J Sci Teacher Educ (2013) 24:111–131
DOI 10.1007/s10972-012-9311-2

Our Practice, Their Readiness: Teacher Educators Collaborate to Explore and Improve Preservice Teacher Readiness for Science and Math Instruction

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Published online: 21 July 2012

Abstract Since many preservice teachers (PTs) display anxiety over teaching math and science, four PT educators collaborated to better understand the PTs' background experiences and attitudes toward those subjects. The research project provided two avenues for professional learning: the data collected from the PTs and the opportunity for collaborative action research. The mixed method study focused on: the relationship between gender and undergraduate major (science versus non-science) with respect to previous and current engagement in science and math, understanding the processes of inquiry, and learning outside the classroom. A field trip to a science center provided the setting for the data collection. From a sample of 132 PTs, a multivariate analysis showed that the science major of PTs explained most of the gender differences with respect to the PTs' attitudes toward science and mathematics. The process of inquiry is generally poorly interpreted by PTs, and non-science majors prefer a more social approach in their learning to teach science and math. The four educators/collaborators reflect on the impacts of the research on their individual practices, for example, the need to: include place-based learning, attend to the different learning strategies taken by non-science majors, emphasize social and environmental contexts for learning science and math, be more explicit regarding the processes of science inquiry, and provide out-of-classroom experiences for PTs. They conclude that the collaboration, though difficult at times, provided powerful opportunities for examining individual praxis.

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Keywords Pre-service teacher science education · Science and math anxiety · Collaborative action research

Introduction

Teaching at the elementary level in Canadian schools requires that classroom teachers be expert generalists in disciplines ranging from Language Studies to Physical and Health Education to Science and Math. This is a tall order and one that is very difficult to achieve.

One way to deal with the overwhelming amount of knowledge required for a generalist is to avoid subjects that are perceived as more difficult, such as math and science. It is well documented that a substantial proportion of preservice teachers (PTs) preparing to teach at the elementary level (K-8) have previously rejected school science and mathematics as being boring and irrelevant to their daily concerns (Brickhouse 2001; Levine 1995, 1996; Russell and Dillon 2010). Avoidance of these subjects by PTs has been noted to be related to anxiety, which is often gender-related (math: Brett et al. 2002; Carrol 1994; Gresham 2008; Rosas and West 2011. Science: Bursal 2008; Mallow et al. 2010; Yuruk 2011). Avoidance of science and math by PTs presents significant pedagogical complications, as both subjects are considered core components of a broad and balanced education. Thus, the gap in science and math ability and confidence among PTs are of real concern to teacher educators whose task it is to prepare them to teach those subjects. In addition to better understanding the PTs in their classrooms, teacher educators recognize the importance of continually assessing their own pedagogical practices (McGee and Lawrence 2009; Sammel 2006; Swennen and Bates 2010). Toward that end, generally, the interventions and research projects that focus on PT preparation are carried out by teacher educators/researchers in efforts to improve their own practice(s). Moreover, teacher educators tend to consider themselves to be working in a collegial community that is engaged in “researching and learning together” (Swennen and Bates 2010, p. 2).

This is the juncture from which we embarked on our own collaborative action research project to explore the math and science perspectives of the PTs in our classes.

Situating Our “Selves” and the Project in the Literature

We are four preservice teacher educators who, at the outset of the project, believed that we shared a common sociocultural perspective on science and mathematics learning and teacher education. We see our role to be that of providing for our students educational opportunities that are “transformatory” (Brickhouse 2001) whereby, through their exploratory engagement with ideas and processes in science and math, students come to enjoy these subjects (Wong et al. 2001). Moreover, as a prerequisite to student engagement, we hold a common desire to better understand our PTs, including their competencies in the disciplines of our instruction. To this end, we became collaborators and co-researchers to explore our PTs’ attitudes toward science and mathematics.

As we talked about the potential for collaborative research, it became clear that each of us brought a different background, individual teaching practices, and varying research questions to the table. Consequently, we chose a model of collaboration that would enable us to share the same goals (Capobianco et al. 2006) yet allow each of our voices to remain distinct (Richmond et al. 1998) with respect to articulating our philosophies, in describing our teaching methods, in identifying research questions, and in analyzing portions of the data. We began the project with the fundamental research question: *How prepared do the pre-service teachers feel they are to teach science and math with respect to their backgrounds?* We believed that in answering that question, we could inform and strengthen our individual and collective teaching and more effectively meet the professional learning needs of our PTs. Indeed, as we worked through the project and met in our retreat to analyze the data, we realized that a question of equal concern was: *How can we teach our courses in ways that increasingly support our PT's in teaching science and math?*

We describe our research on several levels: First, we each provide a brief summary of our backgrounds and the individual theoretical frameworks that we bring to the project and that also inform our teaching; we then discuss the findings from the data, in some cases discussing the same data through our individual theoretical lenses. Lastly, we propose how the findings will impact our teaching practice(s).

Author Alice[1]

My pedagogical approaches are grounded in my experiences as an outdoor and environmental educator, my work as a science teacher and now as a teacher of science education. I understand science to be one of the ways through which we can understand and explain the physical world. Learning science without context or embodied experience hardly seems possible to me; it is a point that John Dewey made almost a century ago (see Wong et al. 2001). Contemporary perspectives in science teaching and learning continue to support hands-on (Krapp 2004) and experiential learning (Louv 2005) and have added the importance of student inquiry (Llewellyn 2009) and social and environmental contexts (Pedretti and Little 2008).

