

Doing Science: Pre-service Teachers' Attitudes and Confidence Teaching Elementary Science and Technology



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Abstract

To investigate how early elementary science and technology (S&T) education, with hands-on experimentation and inquiry-based learning, impacts pre-service teachers' attitudes and confidence to teach S&T education, we used a cross-sectional survey. Our participants were 27 pre-service teachers enrolled in an Ontario elementary S&T teacher education methods course. Those who were taught S&T through hands-on experimentation exhibited more positive attitudes toward S&T and were statistically more confident when reading, understanding, and critically evaluating common S&T media reports. They were also more confident to teach S&T through hands-on experimentation and inquiry-based learning. In almost all cases, participants valued learning S&T by doing S&T (i.e., actively participating/interacting), which influenced their confidence, interest, and desire to embrace hands-on experimentation for their future roles as elementary teachers.

Keywords: pre-service teacher education, science and technology, hands-on experimentation, elementary education, attitudes and confidence, inquiry-based learning

Background/Research Context

We entered the class with limited science education, nervous and reluctant to teach the material to future students, confident that we would teach it poorly. (RK, Pre-Service Elementary Teacher Candidate)

My own educational background made me a nervous participant in science class. (CE, Pre-Service Elementary Teacher Candidate)

We were not confident in teaching science in comparison to language arts or math. (MH, Pre-Service Elementary Teacher Candidate)

Our duty and ethical imperative as science and technology (S&T) educators is multifaceted. First and foremost, we must satisfy the requirements of a provincial teacher's college. This necessitates us to prepare pre-service teachers to educate a future generation of children from the unique perspectives of S&T. On these grounds, the argument for S&T education follows the traditional economic or utilitarian line of thought and reads as follows: S&T provides us with ways to understand our relationship with the natural and physical world, build upon previous knowledge, and create new knowledge through the processes of observation, experimentation, and reasoning. To prepare future generations with the knowledge, skills, and attitudes to thrive in an increasingly information complex and technologically rich era, in Ontario, "scientific and technological literacy for all" has become the primary objective of science and technology education (Ministry of Education, 2007, p. 3). This means that before students enter secondary school, they should have the capacity to read, understand, critically evaluate, and confidently engage in discussions and decision-making activities that involve S&T in their daily lives (Ministry of Education, 2007).

In the development of students' S&T literacy, teachers serve an essential role. Ontario's elementary teachers are responsible for "engaging students in activities that allow them to develop knowledge and understanding of scientific ideas in much the same way as scientists would" (Ministry of Education, 2007, p. 6). Adhering to Ontario's S&T Curriculum, elementary teachers must ensure instructional strategies and assessment methods enable students to become "scientifically literate" (Hodson, 2005, p. 4). According to the Ontario Ministry of Education (2007), scientific literacy is defined as: "1) relating S&T to society and the environment, . . . 2) developing the skills, strategies, and habits of mind required for scientific inquiry and technological problem solving, . . . [and] 3) understanding the basic concepts of S&T" (p. 6). International research examining the attitudes and confidence of pre-service and elementary teachers toward teaching S&T demonstrated that many lacked the content knowledge and confidence to teach S&T effectively (Al Sultan, Henson & Fadde, 2018; Avraamidou, 2013; Danielsson & Warwick, 2014). In Canada, very little research has been done to investigate whether these same issues exist. Such an argument aligns itself neatly with a neoliberal agenda that supports a certain education policy or discourse because of its likelihood to merge social, political, economic, and educational factors as a standard of authority, producing a future workforce on-hand and ready to contribute to an economy propelled along by S&T.

There are other reasons for pre-service elementary teachers to experience and develop competence in S&T education beyond the economic reasoning, including arguments for

ecological sustainability. Our world is experiencing unprecedented environmental and social challenges. This aligns well with a burgeoning body of work in science education under various headings, such as ecojustice education, socio-scientific issues education, place-based education, cultural studies and environmentalism, and youth activism (Mueller & Tippins, 2014; Fazio & Karrow, 2015). Becoming scientifically literate will be increasingly important in adapting to many urgent environmental challenges we currently face (e.g. climate change).

