Teaching Science for Social Justice:
An Examination of Elementary Preservice Teachers’ Beliefs

by

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for the degree of Doctor of Philosophy
Department of Curriculum, Teaching and Learning
Ontario Institute for Studies in Education
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ABSTRACT

This qualitative study examines the beliefs and belief changes of eleven elementary preservice teachers about teaching science for social justice. Using constructivist grounded theory, it forwards a new theory of belief change about teaching science for social justice. The theory posits that three teaching and learning conditions may facilitate belief change: preservice teachers need to recognize (1) the relationship between science and society; (2) the relationship between individuals and society; and (3) the importance of taking action on socioscientific issues.

This research responds to calls by critical scholars of teacher education who contend that beliefs in relation to equity, diversity, and multiculturalism need to be explored. They have found that many preservice teachers hold beliefs that are antithetical to social justice tenets. Since beliefs are generally considered to be precursors to actions, identifying and promoting change in beliefs are important to teaching science for social justice. Such a move may lead to the advancement of
curricular and pedagogical efforts to promote the academic participation and success in elementary science of Aboriginal and racialized minority students.

The study was undertaken in a year-long science methods course taught by the researcher. It was centered on the preservice teachers – their beliefs, their belief changes, and the course pedagogies that they identified as crucial to their changes. However, the course was based on the researcher-instructor’s review of the scholarly literature on science education, teacher education, and social justice. It utilized a critical – cultural theoretical framework, and was aligned to the three dimensions of critical nature of science, critical knowledge and pedagogy, and sociopolitical action.

Findings indicate that, at the beginning of the year, preservice teachers held two types of beliefs (liberal and critical) and, by the end of the course, they experienced three kinds of shifts in beliefs (minimal, substantial, and refined). The shifts in beliefs were attributed by preservice teachers to specific pedagogies. Yet their initial beliefs also served as filters to the pedagogies, consequently impacting their degrees of belief change. Therefore, this study reveals elements of unpredictability when engaging in teaching science for social justice.
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DEDICATION

I dedicate this milestone to my mother, Sheila K. Eslinger and my father, the late James Calvin Eslinger Sr. for instilling in me a deep love and fascination for the natural world. Without that, none of this would have been possible.
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CHAPTER 1
INTRODUCTION

A Challenge and an Inspiration

Early in my career as a fourth grade teacher in an urban elementary school, Tyrell walked into my classroom. He held his science book tight against his chest, with a yellow pencil tucked behind his ear. He greeted me with his usual “Sup, Mr. E.?”

“Science is what’s up, Tyrell. It’s time for science,” I replied.

“C’mon, Mr. E., don’t you know only White kids like science?”

Our conversation ended as quickly as it began, and four days later, Tyrell and his family moved out of state. What he said left me speechless and uncomfortable. At the time, I did not understand Tyrell’s viewpoint, and wished I made science come alive and more relevant to him. Yet what he said about science set in motion within me a series of often-difficult self-reflections that led me to examine my beliefs and practices as an educator. Fifteen years later, challenged and inspired by racialized minority students like Tyrell, I embarked to pursue a doctoral research project on teaching science for social justice.

A Problem in Science Education

In her 1990 essay in Scientific American, Shirley M. Malcolm argues that there is an invisible pool of talent that remains virtually untapped in North American society:

Who are these people who would do science if they could? They are Blacks and Hispanics and American Indians, girls and young women of all races and disabled students of both sexes and all races. The great irony is that as bad as the educational system may be overall, its failure is most dismal precisely for members of these groups. (Malcolm, 1990 p. 112)
About a quarter of a century after Malcolm’s indictment of science education, it seems that little has changed, and the untapped pool of science talent remains the same. Malcolm’s words are a powerful reminder of the need for science education reform that must address the continuous failure to educate all students effectively in science.

Reform efforts in Canada and the United States for the past 30 years have sought to improve the teaching and learning of science for Aboriginal and racialized minority students and to close persistent academic achievement gaps in science. Consequently, numerous educational policies and curriculum documents have adopted a *science for all* agenda (e.g., AAAS, 1993; CMEC, 1997; NRC, 2000; Ontario Curriculum, 2007; SCOC, 1984). *Science for all* is based on the egalitarian belief that all students can and should learn science and demonstrate scientific proficiency on standardized tests. This mandate challenges teachers to hold high academic expectations for, and teach science effectively to, students from diverse racial, ethnic, cultural, and linguistic backgrounds. Although such equity goals are well intended, policies and curriculum documents have provided little guidance on how substantive changes can be implemented at the classroom level (Rodriguez, 1998). Scholarly research and assessment results have also demonstrated continuous low levels of science participation and achievement related to students’ race, ethnicity, socioeconomic status, and English language proficiency (Aikenhead & Michell, 2011; Lee & Buxton, 2010; National Center for Educational Statistics, 2003). In response to what I deem as the unfulfilled promise of the *science for all* agenda, I contend that teaching science with a social justice focus is a significant way to advance reform efforts to promote the academic participation and success of Aboriginal and racialized minority learners.

Research indicates that children are naturally curious beings who ask questions about the world around them (Dewey, 1938; Harlan & Rivkin, 2011). However, some of them start losing
interest in school science by grades 4 to 8 and continue to disengage as they move through school (Alsop, 2005; Porter & Parvin, 2008). While there is no consensus as to why students’ interest in science declines, the consequences for Aboriginal and racialized minority students are detrimental. Many begin receiving lower marks, do not take advanced science courses, and do not pursue careers in the sciences (Lee & Buxton, 2010). Data from the Toronto District School Board reveals that Aboriginal, Black, and Latin American students are among the lowest performing groups in science in Grades 7 and 8 (Brown & Sinay, 2008).

Since research indicates that teachers have the greatest impact on student learning (Darling-Hammond, 2005; Kosnik & Beck, 2009), my research objective has been to understand elementary preservice teachers’ beliefs about teaching science for social justice. My study has been based on the premise that teachers’ commitment to and enactment of social justice would improve student achievement. Consequently, my thesis has been guided by three central research questions. As elementary preservice teachers take a science methods course with a social justice focus:

1. What are their initial beliefs concerning teaching science for social justice?
2. How do their beliefs about teaching science for social justice shift (if at all) during the course?
3. How do the pedagogical choices made in the course by the teacher educator impact their beliefs about teaching science for social justice?

By asking these questions, my research, ultimately, aims to improve the academic participation and success of Aboriginal and racialized minority students in science. Hence, my study lies at the intersection of two areas of research: science for social justice; and teacher education for social justice (see Figure 1.1). In the first area, research on the teaching of science
for social justice has been primarily focused on practicing school teachers and school-university partnerships (Lee & Buxton, 2010). In the second area, research on preparing preservice teachers for social justice is abundant and well established (Ball & Tyson, 2011; Cochran-Smith et al., 2009). However, few studies pertain to the preparation of teachers in specific content areas. In particular, only a handful of published studies address the preparation of teachers in an elementary science methods course with a social justice emphasis (Bianchini et al., 2003; Moore, 2008). Bringing together the two areas of science and teacher education for social justice, my study intends to substantively contribute to an emerging and promising line of scholarly inquiry.