While the practice of science and its pedagogies can be challenging and exciting, science has its limitations. Science and science education, critiqued from a feminist perspective, cannot stand on the claim that they can operate without prejudice (Richmond et al. 1998).

> Feminism demands critique of the practice of science and the knowledge it has created, based on the premise that since people enact science, people cannot be free of personal, political, and social bias any more than they can be (or necessarily desire to be) free of emotional aspects of human personality. (p. 898)

Ecofeminism, an expansion of feminism, urges the inclusion of *environment* as an *Other voice* to which we must attend; via ecofeminism, the feminist critique extends to the consequences of human agency enacted on and within environment (Russell and Bell 1996; Shiva 1997). Science and the teaching of science potentially

[1] Pseudonyms are used for all authors.

take on multiple layers: beyond the study of concepts and facts and the acquisition of skills lies the consideration of social, political, economic, and environmental issues (STSE). In my view, science considered through the lenses of feminism and ecofeminism continues to develop into a richer, more accessible learning experience, one that I strive to share with PTs.

New to PT teaching, I was unsettled by my growing realization that many PTs in my science methods classes were neither comfortable nor confident in a science teaching environment. While this situation is reported to be common in faculties of education (Brickhouse 2001; Taylor and Corrigan 2005), being constantly faced with this situation in my work, the question on my mind is (government curriculum mandates aside) how much rich and valuable science instruction will the PTs deliver? My experience as an educator led me to believe that elementary school science content knowledge (which is easily accessible through information technology) can be learned and understood by any PT who has already achieved an undergraduate degree, regardless of their undergraduate major. The question of comfort and confidence in teaching science, I thought, rests not so much on the issues of content knowledge, as it does on the elements of process skills and contextual engagement. In other words, in my practice, in teaching science methods, I believe that I need to find a gateway through which reluctant PTs can find a starting point for relating to science studies in a more personally meaningful way. My teaching repertoire includes discussions and group work, which I employ because I believe (with Vygotsky (1978)) that they assist individuals in making meaning through social interactions. In my view, science should be taught in our schools, not for the purpose of producing classrooms full of scientists, but rather, through explorations of STSE, to enable students to understand the processes of science with the purpose of becoming informed, wise citizens.

I am further concerned by the tendency of PTs with science backgrounds who, while eager to display and share their science knowledge and skills, demonstrate a disconcerting lack of understanding of the (limited) nature of science and its role in STSE issues. If such a difference was confirmed through my research, then I might better understand the different requirements these two groups have as participants in my science education course.

Questions began to arise from my observations of the PTs: *What are the differences in experiences and attitudes between PTs with a background in science and those without? When and why do PTs become disinterested, or even anxious about science?*

Author Connie

While I agree with Alice's concerns to encourage PTs to connect science to societal and environmental issues, I place a priority on the attitudes of PTs toward science and technology and their beliefs about the nature of the activities they associate with doing and teaching science.

I started my career as a professional scientist, a fact that has influenced my choice of research area within the field of science education. My interests revolve around the science inquiry experiences (scientific investigations) of students in both schools and informal settings; I question whether, and in what ways, these experiences are *authentic/open* and how best to prepare teachers to provide *authentic/open* science inquiry experiences for their students. Here, I mean *authentic* (Roth 1995) as being akin to the sort of science inquiry experiences that scientists use (such as thinking and communicating about investigations that involve posing testable questions, designing procedures, collecting, and analyzing data) and *open* (Lee and Songer 2003; Pizzini et al. 1991; Roth and Bowen 1993) in the sense of being open-ended and student-directed.

I take a social constructivist perspective that views learning what science *is*, to be really about learning the language, thinking and actions that scientists use within the social life that is their context (Lemke 1990). I support the view that the best way for students to learn what science *is* might be to practice doing science in authentic science worlds or networks such as university labs (Hsu and Roth 2009) or within simulations of those worlds, created in schools (Roth and Bowen 1993) or informal settings (Squire and Jan 2007).

The Canadian curricula are increasingly emphasizing inquiry approaches in both science and math, thus efforts have been made, particularly in the past 15 years, to encourage teachers to provide open science inquiry experiences for their students. For a variety of reasons, many teachers do not find this to be an easy task (Lotter et al. 2007; Bencze et al. 2006). Elementary teachers in particular report difficulties with implementing open science inquiry due to a lack of content knowledge and confidence (Bursal 2008; Schwartz et al. 2000). Like many teacher educators of elementary PTs, I stress *doing* science and technology with lots of hands-on activities in the hopes that PTs will come to enjoy science teaching and in turn use hands-on activities with their students.