Lastly, to prepare pre-service elementary teachers for the challenges of a changing world, we would be remiss not to consider an ontological argument, as the ontological claim presupposes everything else (Heidegger, 1927/1962). Up to this point, the previous two arguments construe S&T within its modern frame of reference: that is, a discipline we increasingly *use* to solve *problems* in ways that *aggressively* and *exhaustively* focus on what we have defined as “objects of presence”. Such an *instrumental* and *exhaustive* view of S&T has not always dominated to the degree it does today (Heidegger, 1967/1962). Outside modern political and economic systems, many have been advocating for a post-modern view of S&T (Cobern & Loving, 1998). Within postmodernism, the field of S&T is characterized less instrumentally and exhaustively (less mechanistically) and more organically (complex and emergent); it draws heavily from findings in physics principally informed by quantum and complexity science. Attuned with nature and informed by nature, such an “organic” metaphor demands S&T be viewed as more contingent, less certain, more complex, tentative, emergent, and tolerant of the unknown (Davis, Sumara & Luce-Kapler, 2008). So, what undergirds these modern and post-modern views of S&T?

Modern and post-modern paradigms and their influence on S&T are founded on different metaphysical systems, or ways of being (ontologies) and knowing (epistemologies). Our focus here is in making the ontological argument. S&T education, founded upon a post-modern paradigm, could be an important way to prepare a future generation of teachers, and by extension children, for another *way of being* (i.e. how we are or could be in relation to others and within our natural world) (Karrow & Fazio, 2010). This involves re-experiencing S&T education as pre-service elementary teachers, in ways that don’t view S&T from a modern frame of reference. Harvey (as cited in Terrill, 2019) contrasts the modern and post-modern frames that undergird S&T as follows, by describing our interaction with nature we encounter nature in a technological way because we’re delineating, calculating, and categorizing and classifying [modern]. Instead, as educators we try to teach students to open themselves up to awe and mystery and listen. Once it captures our attentions, our emotions are aroused and then it’s transformative [post-modern].

Thus, S&T can be viewed as a way of coming to understand our human relationship with the natural world, how we can live more harmoniously with it, and re-discover the joy and delight we once experienced in coming to know this world as we did as children. In this sense, S&T education instills within us a familiar joy, passion, and love for learning about our natural world (Karrow, Harvey & Yu, in-press). Experiencing and developing competence in S&T through a post-modern paradigm offers the capacity for a different way of being that is humble, receptive, respects subtlety, lets letting-be, and preserves possibility. This is in stark contrast to a way of being, reinforced through a modern paradigm where S&T reinforces a mechanistic, aggressive, and exhaustive ontology.

For Ontario's elementary teachers to successfully carry out their responsibilities in S&T education, our pre-service teacher preparation programs are key. First, we must understand our pre-service teachers' attitudes toward teaching S&T and examine the educational experiences that influenced the development of those attitudes. Second, we need to assess the degree of confidence our pre-service teachers demonstrate towards teaching S&T. This will facilitate the ongoing development of elementary S&T education curriculum that effectively prepares teachers to meet their responsibilities.

Purpose

Given that international research has shown that early S&T education experiences influence teachers' attitudes and confidence to teach S&T, we were interested to understand how this plays out in Ontario. Specifically, we sought to understand how elementary (grades K-6) S&T education experiences with hands-on experimentation and inquiry-based learning impacts pre-service elementary teachers' attitudes and confidence to teach S&T. For this study, we defined hands-on experimentation as actively learning by doing, rather than reading, lectures, or watching videos; and we defined inquiry-based learning as a dynamic approach to learning directed by student-generated questions, ideas, challenges, and problems.