Figure 1.1. Linking Science and Teacher Education for Social Justice

Research Design and Context

To address the three central research questions on the initial beliefs of preservice teachers, the shifts in their beliefs, and the pedagogical choices that impact beliefs, I decided to pursue a grounded theory approach to qualitative inquiry (Creswell, 2007). This approach enabled me to get in-depth data that identified initial beliefs, the factors and conditions that facilitated shifts in beliefs, and the effective pedagogies from the perspective of the research participants. For this study, I worked with 11 preservice teachers, and used the three qualitative
approaches of interviews, open-ended questionnaires, and document analysis. I chose to focus on preservice teachers’ beliefs about teaching science for social justice for two reasons: the accessibility of research participants; and the possibility for sustained reform in science education. First, I am both a PhD student in the Curriculum Studies and Teacher Development graduate program and a full-time Lecturer in the Initial Teacher Education program at the Ontario Institute for Studies in Education (OISE) of the University of Toronto. As a Lecturer, I teach multiple sections of the required elementary science methods course (EDU 1450). Since my research interest focuses on teacher education, situating my doctoral project at OISE, University of Toronto enabled me to have access to preservice teachers as research participants and to a content area that has received limited, yet crucial scholarly attention. Second, research indicates that practicing teachers are more resistant to science education reform than preservice teachers (Jones & Carter, 2007). This is particularly true in the area of epistemic beliefs or beliefs about the nature of knowledge. While inservice teacher development is important, I argue that for systemic and sustainable science reform to occur, attention must be paid to teacher education programs and how elementary science teachers are prepared.

My approach to preservice teacher beliefs about teaching science for social justice responds to various scholarly and professional concerns regarding elementary science teaching. For over four decades, numerous studies have demonstrated that elementary teachers tend to avoid teaching science for a variety of reasons, including past negative experiences as students of science, lack of appropriate science content and pedagogical content knowledge, and fears about managing students during group activities (Appleton, 2005; 2007). Elementary science teachers also report low levels of confidence and poor self-efficacy when it comes to teaching science. As a result, they use traditional lecture and textbook approaches to instruction (Appleton, 2007;
Harlen & Holroyd, 1997; Lee & Houseal, 2003; Nelson, 2008; Tilgner, 1990). In countries like Canada and the United states where there is enormous pressure for students to perform well on standards-based tests in literacy and numeracy, teachers tend to focus on these two instructional areas at the expense of other subjects, such as science (Goldston, 2005; Volante, 2004). For these reasons, science is often short-changed in the elementary grades, and is often not taught at all.

**Research Significance**

I undertook my doctoral research project within the context of a mostly homogeneous teaching force and a diverse student population in the Canadian city of Toronto. Elementary school teachers in Toronto (and in many Canadian cities) are overwhelmingly White, female, middle class, and English speaking, a demographic profile which starkly contrasts with urban students who are predominantly racialized minorities and immigrants, from poor and working class backgrounds, and whose first and home languages are not English (Gerin-Lajoie, 2008). The demographic and cultural differences between teachers and the students they serve has been seen as a major reason for scholars to challenge existing curriculum, teaching, and learning dynamics in favor of more critical and culturally grounded approaches to working with racially diverse students (Esmonde, 2009; Goldstein, 2003, 2004; McCready, 2010).

My study focuses on preservice teachers’ beliefs because there is general scholarly consensus that beliefs are a precursor to action (Pajares, 1992). In other words, while beliefs do not guarantee actual enactments, they are good indicators of what individuals may potentially do or act upon. My work also responds to the empirical and professional calls by many critical scholars of teacher education who contend that the beliefs of preservice and practicing teachers, especially in relation to equity, diversity, and multiculturalism, need to be explored (Cochran-
Smith et al., 2008; Gay, 2011). They push for the scholarly examination of preservice teacher beliefs since they have found that many White teachers hold beliefs that are antithetical or not conducive to the tenets of equity, diversity, and multiculturalism. In fact, many are resistant to these ideas (Sleeter, 2008; Villegas, 2007).

So, how do teacher beliefs that are not conducive to equity, diversity, and multiculturalism manifest in their actions? Research indicates that teachers discount the role of race and culture in teaching and learning, take a banking approach to education, have low expectations of their students, and do not encourage their students to address and take action on crucial socioscientific issues that impact their lives and communities (Barton et al., 2011). And, what are the consequences of such teacher beliefs and actions on K-12 students? Research reveals that students become passive recipients of knowledge, focus on rote memorization and basic skills, do not make connections between school and society, and disengage from curricular material that is not culturally relevant (Darling-Hammond, 2008). For many, their interest in science wanes, thereby negatively impacting their academic engagement and achievement in science (Bianchini et al., 2011).

Therefore, for my first research question, I aimed to identify the initial beliefs of preservice teachers in order to determine their starting point at the beginning of the year and to gauge their openness to issues of equity, diversity, and multiculturalism. Then, for my second research question, I wanted to determine if their beliefs shifted while taking an elementary science methods course with a social justice focus. By tracking the belief development of preservice teachers over time, I am contributing to the scholarly literature by identifying the varying starting belief points of preservice teachers and determining the different factors that enabled or constrained their belief change.
In addition, there is ongoing scholarly debate in relation to the impact of initial teacher education courses with a social justice focus on the beliefs of preservice teachers. Some argue that these courses have no impact at all, while others contend that even a single course has demonstrated some positive impact (Akiba, 2011; Capella-Santana, 2003; Walker-Dalhouse & Dalhouse, 2006). Taking the latter position as my point of departure, I utilized a mandatory elementary science methods course called “Science and Technology Education for Elementary School Teaching” (EDU 1450) as the main site for my research study (see course outline in Appendix A).

This course is taken by all preservice teachers in the Junior/Intermediate division (Grades 4-10) of the Bachelor of Education Consecutive Program in Initial Teacher Education at the Ontario Institute for Studies in Education (OISE) of the University of Toronto. With my dual roles as the researcher and the course instructor, I completely revised the readings, assignments, and in-class activities, so that the course had an explicit emphasis on social justice. My curricular and pedagogical revision was partly informed by my experiences as a 10-year veteran educator of student in urban elementary schools working with racialized minority students, and largely shaped by my extensive review of the scholarly literature on the integration of science and teacher education for social justice. Therefore, for my third research question, I was interested in finding out how the pedagogical choices made in the course by the teacher educator impacted the beliefs of preservice teachers regarding teaching science for social justice. Of particular interest to me were the course pedagogies that impacted belief change from the perspective of preservice teachers themselves. Hence, I am contributing to the scholarly literature in two ways: by providing a detailed example of a teacher education course in a specific content area (elementary
science education) that integrates social justice; and by delineating effective pedagogical strategies that impact belief change from the vantage point of preservice teachers.

Finally, I engage in the scholarly discussion on the process of belief change in teacher education. Two schools of thought dominate this discussion. One school of thought takes a psychological approach that sets up four conditions for conceptual change, including dissatisfaction, intelligibility, plausibility, and fruitfulness (Posner et al., 1982). The other school of thought takes a constructivist approach that offers a broad set of strategies for ideological change, including reflexivity and dialogicality (Rodriguez, 1998). While both approaches have merit, they do have some notable limitations. Drawing insights from Kathy Charmaz’s version of grounded theory (2006), my thesis will propose a new theory of belief change when teaching science for social justice that will contribute to the scholarly areas of teacher beliefs and belief change, elementary science education, teacher education, and social justice.