I was particularly interested to investigate the open-ended written responses in our survey to the following questions; *What did PTs enjoy and not enjoy about science when they were in school? How do they distinguish between hands-on science activities and science inquiries? How do they distinguish between science and technology?*

Author Chira

Like Connie, I began my career as a scientist. Despite holding a PhD in Science Education, I am a preservice educator of mathematics method and my research has usually included a focus on gender. My explanation for this is, in part, due to my own schooling experiences. I excelled in mathematics throughout school and one day in grade 10, I shared that I wanted to be a mathematician. The teacher responded that my grades were "good enough" but the associated affect was poorly disguised doubt. Later in life, I assumed his doubts related to me being a girl. Through my postgraduate education, I was introduced to the literature about the relationships between gender, socioeconomic status and mathematics, and how they were associated with the exclusion of many able people from particular occupations and personal interests. I tried to unravel the theoretical relationships between pedagogy and epistemology to better understand how the traditional mathematics classroom was, in part, responsible for this social injustice. I drew on William

Perry's (1970) schema of *intellectual and ethical development*, Baxter Magolda's (1992) *Knowing and reasoning in the college years: gender-related reasoning patterns* and Belenky et al.'s (1986) *Women's Ways of Knowing* to inform my theoretical framework from which to view the mathematical experiences of others (Brew 2001).

Unlike Alice, my personal experience as an educator has led me to believe that in order to teach elementary school math through an inquiry approach, content knowledge is critical for PTs. I draw on the research of Ma (1999) that PTs need a profound conceptual understanding of fundamental mathematics. My practice is informed by various reform movements in mathematics during the 1980 s, which led to the National Council of Teachers of Mathematics (NCTM) *Curriculum and Evaluation Standards* (1989) and associated research that encourages inquiry-based models of teaching based within a constructivist framework (e.g., Davis et al. 1990). Despite several decades of reform, each year too many PTs describe school mathematics experiences consistent with the traditional transmission modality and algorithmic approach. My experience resonates with Ball (2001), "Because the mathematics education community has been so active in seeking to improve teaching and learning of mathematics … mathematics reforms are often perceived as having widespread impact. …This impression may be more myth than reality" (p. 11). Consistently, each year, some of the PTs in my class express the view that they do not like learning math but enjoy teaching it nonetheless. This disconnect I find intriguing. In this project, I was interested to explore: *the extent to which gender remained a variable in understanding the differences in levels of confidence and enthusiasm for teaching these subjects*; and *the extent to which our students' prior experience in math and science was correlated with their confidence and enthusiasm for teaching the subjects*.

Author Cheryl

My background and scholarship situate science pedagogy approaches within place-based (Gruenewald 2003; Sobel 2004) and STSE (science, technology, society, and environment) (Pedretti and Hodson 1995) frameworks in education. Place-based education is a community- and student-directed approach to understanding scientific phenomena that is local and personal and that draws upon the societal and environmental dimensions existent within scientific knowledge (Gruenewald and Smith 2008). STSE education encompasses sustainable development, ethics and moral reasoning, personal and political dimensions, critical social reconstruction, and action: empowering people to lead personal and social change (Pedretti 2003). Exploring scientific concepts through a framework of societal influence and environmental impacts promotes critical thinking and provokes us to consider global and local contexts. However, in the classroom, STSE dimensions are often set aside in order to promote a more conceptual understanding of scientific phenomena. Hodson (1999, 2003) suggests that while conceptual understanding is important in science education, a more holistic understanding of the influence and impact of science and technology in our daily lives should become a growing matter of importance.

In this spirit, I believe that an STSE approach is best accompanied by a place-based pedagogy. Place offers a potentially interesting approach to STSE education in that it accentuates the local impacts of science. Indeed, the experiences and backgrounds of teachers influence how they retrieve their students' ideas about science in the communities in which they live and consequently how they use this information to highlight and teach scientific phenomena (Alsop and Ibrahim 2008). Thus, in order to learn about our PTs, we must provide them with an opportunity to candidly share themselves, their past, and their ideas about teaching and learning science without the pressure of schooling (i.e., assignments and grading) and use this information to better our practice. The specific themes of my research enquiries were situated within: the Affective Domain, to explore the passions and spirit of PTs' learning and desire to teach; Teaching Philosophy, to explore PTs' academic and personal backgrounds and how these might serve as a point of departure or re-connection to PT teaching philosophies; and Pedagogy, to understand what PT visions for science education are and how they hope to fulfill those ideals).

The Context of the Study

Prior to our decision to collaborate on a research project, we had made the decision to offer our classes the opportunity to attend a field trip to a science center.[2] We all share the view that out-of-classroom learning has significant educational value; for example, increased engagement in learning, development of language skills, reduction in discipline and classroom management issues, and increased critical thinking skills (Bell et al. 2009; DeWitt and Hohenstein 2010; Lieberman and Hoody 1998; Nielsen et al. 2009). Specifically, it has been demonstrated that out-of-classroom learning opportunities hold promising opportunities for changing PT attitudes to science and math, especially when they involve issues-based experiences that "carry the potential to enhance learning by personalizing subject matter, evoking emotion, stimulating dialogue and debate and promoting reflexivity" (Pedretti 2004, p. 34). Serendipitously, we decided that the field trip would provide the context for us to conduct our research.[3]

Our goals for the collaborative research project were as follows:

- to increase our knowledge of PTs' prior experiences with learning science and math both in and out of elementary and secondary school;

[2] Science North/Dynamic Earth in Sudbury, Ontario, Canada.

[3] The field trip took place on a Saturday in April 2010, toward the end of the school year at the Faculty of Education where we teach. Due to a generous internal university grant for STEM-related projects, the cost to students was minimal and all those who wished to attend were able to do so. Participants and researchers rode together on buses from the campus to the science centers located in a neighboring city. At the science centers, participants and researchers were welcomed by senior staff who spoke with them about the attractions found at the centers, the various programs associated with state mandated science curricula, and about the importance of science education for all students and citizens. Participants and researchers then had the opportunity to take part in guided tours and visit the exhibits on their own or with friends/colleagues.

