva, 2016), to define "areas of comparison" between teacher education programs in the two university contexts. It is noteworthy that this study does not intend to suggest quick solutions; disregarding the cultural, economic, and social differences that permeate the academic life of Brazilian and Canadian teachers and students would be naïve. Rather, as researchers, our aim was to present reflections originated from the sharing of experiences between two researchers who develop similar works in different contexts.

For 20 days between October and November 2019, Dr. Roehrig, a Brazilian researcher, participated and interacted in different contexts within of the teacher education program at UNIV B, such as the observation of Dr. MacLeod's classes in both on-campus and at off-campus sites (subjects: Environmental Education; Curriculum Studies: Secondary Science; Physics 121), the participation of the in-service professional development at the Nova Scotia Teacher's Union Provincial Professional Development Day (organized by the Association of Science Teachers of Nova Scotia, and held at Halifax West High School), observation of physics classes in public schools in the Antigonish region, participation in professional development events held within the Bachelor of Education program such as "Building Bridges" (integration between students of undergraduate courses (pre-service teachers) and their internship advisors, which marks the

beginning of the internship period in schools (practicum placements), among other activities related to teacher education.

From these interactions, we had daily discussions from which field notes were taken concerning the topics of interest. From an analysis of these discussions, three areas of comparison were systematized to be analyzed in this study: (a) aspects about the performance of the educating teachers; (b) aspects about the curricular structure of the teacher education programs; and (c) aspects about university–school interaction. Next, we discuss how UNIV A and UNIV B have facilitated the integration of STSE from these areas of comparison.

FINDINGS AND DISCUSSION

We first discussed and compared our physical situations which we experienced at our respective institutions. An important difference to note about the university structure in which students, the pre-service teachers, specifically future physics teachers, viewed their academic experiences, is that UNIV B has a Faculty of Education, which operates in a separate building from the Center for Physical Sciences. This physical separation and administrative structure mean that, like most Brazilian universities, the UNIV B campus is divided into their specific scientific disciplines which are located in one area of campus and in a different area of campus the teacher education buildings are located where they learn the pedagogical elements of teaching and learning science. Interestingly and very importantly, their professor has had to reach out to the Physical Science Center numerous times for equipment and does has a positive working relationship with the departments.

At UNIV A, the physics teacher degree program has its entire faculty linked to the Academic Department of Physics, so that both the specific disciplines of physics and pedagogical disciplines (physics education) are part of the same group, having a joint collegiate. That is, both professors whose academic background is focused on scientific research (pure physics) and those whose trajectory is focused on research in the teaching of physics, share common spaces and are under the same institutional leadership. This aspect facilitates the interaction between academics from different perspectives, which could bring forth innovative methodologies and new visions of physics teaching in the undergraduate course.

Such differences would seem to favour the Brazilian institution model concerning the possibility of improving the teaching processes and strengthening STSE education for undergraduates, but unfortunately this does not occur yet. Tensions were felt by the researchers from their colleagues on how best to navigate the question of prioritizing content versus critical thinking and STSE opportunities.

Regarding the approach of STSE education at UNIV B due to the nature of course content, the professor and researcher responsible for discipline related to the curriculum and instruction

methodologies course (Science teacher preparation course), articulated science in a way that contextualized the content. Here, they provided students with practical experiences at different levels, differentiated applications of STSE, illustrated relationships, and connected socio-scientific issues. Active participation of students during classes connected real-world content to course materials. Students were engaged in small group discussions, completed presentations, and demonstrated artifacts created during the class. This was shared with the other researcher including resources from all classes. Unfortunately, the researcher was aware from their interaction with students though conversations and reaction from the students who were in the science education classes that, for many, they had never experienced this degree of STSE infusion in previous classes. Rather, lecture-style and random, sporadic hands-on activities with a connection to real-world events maybe a more accurate description of the day-to-day reality. At UNIV A, the situation was comparable despite everything occurring in the same building. The physics faculty appeared to choose to focus on content delivery of physics content over STSE initiatives, seeing the two as distinct entities.

The second area of comparison as discussed by the researchers related the curricular structure of the two teacher education programs. There are very significant differences between the two universities. At UNIV B, the student is required to complete a four-year undergraduate degree whereby the student must obtain a minimum of 30 credits (10 half-year courses) or 18 credits (6 half-year courses) in a "teachable" area. Physics is considered a "teachable" area of the science curriculum. Therefore, students can enter the UNIV B B.Ed. program with a B.Sc. honors (Physics), advanced major, major, or minor in Physics. The decision to enter the teaching profession does not need to occur until the fourth year of the undergraduate program; however, students are encouraged to consider teaching as an option earlier to ensure alignment between program requirements and chosen electives occurs. Additionally, there are a few students who decide to enroll in the B.Ed. program after spending time working in the field, often as laboratory and/or field technicians.

At UNIV A, when choosing the Physics degree stream, all students must follow the trajectory of teacher education. This experience has shown us that there are only a few students who enter the program to be a physics teacher and understand the scope of the subject and the depth and breadth of being a teacher. Other than those few students who chose the program, some will eventually withdrawal from the program, even those who chose physics by affinity and claim to have opted for the course due to the good reputation of the institution may question their decision. Their intention, however, is often to attend the undergraduate physics-based course and follow the path of research in an area of physics that is not connected directly to education. Although the professors have not conducted an in-depth investigation into this shift, it has been noticed that many of UNIV A's best students in recent years have given priority to scientific initiation programs rather than to projects related to teaching, learning, and pedagogical initiation as they pertain to physics education.