**Key Terms and Definitions**

This thesis refers to a few important terms, such as “science,” “elementary,” and “social justice,” which need to be defined. The term “science” refers to both the concepts and processes of science as well as their impact on society and the environment (OME, 2007). For the Initial Teacher Education Program at OISE, University of Toronto, the term “science” also encompasses technology because the two fields of study are codependent and compatible (Roth, 2001). This is evident in my science methods course with the official title “Science and Technology Education for Elementary School Teaching” (EDU 1450). The term “elementary” generally refers to grades K-8 in accordance with the Ontario Ministry of Education. However, OISE, University of Toronto offers a teaching certification in the Junior/Intermediate division for
grades 4-10, and my research participants came from this division. Therefore, even though I refer to elementary science education, my research study was centered on a science methods course that was taken by preservice teachers seeking a Bachelor of Education degree and a teaching certification for grades 4-10.

Although “social justice” has become a popular term in teacher education, it has multiple and contested meanings (North, 2008). Inspired by Marilyn Cochran-Smith’s (2010) theory of teacher education for social justice, I define social justice as pertaining to the eradication of oppression and the equitable distribution of power, opportunity, wealth, and resources. It requires educators to challenge inequities that are deeply rooted in school and society and stratified by markers of social difference (e.g., race, class, gender, sexuality, ability, and language). Teaching for social justice, therefore, refers to the beliefs, knowledge, and practices of activism that enable teachers to dismantle inequitable power relations that make schools alienating and oppressive for Aboriginal and racialized minority students. Teaching for social justice also involves preparing elementary students to be critical of and to challenge inequities themselves.

Social justice is also intricately linked to other key terms, such as “equity,” “diversity,” and “multiculturalism.” Equity refers to the “social and institutional process by which individuals can attain empowerment” (Rodriguez, 1998, p. 591) and is concerned with the fair distribution of opportunities to learn and participate in school and society. Diversity refers to the variety among people who exist in society and includes (but is not limited to) those from different cultural, racial, ethnic, linguistic, and social backgrounds. Teaching for diversity implies that teachers incorporate pedagogies and curriculum that represent and encourage students from different demographics (Grant & Secada, 1990). Multiculturalism is a process aimed at providing equal educational opportunities for all students (equity) by transforming the
school environment so that it is representative of the diverse cultures and groups in society and classrooms (Banks & Banks, 2010). These three concepts are integral to a theory of teacher education for social justice (Cochran-Smith, 2010).

**Situating Myself in the Study**

My science education began in the foothills of the Ozark Mountains in southwest Missouri in the United States. My earliest memories took place planting in our family garden, walking ankle-deep in streams, discovering the forests, or helping my father work on an old tractor. As a young boy, I used to daydream about conducting experiments, and wanted to become a professional scientist. I imagined myself working alongside Albert Einstein, Gregory Mendel, or Galileo Galilei. There were numerous role models that inspired me. The scientists I looked up to, the guest speakers who came to my school, and the star of my favorite television show *Mr. Wizard* always looked like me – White and male. Early on, I wanted to become an elementary school teacher, so that I could share my passion for science with children.

I graduated with my bachelor’s degree and teaching license in 1997, quite confident with my knowledge, skills, and dispositions as a new teacher. I was hired the following year as a fourth grade teacher in a school located in a rural area close to my hometown. The school had students, teachers, and families whose cultural values and backgrounds mirrored my own upbringing. My first year of teaching was rewarding and exciting. My hard work was recognized by my colleagues, and I was given the New Teacher of the Year Award in the school district. Although relatively successful as a new teacher, I yearned for different experiences and to challenge myself personally and professionally. I decided to apply to an urban school district, and was hired in 1999 as a fourth grade teacher in Columbus City Schools (CCS), the largest
district in the state of Ohio. Since I was hired to teach in a grade level that was very familiar to me, I felt confident about my ability to address the curriculum and the students. However, it did not take me long to realize that I still had much to learn.

My school was located in an impoverished area of the city, and the majority of my students were African Americans. I encountered many challenges during my first year in CCS. I found it difficult to motivate my students, and classroom management was frequently a concern. Student engagement was an issue, and I struggled to keep them focused on learning tasks. At that time, it did not occur to me that what and how I was teaching might not be relevant to my students or that there might be issues outside of school that impacted their academic engagement and achievement. What I came to realize, contrasting my teaching experiences in rural and urban schools, was that I could easily interact and develop relationships with students who were White and had similar lived experiences and backgrounds to me. My failure to recognize students’ intersectional attributes of race, class, and culture that are different from mainstream norms missed how schools privileged certain identities and marginalized others and how processes and structures of privilege and marginalization were intricately tied to students’ academic learning and accomplishment.

Unlike in my previous school where the White cultural and rural home backgrounds of my students and their families were similar to mine, in an urban school setting I had to come to terms with the limits of my own personal experiences. Due to my lived experiences, I had a very scant understanding of how social policies inequitably affected many urban students and their families due to their race and socioeconomic status. I did not realize the extent to which racism and classism shaped, and continue to shape, the lived conditions of racialized and economically disadvantaged people and how these conditions impacted their views of schools and teachers. It
was only when I immersed myself in my students’ after-school activities and in the local community that I began to understand why schools were alienating and disempowering places for many people of color in urban areas. Over time, parents shared candidly their personal stories with me. They described countless encounters of individual and systemic forms of racism in school and society, and relayed a general distrust of White institutions like schools and White people who work in them. Although they wanted their children to do well academically, they also saw schools as racist places that did not have their “child’s best interest” in mind.

My initial entrance into my students’ homes and communities resembled the position of a cultural voyeur, noting mere differences between my and their upbringing. However, my eventual immersion and engagement revealed deeper insights into their and my own perspectives about issues of difference, power, and inequity. African American parents’ frank disclosure of schools as racist institutions and of White teachers as not caring for their children was uncomfortable to me, someone who believed that I cared for all children regardless of their racial, class, and cultural backgrounds. However, their candidness was necessary to pierce through my White liberal belief that did not adequately account for issues of historical and contemporary injustice and for my participation and complicity in an educational system that has pushed out many students of color. My discomfort urged me to interrogate my own assumptions, stereotypes, privileges, and practices.

As a White male educator, I have been privileged in many ways due to my race and gender, and I am a beneficiary in school and society steeped in White supremacy and patriarchy. However, I desire to play an active role in disrupting unequal power relations based on racial and ethnic difference. When I came to OISE as a lecturer in 2009, I became involved with a personal and professional community that valued equity, diversity, and multiculturalism. My passion for
science and my commitment to social justice led me to pursue a doctoral degree in Curriculum Studies and Teacher Education in the OISE Department of Curriculum, Teaching and Learning the following year. The academic courses and discussions at OISE, especially regarding anti-colonial theory, critical multiculturalism, and critical pedagogy, have guided the way I have conceptualized my research study. Consequently, I have incorporated concepts and practices of social justice, especially in relation to Aboriginality and race, in my science methods course in the OISE Initial Teacher Education program.

Although my personal and professional background as an urban educator in the United States has provided me with a solid foundation to work with racialized minority students, and I have extensive experience developing and delivering culturally relevant science lessons, understanding Aboriginal knowledges and worldviews especially in relation to science and science education, is new to me. Still at the beginning stage of educating myself about Aboriginal knowledges and worldviews, I strive to learn more and become more competent in this area. For instance, I have attended academic lectures and talks by Aboriginal scholars in these areas. Since I have been immersed in Western knowledges and methodologies throughout my schooling and educational career, I endeavor to decolonize my own thinking and practice as essential to my own growth.