- to determine the nature of relationships that might exist between PTs' attitudes to science and math (and the teaching of these subjects) and their undergraduate major and gender;
- to develop understanding of the effectiveness of some of the pedagogical approaches we were using in our courses, including teaching the processes of science inquiry, using place-based learning, and using constructivist-based models;
- to reflect on and improve our practice as science and math education instructors;
- to provide the PTs with an out-of-classroom science and math learning experience.

Methodology and Data Collection

Working within the tradition of reflective professional practice (Schon 1983), the goals for our research would lead us to plan future actions (Manfra 2009) to improve our practice as science and math teacher educators. Therefore, we viewed our project as action research, which has been defined as "a self-reflective spiral of cycles of planning, action, observing and reflecting" (Carr and Kemmis 1986). It is a "series of procedures teachers can engage in either because they wish to improve aspects of their teaching, or because they wish to evaluate the success and/or appropriacy of certain activities and procedures" (Harmer 2002, p. 344).

We decided to use a concurrent mixed methods design (Creswell 2009) wherein we could both quantify and qualify PTs answers to questions like Alice's: *When and why do individuals become disinterested, or even anxious about science?* Johnson and Onwuegbuzi (2004) position mixed method research philosophically as the "third wave" or third research movement, vis-á-vis quantitative and qualitative methods. "Its logic of inquiry includes the use of induction (or discovery of patterns), deduction (testing of theories and hypothesis) and abduction (uncovering and relying on the best of a set of explanations for understanding one's results)" (p. 17). While qualitative research is traditionally associated with induction and quantitative research with deduction inquiry methods, mixed methods offer a pragmatic approach drawing on the strengths of both (Johnson and Onwuegbuzi 2004). By collecting data using multiple data sources concerning a focus of interest, the aim is to eclipse the weaknesses inherent in singular methods (Brewer and Hunter 1989). Hence, the survey incorporated *closed questions with a five point rating scale* from *strongly agree* to *strongly disagree* and included an *open-ended questions* that provided PTs with the opportunity to elaborate. For example, we asked PTs to choose their response (on the five-point scale) to the statement "I liked science in elementary school" to explore for patterns quantitatively and then asked for the reason(s) for their responses in order to understand why.

The survey was comprised of 50 questions/statements that were grouped in themes that were based on the queries that we had brought individually to the project. PTs were asked to reflect on questions/statement relating to: why they had decided to come on the field trip, their school experiences with, and general attitude toward, science and math, where they believed they learned their science knowledge (we could not assume that science was learned exclusively during formal schooling), and what they thought science teaching should be focused on. We drew on existing well-designed lists from Buluniz and Jarrett (2010) for the latter in order to connect with and build on the extant literature in this area. Given the recent focus to viewing science, math and technology education together as inter-related disciplines (e.g., STEM), we also explored whether PTs viewed them this way.

Data analysis began during a two-day retreat in order for us to immerse ourselves in the data and focus on answering our initial collective question: *How prepared do the pre-service teachers feel they are to teach science and math with respect to their backgrounds?* We began by asking questions of the data relating primarily to our personal research interests. For example, Alice pursued the differences between SM and NSM in both the quantitative and the qualitative domains. The quantitative data were analyzed using SPSS software, with Chira taking a lead in this task, given her mastery of gleaning meaning from data. Correlations, Chi-squared, and multivariate analyses (MANOVA) were conducted. The independent variables included gender and undergraduate major (science major and non-science major[4]). The responses to open-ended questions were coded into themes, quantified, and possible explanations advanced (Strauss and Corbin 1998) by each of us individually and collectively, depending on our research interests. While we began viewing the data through our personal lenses, there were many overlaps in our questions and we found ourselves intrigued by each other's findings. Consequently, data analysis continued long after the retreat came to an end, in face-to-face meetings and through Skype and e-mail. The data proved to be a rich source of information and it continued to generate individual and collaborative questions for several months after the initial analysis.

Findings and Discussion

Demographics

A total of 131 surveys were completed by PTs who largely were aged between 20–24 years (60 %). Most of them had completed a non-science undergraduate major (NSM) (67 %) and were women (75 %). Women were also overrepresented in the NSM group (84 %) but represented about half of the SM (54 %).

Author Alice

Science Majors Versus Non-science Majors

When asked to choose two categories that best described science teaching from a series of statements, the majority of participants chose, "*exploring the unknown and*

[4] Preservice teachers were coded to having a science major if their major was either biology, physics, mathematics, or the human sciences, since these subject areas were most likely to focus on content knowledge as well as scientific method.