The consequences of this shift in focus resulted in the research professor's ongoing and outgoing pedagogical explanations to situate STSE within the science education landscape so as to better engage students in discussions related to their teaching and student learning, even within the discipline of physics education, their own identified pedagogical nucleus. Usually, there is a tendency to give more importance to the disciplines of the content knowledge, here being the physics content rather than the pedagogical knowledge. Another issue witnessed and discussed was the motivation of pre-service teachers. This is a point where the two institutions could benefit from a more detailed study. Through discussions, at UNIV A, this is perceived to be an issue with students appearing to be not motivated whereas at UNIV B, the preservice teachers appeared to be extremely motivated. Here, the premise is that the basic content had been taught during the undergraduate degree and the B.Ed. science content could focus on the pedagogical knowledge and pedagogical content knowledge (Shulman, 1986). There is also a certain level of academic and personal maturity in the UNIV B group of students, as they have successfully completed a four-year undergraduate degree and are in Year 1 or Year 2 of the 2-year B.Ed. degree program.

The third and final area of comparison was the university–school interaction, especially concerning the mandatory internship/practicum. At both institutions, through discussions, we learned that, at both institutions, those who are enrolled in the teacher education program must complete an "internship" or "practicum" placement in a public school. During practicum, the university students work within the local school network together with classroom teachers who act as collaborators and who receive them as interns. During practicum, the student interns, as university students and pre-service teachers, develop classes for grade-school students under the supervision of the teacher responsible for the class. University professors monitor and guide the pre-service teachers throughout the term of the internship/practicum. There are no significant differences in the philosophical outcome of the internship/practicums; the differences lay in the way that they are conducted within the two university systems. At UNIV A, students do internships throughout the semester in a shift-style, meaning that they attend university courses concurrently with the internship. At UNIV B, there is a division in the semester whereby students attend courses for a compressed 9-week semester and then fulfill the full-time internship/practicum in the other five to six weeks with no other concurrent university courses.

We are well aware that Canadian and Brazilian public education systems are different. However, one issue that drew our attention is the importance of the mentoring and coaching relationship between schoolteachers and pre-service teachers (Parker & Vetter, 2020). As Parker and Vetter (2020) noted, "mentoring extends beyond …shar[ing] knowledge and demonstrat[ing] skills" (p. 9) to include more affective elements such as encouraging self-reflection, being open critique, and recognizing the value of reciprocal and active learning (p. 10). This is not to ignore that there are times when that the mentoring model breaks down and the pre-service teacher is required to mimic the pedagogical processes of their host supervisory schoolteacher. The researcher who has acted as a faculty advisor has had to help the pre-service teacher navigate this

relationship and discuss how much change and infusion of STSE is possible given the circumstances and situation.

At UNIV A, through recent experiences with internship/practicum guidance have revealed indicated the same problem. Since the researcher is also a faculty advisor, they have noted the same issues and that the physics classroom can be quite theoretically based yielding a necessity for discussion as to what movement can be obtained pedagogically away from the traditional track and towards an STSE focus. It was discussed that from both locations, some supervising classroom teachers are open to pre-service teachers trying new technologies and different pedagogical strategies, but most teachers deliver content via how their curriculum is written and with how they are comfortable with the delivery. In this context, it is difficult to embed STSE pedagogical opportunities and ensure that students can actively participate in STSE-based physics lessons and activities during the internship/practicum. Further, it can be difficult to encourage pre-service teachers to plan, teach, and deliver STSE-based physics lessons when the supervisory classroom teacher does not themselves—and this is why these discussions and movement of research is of great importance.

FINAL CONSIDERATIONS

With this work, we intend to continue the discussion that will allow the development of future funding opportunities to promote and strengthen STSE education at both UNIV B and UNIV A. The opportunity to visit a Canadian institution and understand the activities of another science education program for physics teachers was fundamental to establish comparison parameters between elements associated with the insertion of STSE education between the two pedagogical contexts. The areas of comparison established for the analysis were defined from the aspects that caught our attention over a 20-day site visit, critical observations, engagement with students and peers, and subsequent remote discussions about STSE between one Brazilian researcher and one Canadian researcher.

The discussion of the three areas of comparison allowed us to infer that the two university realities face challenges to consolidate education with a STSE focus on initial teacher education, although research in this area is on the rise in both countries. However, one of the considerations we can make at this moment is that if an initial education program of physics teachers aims to encourage its students to embrace the premises of STSE education into their professional practice, it is necessary to model these elements in the academic realm explicitly. Undergraduate students and pre-service teachers need to be immersed in STSE education over the years of their degree program(s). Within an STSE contextualized experience, students need to feel safe to make mistakes, learn how to prepare classes, select the necessary resources, plan how to integrate science into solution-based explorations of society's concerns, respect cultural values and ethical issues

without compromising critical thinking, and promote a science education that leads and champions the account of STSE relationships. As physics educators we want to promote and help students, people of all ages, learn the content of physics. STSE provides a way into the content that is both accessible in terms of meaningful and keeps the necessity of the rigor of the discipline.

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