**Charting the Thesis**

My doctoral thesis is organized in seven chapters, including this introductory chapter. In Chapter Two, I will review the relevant scholarly literature to lay out the conceptual frameworks for my thesis. I will examine the literature on the nature of beliefs, the theories on belief change, and the resistance to and unpredictability of teaching for equity, diversity, and multiculturalism.
Then I will outline my conceptualization of teaching science for social justice, especially through three dimensions that synthesize the scholarly literature in science education, as well as my critical – cultural theoretical framework which underpins this study. In Chapter Three, I will explain my qualitative research methodology to answer the three central research questions. I will provide information about the research context and participants as well as my use of constructivist grounded theory as the main approach for data collection and analysis. In this chapter, I will also address issues of validity, ethics, and limitations as they relate to my thesis study.

The next three chapters – Chapters Four, Five, and Six – will function as respective answers to each central research question. Chapter Four will be divided into four themes: the preservice teachers’ beliefs about science, about teaching science, about social justice, and about teaching science for social justice. This chapter will indicate that, at the beginning of the year, the 11 preservice teachers in the study could be categorized into two groups: those who held liberal beliefs and those who possessed critical beliefs. Chapter Five will elaborate on a key finding regarding the participants’ changes in beliefs about teaching science for social justice. At the end of the year, all 11 preservice teachers demonstrated shifts in their initial beliefs. They demonstrated three types or degrees of shifts – minimal, substantial, and refined. Chapter Six will build on the previous chapters’ findings, and will indicate the pedagogical choices that impacted their belief changes. My analysis of what participants indicated as key pedagogical choices revealed six enabling factors for change. These factors include: (1) engaging with diverse perspectives in science, especially with Aboriginal worldviews; (2) challenging the positivism of science; (3) recognition of their own social location as preservice teachers; (4) incorporation of the role of race and culture in teaching and learning; (5) development of their
students’ critical consciousness; and (6) encouragement of student agency. In the final Chapter Seven, I will propose a theory of belief change about teaching science for social justice, that needs to account for three forms of relations, and will delineate the implications of this study for teacher education and for future research.
CHAPTER 2

LITERATURE REVIEW

In this chapter, I will review relevant scholarly literature to lay out the conceptual frameworks for my thesis. First, I will examine the nature of beliefs and theories of belief change. Second, I will delineate the common resistance strategies that preservice teachers utilize to uphold their current beliefs, and will discuss the unpredictability of teaching for equity, diversity, and multiculturalism. Third, I will outline various pedagogical attempts to shift preservice science teachers’ beliefs regarding equity, diversity, and multiculturalism. Fourth, I will delineate how I conceptualize teaching science for social justice, and will elaborate on three specific dimensions based on my analysis of the scholarly literature in science education. Lastly, I will explain the critical – cultural theoretical framework that underpins this thesis project. I should note that my review of the scholarly literature has two purposes: one, it serves the conventional purpose of identifying key concepts, thinkers, debates, and gaps in the theoretical and empirical studies of the scholarly areas where I situate my work; and two, it provides a conceptual foundation and synthesis for my science methods course, which enables me to formulate an overarching critical – cultural framework and the three dimensions of teaching science for social justice.

Nature of Beliefs

Researchers have argued that teachers’ beliefs about equity, diversity, and multiculturalism are integral to increasing the academic achievement of Aboriginal and racialized minority youth. However, my review of the scholarly literature reveals divergent
findings on the role and impact of teacher education on preservice teacher beliefs. Some scholars suggest that teacher education has a very limited impact, if any, on changing preservice teachers’ beliefs regarding equity, diversity, and multiculturalism (Haberman & Post, 1992; Richardson, 1996), while others demonstrate that even a single course can have a positive impact on these beliefs (Artiles & McClafferty, 1998; Capella-Santana, 2003; Dinkelman, 1999; Greenman & Dieckmann, 2004; Mensah, 2009; Olmedo, 1997; Peterson et al., 2000; Torok & Aguilar, 2000). My thesis takes the latter position as its point of departure, and responds to the imperative call by critical scholars for researchers to study preservice teacher beliefs regarding equity, diversity, and multiculturalism (Castro, 2010; Cochran-Smith & Zeichner, 2005; Gay, 2011; Irvine, 2004; Nieto, 2005; Rodriguez & Kitchen, 2005; Villegas, 2007). Understanding preservice teacher beliefs about equity, diversity, and multiculturalism is important because beliefs are “the best indicators of the decisions that individuals make throughout their lives” (Pajares, 1992, p. 307) and they are regarded as the “most valuable psychological construct to teacher education” (Pintrich, 1990, p. 308). While there is scholarly debate on the strength of the correlation between beliefs and actions, there is consensus that changing beliefs is crucial to changing practices (Fang, 1996; Rimm-Kaufman & Sawyer, 2004).

The term beliefs “travel in disguise and often under aliases” (Pajares, 1992, p. 2). They have been called views, perspectives, conceptions, ideologies, preconceptions, attitudes, tenets, philosophies, personal convictions, explicit propositions, personal pedagogical systems, perceptions, theories for practice, and untested assumptions (Calderhead, 1996; Kagan, 1992; Pajares, 1992). Much of the scholarship pertaining to the nature of beliefs comes from the field of psychology. For example, Milton Rokeach (1972) defines beliefs as “any simple proposition, conscious or unconscious, inferred from what a person says or does, capable of being preceded
by the phrase ‘I believe that’” (p. 113). He maintains that all beliefs have three components: a cognitive component, which represents an individual’s knowledge about what is true or false; an affective component, which is capable of arousing emotion; and a behavioral component, which is activated when action is required. For Rokeach, beliefs are structured like an atom, with an individual’s most important aspect representing the nucleus, which is highly resistant to change.

Jan Nespor (1987) expands on Rokeach’s work, and devises a framework identifying four features of beliefs: existential presumption; alterativity; affective and effective loading; and episodic structure. Existential presumptions are “the incontrovertible, personal truths everyone holds” (Pajares, 1992, p. 309), which range from assumptions about the existence of entities or phenomena such as God, to assumptions that teachers make about a student’s academic ability, maturity level, or intrinsic motivation. This feature of beliefs can be particularly harmful to students because it positions the assumptions about students (e.g., boys’ natural affinity for science) as immutable or beyond the teachers’ influence. The second feature of alterativity refers to “conceptualizations of ideal situations differing significantly from present realities” (Nespor, 1987, p. 319). Nespor provides a case study of a teacher named Ms. Skylark who recalled not enjoying school as a child because her classes were never fun but she wanted them to be. As a result, when she entered the teaching profession, it became her goal to create a relaxed and friendly environment for her students. Nespor explains, “Although she worked to shape her class to that ideal, she had never achieved it; nor had she experienced it as a child. Rather this was a sort of utopian alternative to the sorts of classrooms she was familiar with” (Ibid.). In Ms. Skylark’s case, her vision of creating a fun environment resulted to ineffective classroom management, constant redirection, repeated explanations of assignments, and half-covered lessons. The third feature of affective and effective loading depends on elements, such
as feelings, moods, and subjective evaluations based on personal preferences. It deals with how teachers feel about the subject matter or how content should be delivered. For example, many elementary teachers do not like science and subsequently do not teach it. For another example, teachers feel that science is merely a body of facts to be learned by students, and therefore teach it in a didactic way (Appleton, 2007). For the last feature, Nespor contends that beliefs are linked to specific events and past experiences that reside in episodic memory. This feature speaks to the importance of teacher educators creating transformative experiences because they can potentially “produce a richly-detailed episodic memory which later serves the student as an inspiration and template for his or her own teaching practices” (Nespor, 1987, p. 320).