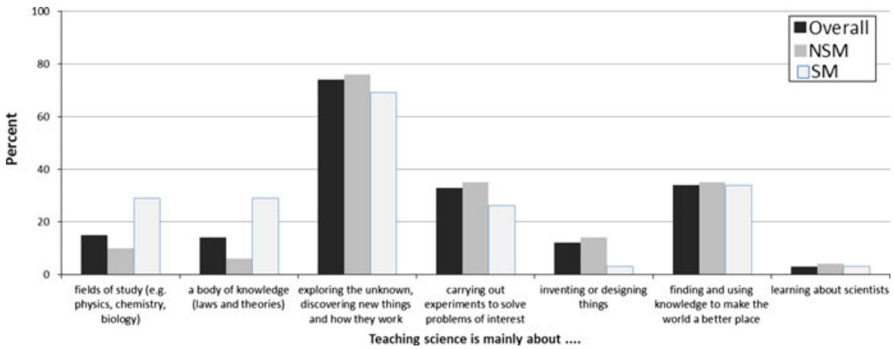

Fig. 1 Survey respondents' beliefs about what science teaching is mainly about

discovering new things about our world and the universe and how they work," and this was independent of their undergraduate major (Fig. 1). The second and third largest categories, also independent of their major, were a belief that science teaching was about "*carrying out experiments to solve problems of interest about the world around us*" and "*finding and using knowledge to make this world a better place in which to live.*" I take heart from these findings as these common sentiments mirror the teaching philosophy espoused in our faculty of education, where the pedagogy of science includes not only the acquisition of knowledge and skills, but also an understanding of social and environmental issues. Not surprisingly, though, there were some significant differences by major. A higher proportion of the SM viewed science teaching as including "*discrete fields of study*" ($\chi 2 = 3.99$; $p < 0.05$) and "*a body of knowledge such as principles, laws and theories*" ($\chi 2 = 6.82$; $p < 0.01$). I interpreted this result to be due to the SMs' experiences in secondary and tertiary education where science disciplines are presented separately and with heavy focus on content knowledge. The findings also explain my anecdotal observations that SM, more than NSM, tends to avoid societal and environmental issues in science studies.

Teachers were reported to be the main source of science knowledge (80 %) with *Radio* the least (6 %). While the sources of science knowledge were similar for both NSM and SM, there were some interesting differences. *Textbooks* ($t = 1.969$; $df = 117$; $p < 0.05$) were more important sources of knowledge for SM compared to the NSM and a strong trend that SM relied more on their *Teachers* ($t = 1.847$; $df = 98.63$; $p = 0.07$). The NSM reported that *TV* ($t = -2.160$; $df = 118$; $p < 0.05$) and *Museums* and *Zoos* ($t = -2.348$; $df = 53.569$; $p < 0.05$) were more important sources of science learning compared to SM. For SM, science seems more connected to formal schooling through teachers and textbooks compared to NSM, for whom science learning emphasized more out-of-school connections.

Not surprisingly, the NSM reported that they did not enjoy science as much in school as their SM counterparts, a trend that worsened in their high school years (Table 1). Neither were the NSM as enthusiastic about teaching science as the SM; the NSM revealed that they felt less confident, more nervous, and had a less positive attitude toward teaching science (Table 1).

Table 1 Attitude toward science and science teaching by undergraduate major

	Major	Mean	SD	*F* value	*p* value	Effect size
I have a personal interest in science	SM	4.65	0.753	25.141	<0.001	0.17
	NSM	3.75	0.962			
I am enthusiastic about teaching science	SM	4.68	0.530	29.096	<0.001	0.20
	NSM	3.74	0.995			
I liked science in elementary school	SM	4.49	0.837	18.21	<0.001	0.13
	NSM	3.68	1.003			
I liked science in high school	SM	4.65	0.716	35.141	<0.001	0.23
	NSM	3.29	1.308			
I feel confident about teaching science	SM	4.46	0.900	22.725	<0.001	0.16
	NSM	3.63	0.882			
The thought of having to teach science makes me nervous	SM	1.70	1.199	5.641	<0.05	0.05
	NSM	2.19	1.000			

Effect size measured by partial eta-squared values

Thus, it was unexpected that so many NSM (over half of the participants) decided to go on a science field trip. I wondered at their motivations for coming. Compared to the SM, the NSM viewed the field trip more as a social activity or adventure to a new location that promised to be fun (Fun: $\chi 2 = 9.804$; df = 1; $p < 0.01$; Friends coming: $\chi 2 = 3.80$; df = 1; $p = 0.06$). Their choice to engage in "science" was made more for social than for educational reasons, yet I could not dismiss the NSM motivations as frivolous. Learning is understood as a social activity (Vygotsky 1978), so the choice to confront learning in a discipline that does not hold great appeal (science) with a group of friends, and in the context of a social gathering, demonstrates a useful learning strategy. This is a finding consistent with the elevated role of TV, museums, and zoos as a source of science knowledge among NSM, since all three can be viewed as having social aspects.

Did their strategy work? The reported benefits of the trip would suggest so. For the NSM, 85 % reported improvement in their science knowledge (SM 54 %) and 65 % of the NSM indicated that they learned new science teaching strategies (SM 45 %). While the improvement in knowledge and teaching strategies is self-reported (so difficult to substantiate), what I took from these responses is that the NSM felt increased confidence and readiness to teach science.

Author Connie

Early Experiences with Science

It was heartening to learn that the majority of PTs reported enjoying science in elementary (71 %) despite a small overall decline reported in secondary school (61 %). In total, 29 % of PTs reported a decline in enjoyment of science during the school transition with 15 % reporting science had actually become more enjoyable.

I chose to explore the PTs written explanations concerning their school science experiences with respect to three groups: Group A (29 %) liked science in elementary school but their interest waned in high school; Group B (63 %) liked science in elementary school and their interest grew in high school or did not decline; and Group C (9 % of respondents) did not like science in either elementary or high school.