Method

A cross-sectional survey design was used to collect data from pre-service teachers enrolled in an accredited Ontario elementary S&T teacher education methods course at Brock University. Survey questions were adapted from those used by Jesky-Smith (2002) and Sen & Sari (2017). Participation was voluntary and anonymous. Informed consent was obtained through e-mail upon survey commencement. The survey, launched in the Winter of 2018, consisted of 20 questions which collected information regarding participants' elementary S&T education experiences, S&T literacy, attitudes towards S&T, and confidence to teach S&T. Fourteen questions used a 4-point Likert scale (1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree). Three questions used categorical responses based on the number of S&T teacher education courses participants completed, the grade and the frequency in which participants were first taught S&T. Three questions collected textual responses regarding 1) elementary S&T education program goals, 2) participants' most memorable elementary S&T education experiences, and 3) the influence those experiences had on their attitudes toward S&T education. Anonymous responses were received over five weeks. Categorical responses were compared for significance using univariate statistical analysis (i.e., chi-square test for independence) with condensed Likert categories of strongly agree/agree and disagree/strongly disagree). A p -value of <0.05 was used to determine significance. Textual data was organized into themes according to word/phrase synonyms.

Results

Of the 27 pre-service elementary teachers who participated in the survey (response rate = 13%), 44% had not completed a teacher education S&T methods course prior. We also found that 56% of participants indicated their first exposure to S&T education took place from kindergarten to grade two, and 69% of participants indicated being taught S&T education at least

two to three times a week. All participants agreed/strongly agreed that teaching S&T in elementary school was important.

Data related to attitudes towards S&T and confidence to teach S&T was analyzed across participants who were and were not taught S&T in elementary school through 1) hands-on experimentation, and 2) inquiry-based learning. In addition to being more confident to engage in S&T discussions and decision-making activities, participants who were taught S&T through hands-on experimentation demonstrated an attitude more receptive to hands-on experimentation in elementary school S&T and were statistically more confident to read, understand, and critically evaluate common S&T media reports (see figure 1). Additionally, this group was more confident to answer students' S&T questions, teach S&T through inquiry-based learning, and statistically more confident to teach S&T through hands-on learning (see figure 2). When the same variables were analyzed according to participants who were and were not taught S&T through inquiry-based learning, no statistical difference was found in attitudes or confidence to teach S&T. We examined this apparent discrepancy in the next section, and conjecture why this may be so.

When participants were asked, "*what are the goals of a good elementary S&T education program?*" (see table 1) themes drawn from the responses centered on 1) hands-on learning/exploration, 2) curiosity/discovery, 3) teaching through inquiry, and 4) encouraging students' S&T understanding. When participants were prompted, "*my most memorable experience of elementary S&T education was . . .*" almost all responses related to actively learning S&T by *doing* S&T through hands-on experimentation (creating, building, decoding, hatching, working with) or interactive learning experiences (going on field trips, a scientist in the school, science fair). Similarly, when prompted with "*my most memorable experience of elementary S&T education has influenced my feelings toward S&T education . . .*" all participants responded with thoughts that reflected their personal elementary S&T education experiences. This included: 1) hands-on experimentation/experiential learning, 2) making S&T relevant and fun using "real-world" contexts, and 3) inquiry-based learning.

Discussion/Conclusions

Although pedagogy matters in regard to the way that teachers engage students in hands-on learning and scientific inquiry (i.e. the teacher's own openness and excitement about scientific inquiry and how the teacher facilitates learning afterward), the goal of this study was to understand how pre-service elementary teachers' experiences with hands-on experimentation and inquiry-based learning during their elementary schooling impacted their attitudes towards S&T and confidence to teach S&T. Our findings were consistent with international research in this area (Riegler-Crumb, Morton, Moore, Chimonidou, Labrake & Kopp, 2015; Santau, Maerten-Rivera, Bovis & Orend, 2014; Yoon, Joung & Kim, 2012). We showed that pre-service elementary teachers had a more positive attitude towards and greater confidence to teach S&T if they were taught S&T through hands-on experimentation during their elementary education. This observed difference did not extend to those who were taught S&T through inquiry-based learning. We surmise that because inquiry-based learning is an instructional strategy used in other courses besides S&T education, (e.g., language literacy and numeracy), participants did not solely attribute inquiry-based learning to their elementary S&T education experiences (Vajoczki,