Responding to the numerous ways that beliefs have been conceptualized, M. Frank Pajares (1992) provides a synthesis of the scholarly literature on the nature and feature of beliefs. He offers a useful definition of belief: “an individual’s judgment of the truth or falsity of a proposition, a judgment that can only be inferred from a collective understanding of what humans say, intend, and do” (p. 316). According to Pajares, beliefs have several features. They are: formed early in life; acquired through life experiences and cultural transmission; both conscious and unconscious; episodic in nature and act as filters, which shape interpretation of new knowledge; prioritized based on their relationships to other beliefs; resistant to change, even in light of new information; and ultimately, instrumental in pedagogical decision making. Moreover, Ruth Kane and her colleagues (2002) refer to beliefs as theories in action and indicate two types – espoused and in-use. Espoused theories are beliefs that individuals describe when asked, and theories-in-use are beliefs that are apparent through their actions.

For my study, I am interested in using both Pajares’ and Kane’s conceptions of beliefs. These authors, as well as many others who have been foundational to the scholarly literature on
beliefs (e.g., Abelson, 1979; Kagan, 1992; Pintrich, 1990; Rokeach, 1972), derive their insights from a psychological standpoint. Based on my review of their writings, none of them engages with the nature of beliefs from what one might call a critical or social justice orientation. Yet, even though their works do not take a critical or social justice perspective, they ought not to be easily dismissed. In fact, their psychologically-grounded conceptions of beliefs have been taken up by scholars who are interested in preservice teachers’ beliefs about equity, diversity, and multiculturalism and take a critical orientation in their analytical and empirical projects (e.g., Bianchini et al., 2003; Moore, 2008; Richmond et al., 1998). Similar to these critical scholars, my research interest focuses on the impact that a science methods course can have on preservice teacher beliefs, especially in the self-reflexive and pedagogical process of belief change.

Both science and science education are not immune to the influences of broader social contexts with values and beliefs that impact schools. To better understand this, Rick Arnold and his colleagues (1991) offer a typology of three political approaches to education that are useful when examining power relations in schools and society. These approaches are conservative, liberal, and transformational, and each approach is underpinned by particular beliefs about teaching and learning.

A conservative approach to education functions as a tool of social assimilation, and is structured around the “worldview[s] and experience[s] of the elites, which all others are expected to appreciate, if not emulate” (Arnold et al., 1991, p. 19). In other words, it foregrounds the beliefs, values, and ways of being of White, middle class, Protestant, heterosexual males, and prioritizes a common or universal curriculum that represents the norms and experiences of the dominant sector (Hirsch, 2010). In doing so, curricular and pedagogical practices in a
conservative approach dismiss the intersecting roles of social difference and power relations, and instead favor competency-based and “survival of the fittest” views (Jeynes, 2011, p. 538).

Whereas a conservative approach to education negates the role of race and other forms of diversity in schooling, a liberal approach sees schools as a place to promote intercultural respect. Arnold and his colleagues (1991) define this approach as emphasizing “individualism, the self-directed learning of autonomous adults … [with a focus] on attitudes rather than structures … on personal growth rather than transformation” (p. 21). Teachers with liberal beliefs see curricular content as a neutral body of knowledge that all students should learn in order to better themselves, rise above their circumstances, and become productive members of society. Although a liberal approach promotes tolerance and learning about social differences, it makes minimal attempts to interrogate deeply rooted inequities in schools and society.

A transformational approach aims for “individual and collective liberation [and] promotes learning for critical consciousness and collective action. Such education seeks to transform power relations in society” (p. 22). In other words, it seeks to educate for social change by examining aspects of schooling within broader sociopolitical contexts and empowering all students to critique and become agents of social change. Such an approach takes an anti-oppressive stance towards pedagogy and curriculum by making social difference central to teaching and learning. Whereas the liberal approach is concerned with individuals, a transformational approach takes a critical analysis of power relations within systems and structures and their effects on groups and communities. This approach strives to help teachers and students to understand and act on the complex web of oppression based on the intersection of social identities that marginalize individuals and social groups (McCready, 2010).
Arnold and his colleagues offer three approaches to education that are informed by different beliefs concerning pedagogy, curriculum, equity, diversity, and multiculturalism. Their typology of conservative, liberal, and transformational approaches offers a useful framework for classifying preservice teacher beliefs and their potential changes.

**Theories of Belief Change**

The field of science education has been keen to examine, challenge, and change preservice teacher beliefs for the past thirty years. It has investigated beliefs about science content (Yilmaz-Tuzun, 2008), epistemology (Cobern & Loving, 2002), instructional strategies (BouJaoude, 2000), classroom management (Moss & Kaufman, 2003), as well as student diversity and multiculturalism (Southerland & Gess-Newsome, 1999). Lynn Bryan and Mary Atwater (2002) provide a convincing rationale for the development of science teacher education programs that examine preservice teachers’ beliefs “about multicultural issues and their impact on teaching and learning” (p. 821). They argue that failing to do so will continue to undermine equitable science education for students from diverse backgrounds. Many preservice teachers enter teacher preparation programs with beliefs that are antithetical to teaching for social justice. In their synthesis of the scholarly literature on teacher beliefs and diversity, Etta Hollins and Maria Guzman (2005) conclude that many White preservice teachers hold negative, stereotypical, and deficit beliefs concerning racialized minority students and families. They find that preservice teachers hold on to their beliefs, and exhibit resistance when they are challenged.

So, how has the field of science education addressed belief change? Two major frameworks emerge in my analysis. George Posner and his colleagues (1982) forward a theory of conceptual change, which provides a model to explain how individuals experience cognitive
shifts. Conceptual change is generally defined as a transformative restructuring of an existing belief or conception. According to Posner, beliefs can be changed when four conditions are met. First, individuals must become dissatisfied with their current beliefs. Second, the new beliefs must be intelligible or understandable. Third, the new beliefs must be plausible and seem worthy to them. Fourth, the new beliefs must be fruitful or productive to the individual. This means that teacher educators must help preservice teachers become aware of their beliefs, provide learning opportunities that challenge them, and provide acceptable alternatives to previous beliefs.

However, Posner’s conceptual change model has been critiqued for a number of reasons. Gale Sinatra and Paul Pintrich (2003) argue that this model falls short because it does not account for the affective aspects of belief change, such as interests, values, and motivation, leading Pintrich to call it a “cold conceptual change” in an earlier article (Pintrich et al., 1993, p. 167). They also claim that the model does little to recognize the impact of the sociocultural context on the conceptual ecology. Furthermore, Posner’s conceptual change model presents a rational approach that assumes logical and rational thinking and does not account for contradiction or unpredictability. While his conceptual change model offers insight into the conditions necessary to shift preservice teachers’ beliefs, it is limited in that it does not address the resistance exhibited by preservice teachers. To address the limitation of Posner’s theory of conceptual change, other scholars turn to social constructivism.