While only about half (55 %) of the PTs actually provided a written explanation, this was adequate to gather some comparative themes. Group A offered five reasons to explain their decline in interest. In order to prominence, they were the increasing level of difficulty, the lack of hands-on activities, feeling bored, a greater identification with the humanities, and lastly poor teachers. Example responses included: *"(it) got difficult in high school*;" "*We did a lot of hands on activities (in elementary)*;" "*Very interesting until high school*;" "*I am much better at English*;" *"I didn't have a good high school science teacher.*"

Why then did Group B *like* high school science? Again, five main reasons emerged. By far, the most common reason was the level of interest and sense of fun their science lessons generated, the opportunities for hands-on activities, a sense of being good at science made it seem easy, identification with scientific thinking, and lastly good teachers. Example responses included: "*It's just so interesting learning about how and why things are the way they are*;" "*I liked hands on activities, I still do*;" "*I generally understood and was successful in science*;" "*It was interesting and I was good at it*;" "*Excellent teachers who prepared engaging lessons*;" "*It's the future*!" For Group C, science had always been conceptually difficult throughout school, "*I did not understand it. I was not engaged.*" Science was reported as boring because there was "*lots of memorization*" and lack of success, their "*experiments never worked out.*"

The hands-on element (or lack thereof) in science classrooms was a common thread in both Group A and B's comments and this leads to a consideration of the PTs' understanding of the relationship between hands-on activities and the process of science inquiry.

Hands-On Activities and Science Inquiry

I am concerned that PTs, and ultimately the students in their future classrooms, understand the difference between "hands-on" activities and the process of science inquiry that scientists use. In my program, I believe I convey that the terminology *hands-on activity* to mean any science or technology activity, and the term *science inquiry* to refer to those activities directed toward using the processes of science (initiating and planning, preforming and recording, analyzing and interpreting, and communicating results) (Ministry of Education of Ontario 2007). In other words, I want the PTs in my class to understand that when involving their students in hands-on science activities, they are not necessarily engaged in *science inquiry*, and not all the aspects of *science inquiry* involve *hands-on activities.*

To explore the PTs understanding of these terms, we asked: *Is it your understanding that hands-on science learning is the same as learning through science inquiry? Please elaborate giving specific examples.* This was apparently perceived as a difficult question as less than half (44 %) of PTs answered it and some of them only provided a *yes/no/not necessarily* answer. Essentially, one-third answered *yes*, one-third *no*, and one-third *not necessarily*; these responses were found to be independent of their graduate major. Those PTs who viewed science inquiry either the same as hands-on, or always involving hands-on activities, explained that science inquiry involves investigations and that these are always associated with hands-on activities or experiments. To illustrate: *"In my experience, students engaging in scientific inquiry have done so through hands-on experiments;" "Inquiry is investigation that is supplemented by hands-on activities;" "yes- in both cases students are making predictions and then conducting experiments to see if they were correct;" "yes because inquiry implies that we are exploring in an active manner."*

Those PTs who believed that science inquiry can, but need not, involve hands-on activities explained that: "*Hands on is manipulating things. Inquiry could be just looking up information in books or on the internet;" "I think through hands on learning you will encounter science inquiry, but you may not have hands on in all science inquiry;" "In my opinion, hands-on science learning is related to science investigation that allows students the opportunity to experience and engage with science in real-life contexts. Inquiry does not have to be real-life, it can simulated through textbooks."*

Those who understood inquiry and hands-on activities to be different explained: "*Hands on science learning is experimental and exploring whereas science inquiry is a step by step process to replicate other scientific data." "No, hands-on is lab work, inquiry is information gathering;" "not the same, hands on involves experiments, inquiry involves more text work."*

The small number of PTs who chose to provide any answer, coupled with the smaller number who chose to elaborate, combined with the evidence that many of these identify inquiry as not involving scientific hands-on investigation, suggests that the process of inquiry is poorly interpreted and misunderstood by PTs generally. The curriculum itself may contribute to this misinterpretation because PTs are required to teach both science *and* technology together.

Distinguishing Between Science and Technology

From a series of Venn diagrams, PTs chose the figure that best represented the relationship between science and technology (Fig. 2). A full range of views were evident: 2 % no overlap, 5 % minimal overlap, 38 % considerable overlap, 35 % substantial overlap, and 13 % the same. The SM perceived a greater overlap than NSM ($t = 2.89$; df $= 119$; $p = 0.005$) reflecting the growing inter-dependency of these domains. In my view, instructors need to make clear the distinction between the two areas.

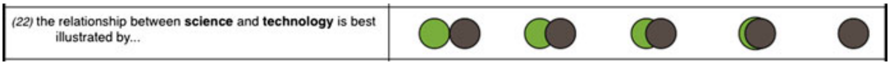

Fig. 2 The choice of Venn diagrams to convey the perceived relationship between science and technology