Watt, Vine & Liao, 2011; Opong-Nuako, Shore, Saunders-Stewart & Gyles, 2015). Furthermore, our narrow definition of inquiry-based learning, which we used in our survey, as a “dynamic approach to learning directed by student-generated questions, ideas, challenges, and problems” may have de-limited the responses obtained on our survey. Recognizing that inquiry-based learning may occur along a spectrum framed by the degree of autonomy a student has over his/her learning relative to the degree of structure and guidance the teacher retains over this learning (i.e., directed inquiry, guided inquiry, or open inquiry), our predilection to equate inquiry-based learning directly with the “student-centered” (i.e., open inquiry) end of the continuum may have paralleled our participants’ views (Colborn, 2002). Our results indicate that such student-centered inquiry-based learning did not translate directly into greater confidence with S&T teaching. This is supported by other studies, such as the one conducted by Kirschner, Sweller and Clark (2006), who were more strident in their conclusions. They stated:

After a half-century of advocacy associated with instruction using minimal guidance, it appears that there is no body of research supporting the technique. . . . Not only is unguided instruction normally less effective; there is also evidence that it may have negative results when students acquire misconceptions or incomplete or disorganized knowledge (p. 84).

After all, few S&T teachers (usually only the most accomplished and experienced) take a strictly student-centered approach to inquiry-based learning. As such, participants may not have received the level of student-centered inquiry exposure desirable to increase their teaching confidence.

Another contributing factor may have been some definitional confusion over what constitutes “hands-on experimentation” and “inquiry-based learning”. While our definition for hands-on experimentation is generally well-accepted and understood by pre-service elementary teachers (Jeskey-Smith, 2002), our definition for “inquiry-based learning” is somewhat narrow and is more nuanced. What’s more, there is some research to support pre-service elementary teachers’ confusion over the two terms (Jeskey-Smith, 2002). We address this further under the section heading “future studies”.

In almost all cases, regardless of their S&T literacy, S&T content knowledge, attitudes towards S&T, or confidence to teach S&T, pre-service teachers in our study valued learning S&T by *doing* S&T (i.e., actively participating/interacting). Their most memorable S&T elementary education experiences involved learning through hands-on experimentation, and those experiences influenced their confidence, interest, and desire to embrace hands-on experimentation as future elementary teachers.

Reasons why pre-service elementary teachers are challenged to teach S&T have largely been attributed to their lack of S&T content knowledge and confidence to teach S&T (Kazemour, 2013; 2014; Pan, 2017). From our perspective, this makes sense as most pre-service elementary teachers enter the program without having a strong science background or degree in science. Some candidates may have one or two post-secondary education science-related courses, but most have only studied science up to grade ten. Furthermore, elementary teachers are often trained as generalists who receive less S&T content knowledge in their teacher preparation programs compared to their intermediate and secondary peers. According to the Ontario College of Teachers’ guidelines, primary/junior (grades K-6), teachers are not required to specialize in science education (Ontario College of Teachers 2015; 2017). In fact, there are no

specified course hour requirements for any primary/junior subject discipline as it's up to each teacher education program to determine the requirements. At the secondary level, the difference between a first and second subject teachable (courses that teachers are qualified to teach) are entrance requirements for each subject teachable based on undergraduate courses. In Brock's Teacher Education Program, primary/junior and junior/intermediate pre-service candidates take a 0.5 credit-weight (36 hours) S&T education course. In contrast, intermediate/secondary peers are required to take two 1.0 credit-weight (144 hours) S&T education courses. Although increasing the instructional time requirement for S&T content knowledge in pre-service elementary teacher education programs may seem like an apparent solution to this problem, on its own it has not proven to be a successful strategy (Skamp, 1997; Skamp & Mueller, 2001).

In fact, research suggests that how elementary teachers were first taught S&T as part of their personal elementary education experiences, directly influences their attitudes and confidence to teach S&T (Irez, 2006; Kim & Tan, 2011). From this, we wish to capitalize further as pre-service elementary teacher S&T educators by maintaining and enhancing such hands-on experimental S&T learning experiences in our courses. In addition to the descriptors frequently used by preservice elementary teachers, ("creating," "building," "decoding," "hatching," "working with," "experimenting," etc.), what is it about the nature of these hands-on experimental experiences that become internalized, recalled, embodied, and in turn, confidence instilling? In what ways might the nature of science, as contrasted through modern vs. post-modern paradigms, bear directly on elementary preservice teachers' attitudes and confidence in teaching S&T?