Alberto Rodriguez (1998, 2005) describes two types of resistance from preservice teachers: resistance to pedagogical change and resistance to ideological change. On the one hand, resistance to pedagogical change is defined as “resistance to teaching for understanding” (p. 593), or the resistance that preservice teachers exhibit when they encounter theories of teaching and learning that are at odds with what they perceive to be proper pedagogy. On the other hand,
Resistance to ideological change is “resistance to teaching for diversity” (p. 590), or the resistance that preservice teachers demonstrate in relation to their beliefs when they are asked to confront racism and other forms of oppression. Many scholars write about preservice teachers’ resistance to ideological change when taking equity, diversity, and multiculturalism courses (Solomon et al., 2005; Sleeter, 2008).

Rodriguez (2005) forwards “sociotransformative constructivism” (STC) as a theoretical framework of teaching and learning that brings together social constructivism and multicultural education, thereby integrating the social nature of learning with issues of power, justice, and social reproduction (Bourdieu, 2000). STC encompasses four elements: reflexivity, dialogic conversation, authentic activity, and metacognition. These elements work together, but are not hierarchical and do not occur in any particular order. They offer teacher educators with four broad “socially responsive and transformative pedagogical strategies” that can be used to address resistance to pedagogical change and to ideological change (Rodriguez, 2005, p. 22). Rodriguez offers two examples where STC is used to promote pedagogical and ideological changes in preservice teachers. For pedagogical change, he uses authentic activity and metacognition, whereas for ideological change, he mobilizes the elements of reflexivity and dialogic conversation. Since my research aims to study what Rodriguez calls as ideological change, I will focus on his sociotransformative constructivist elements of reflexivity and dialogic conversation.

Although preservice teacher beliefs are resistant to change, research demonstrates that both elements of reflexivity and dialogic conversation have been used to positively impact them. Scholars, such as Marilyn Cochran-Smith (2004; see also Cochran-Smith et al., 2009; Enterline et al., 2008), write about the generative potential of teacher reflection. For Rodriguez (2005), reflexivity is a critical process through which teachers interrogate their social identities and
locations in relation to others, as well as their beliefs and values concerning power, privilege, and oppression. In order to teach for social justice, preservice teachers must understand what Lisa Delpit (2006) calls the “culture of power” and how they are privileged and/or marginalized in order to “transform [the culture of power] for the benefit of all and not just a few” (Rodriguez, 1998, p. 601). Closely related to reflexivity is the element of dialogic conversation. For Rodriguez (2005), dialogic conversation builds on Mikhail Bakhtin’s (1981) notion of dialogicality. Dialogue is more than just spoken word; it embodies one’s lived experiences as it has been influenced by others. For example, constructs such as race, class, and gender provide a social context for not only what one says, but also how, why, and when one speaks. Participants in dialogic conversations strive to understand how one’s social position shapes communication and meaning making. In other words, “the speaker’s voices are embedded in cultural, historical, and institutional context that could have multiple meanings” which could be open to a variety of interpretations and understandings (Rodriguez, 1998, p. 599). Ultimately, Rodriguez’s sociotransformative constructivism provides a theoretical framework and practical strategies that can be used to counter the resistance that preservice teachers exhibit when engaging in ideologically-laden teacher education contexts.

The two major frameworks in the field of science education delineated by George Posner (Posner et al., 1982) and Alberto Rodriguez (1998, 2005) provide teacher educators with conceptual and practical tools to potentially impact preservice teachers’ beliefs. While Posner’s theory of conceptual change is useful in understanding belief change from a psychological perspective, it is limited when I consider the sociocultural aspect of learning in my science methods course. Rodriguez’s theory addresses this limitation with sociotransformative constructivism. His articulation of reflexivity and dialogic conversation are broad strategies of
counter-resistance that can be taken up through numerous pedagogical activities. Rodriguez’s theory can also be utilized in numerous content areas (Aguirre, 2005; Rodriguez, 2010). Since my aim is to explore specific pedagogical practices that impact preservice teachers’ beliefs about science and science education, a theory of belief change about teaching science for social justice is important. In the next section, I will elaborate more on preservice teacher resistance, the unpredictability of changing beliefs, and the positive impact that one teacher education course can have on beliefs.

**Preservice Teacher Resistance**

Many preservice teacher educators have prioritized teaching issues of equity, diversity, and multiculturalism in their courses (Cochran-Smith et al., 2009; Goldstein, 2004, in press; Kosnik & Beck, 2009), particularly in light of the “demographic divide” between teachers and students in K-12 schools (Banks & Banks, 2010). Rodriguez (1998, 2005) delineates resistance as pertaining to pedagogical and ideological change, and offers four counter-resistance strategies that teacher educators might employ. A closer analysis of the scholarly literature pertaining to teacher education and issues of equity, diversity, and multiculturalism reveals two major strategies that preservice teachers enact to resist changing their beliefs: their claim of color-blindness and refusal to interrogate whiteness; and their assertions of individual responsibility and the meritocratic foundation of school and society.

**Color-Blindness and Whiteness**

Teacher educators have reported that many White preservice teachers, while learning about equity, diversity, and multiculturalism, make claims that they “just see kids, not color” or
“race doesn’t matter, I treat all my students the same” (Eslinger, 2013). This type of preservice teacher resistance has been referred to as color-blindness (Atwater, 2008; Daniel, 2009; Derman-Sparks & Phillips, 1997; Pennington et al., 2012). Color-blindness is the belief that the best way to treat all students equally is to claim to not see students’ race or ethnicity. Christine Sleeter (1993) posits that White people make color-blind statements in order to not appear to be racist; in other words, they believe that seeing and acknowledging racial or ethnic difference somehow implicates them in racism. Color-blind statements are based on the assumption that erasure of social and structural oppression can be achieved if racial differences can be ignored, thereby achieving a mythical state of equality. They presume that we live in a post-racial society that is not stratified by race and other markers and intersections of differences and that there are negligible implications to racial difference.

Teachers’ assertion that race and culture do not play a role in the classroom or do not exist at all can potentially have negative consequences (Chambers & McCready, 2011; Esmonde et al., 2009). First, their assertion of color-blindness denies the historical and contemporary lived experiences and cultures of racialized minorities, and minimizes the harmful and ongoing effects of racism. In other words, they believe that racialization does not affect one’s social status and well-being. Second, by denying the impact of race and racism, their color-blind beliefs serve to relieve them from fighting against racism. Third, they dismiss White complicity in a racial hierarchy that privileges them at the expense of others. Fourth, color-blind sentiments veil the reality of racism by attributing the problem to seeing difference rather than a system that denies racialized minority groups equitable access to political, economic, and sociocultural resources and benefits (Bell, 2002; Sleeter, 1993). Lastly, color-blind perspectives are predominantly held by White people and maintained by a system that privileges whiteness.
Closely associated with color-blindness is another resistance strategy frequently employed by White preservice teachers: their refusal to interrogate whiteness and the privileges associated with whiteness. According to Zeus Leonardo (2002), whiteness is a “racial perspective or worldview … supported by material practices and institutions” (p. 31). For many White preservice teachers, asking them to view themselves as racialized beings is difficult and foreign to them due to the degree that whiteness has become the norm by which difference is judged. Furthermore, the normalization of whiteness creates a system of inequity that bestows privileges and benefits to Whites. According to Leonardo (2002), whiteness has the following characteristics: “an unwillingness to name the contours of racism; the avoidance of identifying with racial experience or group; [and] the minimization of racist legacy” (p. 119). These characteristics are consistent with the findings of Kim Case and Annette Hemmings (2005) when they examined the beliefs of preservice teachers who took an anti-racist teacher education course aimed to raise awareness about critical consciousness and racism. The preservice teachers in their study enacted “distancing strategies” as a means of resistance by minimizing White privilege, engaging in victim blaming, and locating racism in the past rather than a contemporary and ongoing issue. This first set of resistance strategies – claiming color-blindness and refusing to interrogate whiteness – is inextricably linked to the second set of resistance strategies – asserting individualism and meritocracy in school and society.