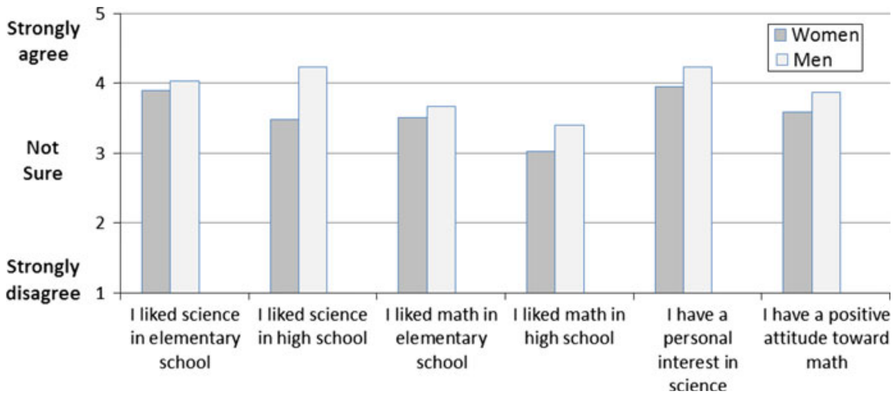

Fig. 3 Prior experiences and attitude toward science and math by gender

In summary, although PTs found hands-on activities engaging in their own education and are therefore likely to offer science activities in their own classrooms, the data suggest that few PTs see how these activities connect to the science inquiry actions that scientists take to construct science knowledge. The difficulty that PTs have with this association may be compounded by the fact that in the one course (science education) they are learning about the actions of scientists and also about the distinctly different actions of engineers.

Author Chira

Experiences with Mathematics: Quantitative Findings

While an initial analysis confirmed my perspective that men have had more positive experiences with math and are more comfortable with teaching the discipline (Fig. 3), these differences all but fell away when the PTs' major was part of the mix (Fig. 4). Men are far more likely to have a science major than the women ($\chi 2 = 11.973$, df $= 2$, $p < 0.001$), which accounted for the gender-related responses to the questions listed in Fig. 3. There were two gender-related differences of note that did not reflect the SM/NSM pattern: the womens' overall liking for science declined from elementary to secondary school while it was enhanced for the men; and while both the men and women reported a decline in their liking of mathematics from elementary to secondary school, the decline was more pronounced for the women (Fig. 3). The implication for these findings for me professionally is to reconsider the way I "see" as well as support the PTs. It seems surprising to me that I had never thought before to consider the critical role that a science major background might have on their attitude toward teaching math.

Experiences with Mathematics: Qualitative Findings

While there was an overall decline reported in the liking of math from elementary to secondary school, (not unexpected) I was particularly interested in examining the

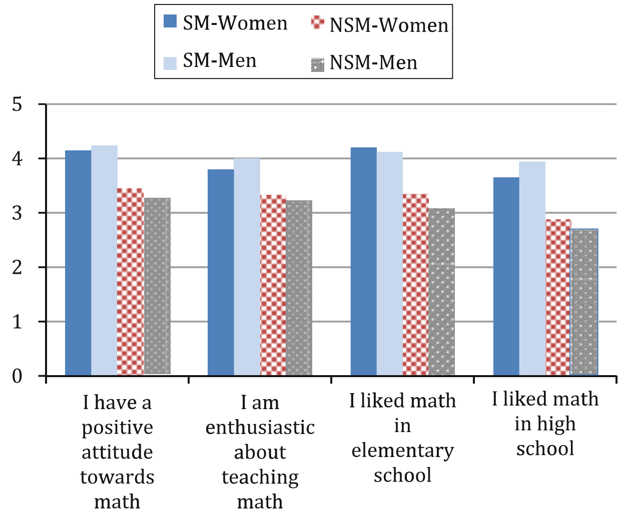

Fig. 4 Attitude toward math, math teaching, and prior school experiences by major and gender

explanations of any PTs whose experiences went against this pattern (given that my work is, in part, to rectify negative attitudes). There were 16 PTs who reported liking mathematics more in secondary school than in elementary school, citing *good teachers* and *good teaching* as major reasons (62 %). Their responses included: "*teacher was amazing*," "*still wasn't good at it but awesome teacher*," and "*good teaching, intellectually fulfilling.*" These responses hint at a feeling of enjoyment and being challenged, something that I consistently aim to deliver in my teaching practice and hence affirming for me. Findings that were less affirming of my practice concerned the two main reasons PTs gave for not liking math: *it was hard* (45 %) and 27 % *experienced failure*. I was very surprised at the low emphasis on *boredom* (9 %) and *poor teaching* (18 %). The findings are somewhat of a paradox for me in my teaching. While I know I am asking PTs to attempt math and to enjoy the attempt, by challenging them conceptually with interesting and engaging tasks, many of the PTs have avoided math in the past because it seemed too hard. A heightened sense of the tall order I require of those with impoverished school experiences has been brought home to me.

Author Cheryl

The themes of interest to me highlight how our PTs view themselves through their experiences growing up and their roles as members of their community. Their perspectives on these areas offer a point of departure from normative practices in the university classroom, inspiring possibilities that could be more student-centered, contextualized, and meaningful. Such perspectives can be revealed in the following three ways:

Affective Domain

Via an exploration of the affective domain, the PTs felt an emotional reaction to past learning and teaching experiences. For example, more PTs could recall memories of specific out-of-school learning experiences (81 %) compared to specific experiences in science lessons (71 %) and NSM were less inclined compared to SM to remember science when it was part of the normative high school lesson structure ($\chi 2 = 3.841$, $p = 0.05$), which further advocates for pedagogical approaches that offer experiential opportunities for out-of-classroom learning.

Teaching Philosophy

The PTs identified their philosophies regarding the purpose of teaching science, by choosing statement like "*exploring the unknown and discovering new things about our world and the universe and how they work*," "*carrying out experiments to solve problems of interest about the world around us*," and *"finding and using knowledge to make this world a better place in which to live.*" These responses reveal a belief that science teaching should be localized, student-generated, responsive to personal questions, and requiring inquiry, research, and experimentation.