Additional reasons why Ontario's pre-service elementary teachers lack the confidence to teach S&T have been attributed to the effects of provincially mandated testing in language literacy and mathematics education (Fazio & Karrow, 2013). Since 1996, Ontario schools have focused on improving students' language and numeracy literacies and achievements through the Education Quality and Accountability Office's (EQAO) educational assessment initiative (EQAO, 2013). Given that many of Ontario's school funding programs have been linked to students' EQAO test scores, an unintentional but significant result of this initiative is that teachers are spending less instructional time on S&T instructions, and schools are hiring fewer qualified science teachers (Fazio & Karrow, 2013). A recent Ontario education report captured these concerns, as expressed by a grade five teacher, "I need a rationale for implementing any new science program . . . if I find that I can't connect it to my literacy or my mathematics, I may not implement it" (Fazio & Karrow, 2013, p. 4).

When teachers lack the confidence to teach S&T, they are more likely to utilize conventional teacher-centered instructional methods (transmission of information or "download of facts" onto students), rather than challenging students to develop S&T literacy competencies such as critical thinking through collaborative discourse and creative discovery (Appleton, 2003). Likewise, teachers who are scientifically and technologically literate role models (can know, do and relate science to their surrounding world) are more likely to positively influence their students' future academic achievements in S&T and their overall S&T literacy (Xie & Shauman, 2003). We argue that teaching elementary S&T through hands-on experimentation is an important strategy to foster S&T literacy. The beauty of teaching S&T through hands-on experimentation, given the right teacher guidance and direction, is that it can naturally spark

students' curiosity to discover. Hands-on experimentation teaches students to use science as a way of thinking and critically evaluating information through prediction, observation, measurement, recording, classification, analysis, and reasoning (Turiman, Omar, Mohd Daud & Osman, 2012). Accordingly, we believe that pre-service elementary teacher S&T curriculum should have a strong pedagogical foundation centering on the design and delivery of hands-on experimentation that enhances S&T literacy.

Future Studies

Our study demonstrates that pre-service elementary teachers who were exposed to hands-on experimentation in their elementary S&T school years, exhibit a more positive attitude toward S&T and are more confident to teach S&T. Teacher education programs that currently capitalize on this co-relationship do so by incorporating hands-on experimental learning activities in their S&T courses. Graduate students interested in S&T education issues and policy-makers in the process of re-evaluating provincial science education policy should consider further research in this area. Assessment tools that measure pre-service teachers' S&T literacy, attitudes towards S&T, and confidence to teach S&T through hands-on experimentation should consider the level of pedagogical content in S&T teacher-education curriculum that centers on the design and delivery of hands-on experimentation to foster S&T literacy. What's more, it would be informative and interesting to conduct further studies on the specific nature of hands-on experimentation to understand further why such experiences are vivid and internalized by elementary preservice teachers, to the degree they develop positive attitudes about S&T, and furthermore, instill confidence in them to teach S&T. In other words: Will any "hands-on experimentation" do? Is there a particular quality about it that matters? Does the teacher's pedagogical approach make a difference? Is there something uniquely triggered within the learner? All of these questions beg further examination reflecting the highly nuanced and complex nature of the phenomenon.

Finally, in advocating for pre-service elementary teachers to experience and develop competence in S&T education, vis-a-vis "scientific literacy", we return briefly to the three arguments we previously cited: the economic, environmental, and ontological arguments underscoring the importance of scientific literacy. While the economic argument supporting S&T literacy remains strong for the foreseeable future, the environmental and ontological arguments are more tenuous. If hands-on experimentation can instill positive and long-lasting attitudes in children, so that if they become teachers they too will have the desire and confidence to replicate such hands-on experimentation with their own students, what environmental and ontological implications might this have? Perhaps there are opportunities to introduce preservice students, and by extension their own students, to hands-on experimentation that service more environmental and ontological purposes? It seems to us the key to this rests in a different yet contemporary view of the nature of science, framed by a post-modern paradigm, more complexified and organic. Given the ecological, social, and ontological urgency of this, there is important and urgent work to contribute to this growing body of literature.

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