**Individualism and Meritocracy**

Joe Feagin (2001) uses the term “sincere fictions” to refer to White Americans’ beliefs concerning the roles that individualism and meritocracy play in one’s social, political, and economic advancement. These beliefs are “sincere” because those who espouse them truly
believe they are color-blind, yet they are “fictions” because they ignore the realities of racism in North America. Put differently, these beliefs forward the notion that people, regardless of race, class, gender, or other markers of difference, can succeed if only they work hard enough. The mantra of “rugged individualism” has had great significance in North American history since the last part of the 19th century (McNamee & Miller, 2009). It values the traits of self-reliance and self-determination, and showcases hard working people who are rewarded for their perseverance. Consequently, people who are deemed lazy or unmotivated are responsible for their own failures. The belief that success is exclusively based on individual effort and hard work has been regarded as a myth because it fails to take into account the history and continuity of social, political, and economic mobility as bound to race, class, and gender. Or as Pearl Rosenberg (2004) states, the “ideology of equal opportunity and access obscures the actual unequal distribution of resources and outcomes for a variety of individuals based on social categories” (p. 259). Even so, beliefs adhering to individualism and meritocracy deeply permeate both American and Canadian consciousness (Carr & Lund, 2007).

In a study of 200 preservice teachers in two Canadian universities, Patrick Solomon and his colleagues (2005) found that beliefs adhering to individualism and meritocracy were a recurring form of resistance. In their study, participants were asked to read and respond to Peggy McIntosh’s article “White Privilege: Unpacking the Invisible Knapsack” (1990). The comments from the participants included reverse discrimination, the promise of hard work paying off, and blaming the victim for their lack of academic success. Solomon and his colleagues frame their resistance as a “discourse of denial” that is embedded in “ideological incongruence; liberalist notions of individualism and meritocracy; and negating White capital” (Solomon et al., 2005, p. 153). When confronted with issues of racism and whiteness and when asked to interrogate their
taken-for-granted privileges, many White preservice teachers became angry and frustrated. As a result, for these preservice teachers, race and racism “are regarded as realities and sites of contention that would best be addressed by ignoring it” (p. 161). While preservice teacher resistance to teacher education courses that focus on and/or integrate equity, diversity and multiculturalism is well documented in the scholarly literature, other scholars have referred to this type of critical, anti-oppressive teaching as unpredictable.

**Challenging Beliefs: An Unpredictable Endeavor**

The scholarly literature on the role and impact of teacher education courses that focus on equity, diversity, and multiculturalism is generally construed and divided into two major strands – between those that purport a positive change in preservice teacher beliefs and those that find no or negligible change in their beliefs. Underexplored is a third strand in the literature, which I will refer to as the “element of unpredictability” in challenging the beliefs and resistance of preservice teachers. In this section, I will outline Kevin Kumashiro’s (2000) theory of anti-oppressive education which can be used to address the knowledge, beliefs, and resistance of preservice teachers. Then, I will focus on Tara Goldstein’s (in press) pedagogy as a useful example of how to put Kumashiro’s theory to work as a teacher educator. While neither Kumashiro’s nor Goldstein’s article pertains specifically to science education, they both highlight the important and unpredictable nature of teaching for equity, diversity, and multiculturalism.
Theory of Anti-Oppressive Education

In his review of the scholarly literature on oppression, resistance, and education, Kumashiro (2000) offers a theory of anti-oppressive education. His theory draws from critical, feminist, queer, and multicultural perspectives, and highlights four distinct yet highly related approaches to conceptualizing and challenging different forms of oppression. Kumashiro posits that teachers should use a combination of the following four approaches: education for the Other; education about the Other; education that is critical of privileging and Othering; and, education that changes students and society (p. 25). For Kumashiro, the “Other” refers to those individuals and groups who have been traditionally marginalized in school and society based on their social identities, including Aboriginal and racialized minority students.

The first approach, education for the Other, is based on the premise that schools are harmful spaces to marginalized students. This can occur through harassment or exclusion, or through the inaction of teachers who are unsure or afraid of addressing racist and other discriminatory remarks. Hence, education for the Other aims to provide safe and affirming spaces for marginalized students, and calls on teachers to not only “acknowledge the diversity among their students, but also to embrace these differences and to treat their students as raced, gendered, sexualized, and classed individuals” (p. 28). In other words, teachers should see difference and act accordingly in response to difference.

The second approach to anti-oppressive education is education about the Other. Rather than focusing on how the Other is treated, this approach aims to disrupt harmful knowledges that have been transmitted about the Other in school and society. Of particular concern is knowledge that has been normalized and based on dominant ways of being. Teachers utilizing this approach include specific curricular units on the Other or “integrate Otherness throughout the curriculum”
Explicitly integrating the Other in a cross-curricular and ongoing manner can potentially remedy distorted and inaccurate knowledges about the Other, and can challenge the normativity of particular ways of being by normalizing differences.

The third approach to anti-oppressive education, education that is critical of privileging and Othering, examines and disrupts social structures and hierarchies that privilege some at the expense of Others. This approach “advocates a critique and transformation of hegemonic structures and ideologies” (p. 36) by requiring teachers and students to engage in analyzing oppression and how it is reinforced and maintained in school and society. Consciousness raising serves as the nucleus of this approach, whereby teachers learn how and why they have been oppressed as well as how and why they contribute and are complicit to the oppression of Others.

For the fourth approach of education that changes students and society, Kumashiro turns to insights from post-structuralism with its emphasis on discourse analysis. He suggests that oppression is produced by discourse, especially when certain discourses as ways of thinking that privilege certain identities and marginalize others are cited and repeated over and over. Kumashiro contends that anti-oppressive educators must “supplement” or alter the repetition of harmful citations, such as stereotypes, so the discourse that oppresses is fundamentally changed.

Kumashiro offers three other assertions about education that changes students and society. It involves self-reflexivity and personal change; crisis; and is an unknowable endeavor. Like Rodriguez’s (2005) theory of sociotransformative constructivism for ideological change, Kumashiro (2000) states that anti-oppressive education requires intense self-reflexivity. Students need to interrogate how they are implicated in dynamics of privilege and oppression, and then bring this knowledge and awareness “to bear on his or her own sense of self” in a way that “significantly change[es] how they see themselves and who they are” (p. 45). For many, this
process invokes crisis as students encounter learning that challenges their held beliefs. Crisis involves the emotive reactions that many have as they realize they contribute to and are implicated in multiple and overlapping systems of privilege and oppression. Lastly, Kumashiro posits that teaching involves unknowability, or the disconnect between what the teachers aim to deliver and what is received or learned by students. Anti-oppressive work must acknowledge this unknowable space between teachers and learners, and work within it to disrupt oppressive discourses.

**Element of Unpredictability**

Kumashiro contends that there is no single best approach to anti-oppressive education, and that teachers must be familiar with all four approaches and utilize a combination of them in their work. Tara Goldstein (in press) situates her work as a critical teacher education scholar and playwright in Kumashiro’s framework, and takes a novel approach to operationalizing the approach of education about the Other. Her work with preservice teachers highlights the crucial element of unpredictability in anti-oppressive education.