Pedagogy

I searched for cues to inform me about our PTs' intended pedagogical approaches to teaching math and science. A commitment to providing out-of-school experiences for their students was reported by only about half (54 %) of the PTs. While logistical factors can impede the feasibility of organizing a regular out-of-classroom learning, it is clear that we need to model and create pedagogical possibilities in university science and math education teaching that are connected to community and context, personal interest, and hands-on activities.

Conclusions

Here, we review the findings with respect to: *How prepared do the pre-service teachers feel they are to teach science and math given their backgrounds?* We then consider in light of these findings: *How can we teach our courses in ways that increasingly support our PT's in teaching science and math?* We end with a comment on the process of collaboration.

PT Preparedness

Addressing the perceived preparedness of the PTs is predictably complex. There are significant differences among the PTs in our program, both in terms of their attitudes and prior experiences of science and math education, and in their confidence in engaging their students in these subjects. The PTs have a broad range of views regarding fundamental concepts around science inquiry, the construction of science knowledge, and the relationship between science and technology. About 30 % of our PTs admit to feeling somewhat disengaged and/or stressed about having to teach elementary science and math, and these PTs reported largely negative or neutral experiences of science and math during their schooling. All of these PTs were NSM. The silver lining is that the majority of the participants on the field trip were NSM, and they reported the experience as being quite positive and useful. The point is that when a professional learning opportunity in a social context is offered, the NSM are likely to take advantage of it.

It was somewhat surprising to find that PTs' science backgrounds, rather than gender, best explained their levels of confidence, enthusiasm, and anxiety about teaching mathematics. We might view gender as a variable in attitudes toward math and science (because we have been sensitized in that regard), but science background would seem to be a better indicator. Our attention needs to turn away from perceived differences between the men and women in our classes, and toward their background experiences and education, and seek ways in which we can link those experiences with their current learning and future teaching.

Impact of the Study on Our Practice(s)

Our collaborative research project provided two avenues for professional learning: the findings we established from the data collected from our PTs and the actual experience of collaborating and learning about each others' philosophical stances. Each of us must determine to what extent we choose to actually embed them in our individual practice.

We established key markers that we might take into account in our teaching practice(s) (e.g., SM/NSM; place-based learning). In addition, the research confirmed for us certain strategies that already existed in our collective practice that would strongly support PT preparation in science and math teaching, but our individual philosophical stances have hindered us from using them. It would be inaccurate to say that out practices have been transformed through this project; rather the project has provided us a first step, the opportunity to work with each other's different philosophies and experience how they connect to teaching practices. Chira for example chose to take her next cohort of PTs out into the campus forest in the second week of the program to connect early numeracy ideas with the environment, influenced by the STSE and place-based learning philosophical stances of Alice and Cheryl, respectively. While this session did reduce time for other key aspects of the program, it has been a session PTs have referred to in their assignments and discussions in subsequent classes.

Connie took heart from the reasons that PTs gave to describe their positive school science experiences; these conveyed a sense of commitment to include hands-on science activities as fundamental aspects of science and technology learning in their teaching. She also recognized that she needed to engage PTs in more explicit discussion about how these relate to the processes of science inquiry and how science and technology are related but different.

From Alice's practice, we understand the importance of STSE activities that provide opportunities for PTs to attach personal relevance to math and science topics, and the importance of an emphasis on group learning in social contexts. Both Alice's and Chira's data analyses identified the significance of the undergraduate degree in PT attitudes toward science and math. Alice also gained further respect for the place-based learning perspective, "but it is not what I do, and in a 24 h course I cannot see how I could fit that in as well." It is through the planned annual field trip, however, that this influence is most likely to take root.

Comments on Collaboration

The collaborative research process we liken to the feminist quilt (McFague 1993) wherein each collaborator contributes to the whole. The collaborative model within which we chose to work did not meld the voices of the four researchers into one, but rather allowed each voice to stand on its own. While we found the process of collaboration to be a rich learning experience, from the organization and implementation of the field trip, through the design of the survey, to the processes of analysis and writing, it was not without issues. Complementary benefits of four perspectives were countered by the challenges of allowing four voices to be heard. At the outset of the project, we believed that we shared common perspectives on preservice teaching, but the collaborative process teased out differences in our preferred pedagogies. For Connie, fully understanding the scientific inquiry process was the framework on which her science methods course was built, while for Alice it was the overriding importance of contextualizing science through an STSE lens in order for learners to make interconnections with their everyday lives; the first focuses on the work of scientists while the second focuses on the responsibilities of citizens. For Chira, a belief that a profound understanding of mathematical content knowledge is required to be competent and feel comfortable to teach through inquiry methods compared with Alice's perspective, that the comfort and confidence in teaching science rests not so much on issues of content knowledge, as on the elements of process skills and contextual engagement.

We were fortunate to have recognized early in the project that each of us brought different expertise to the table: organizational abilities, data analysis skills, experience in multi-layered research, and writing and editorial skills, which provided pathways to distribute the work. Yet when diverse directions surfaced based on our philosophical stances, it was our genuine respect for each other as humans and as educators that enabled us to prevail as collaborators. This experience will enrich our practice and, we hope, the practice of the communities in which we teach and learn.

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