Responding to the persistent scholarly and professional calls for teachers to learn about the families and home lives of their students, Tara Goldstein (in press) utilizes performed ethnographies with her preservice teachers as a pedagogical tool to teach “about Other people’s families” (p. 1). She uses her plays, *Harriet’s House* (2012) and *Ana’s Shadow* (2012), to explore the lived experiences of transnational and transracial, adoptive, same-sex families. Both plays follow the lives of two sisters from Bogota, Colombia—Luisa and Ana—who were adopted by Harriet, a White, middle-class woman in Canada who comes out as a lesbian in mid-life. The older sister, Luisa, has a strong desire to learn about her birth family and the community
from which she comes, and hopes to return to Colombia and build a health clinic next to the orphanage where they lived. While Luisa expresses a strong connection to Colombia, Ana has no interest in returning or learning about her birth family. In her research on preservice teachers as they engaged with the two plays, Goldstein aims to examine how her plays can be used to disrupt negative, essentialized, and potentially detrimental knowledges that preservice teachers possess about students and families that are different from their own.

Mindful of Kumashiro’s (2000) critique that teaching about the Other may potentially present reductive narratives about the Other or position the Other as the expert, Goldstein had her preservice teachers read, perform, and reflect on the plays, and then had them respond to one of two open-ended prompts:

1. How does knowing something about Luisa, Ana and/or Clare’s family life help you as a teacher to engage or relate with them as students…? Be specific about one or two things you learned about the sisters’ family life and how your learning may help you work with them.
2. How would you create a lesson or set of lessons that would connect your curriculum to the world that Luisa, Ana, and/or Clare live in? (Goldstein, in press, p. 7)

When she assessed her preservice teachers’ journal entries, she responded with her own written comments and questions, some of which may act as “disruptive moves” (p. 19) to push them into deeper and more challenging levels of reflection. She analyzed for evidence that disrupted negative knowledge about Other families, and five themes emerged from her data: ideas about adoption; ideas about returning to Colombia; ideas about engaging with students’ family lives; writing about ethnicity, culture and health; and not writing about sexuality.

Goldstein’s analysis of her preservice teachers’ journal entries revealed a mix of findings. For some preservice teachers, the plays Harriet’s House and Ana’s Shadow worked against dominant narratives about the Other. However, for others, there was no evidence that the plays had a disruptive or challenging effect. Her analysis further reveals that some preservice teachers
were selective in what issues they elected to write about and how they wrote about them. She concluded that their personal experiences and beliefs played a strong role in how they responded in their journals. For example, one participant shared an experience he had as an adolescent and used it to rationalize his beliefs about teenagers. Drawing on his own experience as a student who kept quiet about his illness, he generalized that all teenagers (including Luisa and Ana) would have similar feelings about keeping silent about their adoptive past and home life. He used his personal experiences and beliefs to justify why he would choose to not learn about and respond to his students’ home lives. Ultimately, Goldstein contends that

the most compelling finding is that work that the plays do is unpredictable. While my work with plays sometimes provokes thoughtful reflection on my students’ own experiences and their future teaching practice, they do not always disrupt the prior knowledges teachers bring with them to teaching. (p. 22)

She argues that while anti-oppressive efforts, especially challenging preservice teachers’ beliefs, are a “complicated endeavor” (p. 4), it is important ongoing work that teacher educators must take up.

In the previous two sections, I addressed the strategies of resistance that preservice teachers utilize to resist changes to their beliefs, such as their claim of color-blindness and refusal to interrogate whiteness, and their assertions of individual responsibility and the meritocratic foundation of school and society. Then I examined the element of unpredictability in challenging preservice teachers’ beliefs by using Kumashiro’s theory of anti-oppressive education in general and Goldstein’s pedagogical example of using her plays in particular. In the next section, I will review scholarly studies that examine preservice teacher beliefs specifically about science knowledge and teaching and how to impact and change them.
Impacting Preservice Teachers’ Beliefs about Science

There are few studies that examine how a science course with a focus on equity, diversity, and multiculturalism impacts preservice teachers’ beliefs. This body of scholarship generally pertains to feminist critiques of the nature of science and to shifting preservice teachers’ deficit beliefs about working with racialized minority students. For example, Gail Richmond and her colleagues (1998) utilize feminist frameworks to challenge their elementary and secondary preservice teachers’ beliefs about the nature of science. They urge their students to consider the implications of an androgenic epistemology underpinning science and to consider science as a social enterprise that has alienated many females and racialized minority students. They also challenged them to consider alternative pedagogies to make science relevant to diverse students. Yet, in spite of their efforts, they found preservice teachers to be resistant to feminist critiques of science.

For example, Sherry Southerland and Julie Gess-Newsome (1999) examine elementary preservice teachers’ beliefs about inclusive science teaching; that is, science instruction that is “accessible to all individuals regardless of gender, ethnicity, culture, economic circumstance, background, primary language, disability, future aspirations or current motivations” (p. 132). They find that their participants possess positivistic beliefs about scientific knowledge, teaching and learning and that these beliefs undermine the goals of inclusion and equity. Therefore, they recommend that science teacher educators pay more attention to teaching the nature of science and provide preservice teachers with ample opportunities for critical reflection.

Julie Bianchini and her colleagues (2003) investigate how twelve secondary preservice science teachers’ views shifted concerning equitable educational practices and their conceptions of “contemporary descriptions of science” during one science methods course. By contemporary
descriptions of science, they refer to a critical understanding of the nature of science or that science is a human activity, practiced in various ways by different cultural groups and influenced by broader societal contexts. They argue that teaching science in equitable and contemporary ways are inextricably connected, and that neither can be achieved singularly. In the science methods course, the activities focus on three themes: who scientists are; how science is practiced; and how science is situated in social, cultural and political contexts. Preservice teachers read science studies scholarship reflecting feminist, multicultural, and anti-racist perspectives; examine historical and contemporary issues pertaining to science and scientists (e.g., Galileo and Newton, and the bombing of Japan during WWII); interrogate common myths about science held by teachers and students; view a video about gender and science; and visit a breast implant facility. They also engage in writing exercises that further push them to examine their own views about the nature of science and equitable science instruction.

Bianchini and her colleagues examine preservice teachers’ conceptions of each course theme, their rationales for teaching that theme to secondary students, and their proposed instructional strategies to do so. Furthermore, they analyze preservice teachers’ instructional suggestions for their potential to convey science in an equitable way, that is, teach “science to all students” (Bianchini et al., 2003, p. 260). Their study, ultimately, generated two important findings. First, change in preservice beliefs about the nature of science is possible. Although the researchers do not use quantitative measures, they state that “some” preservice teachers made great strides in their beliefs and conceptions about the nature of science and equitable teaching practices. Second, they evaluate the data for each participant to ascertain whether or not their responses indicate a “connection” across their conceptions, rationales, and strategies. For example, one participant indicates that there is a need to encourage more students to participate
in science (rationale); however, he holds very narrow beliefs about who should count as a scientist (conception). This indicates a disconnect or lack of coherence between his conception, rationale, and strategy. Of the twelve participants, only one preservice teacher holds views that “clearly aligned to nature of science descriptions and equity concerns presented in the preservice course” (p. 276). In other words, this participant demonstrates beliefs that indicate strong connections among all three categories. In the end, Bianchini and her colleagues suggest that science teacher educators need to: provide preservice teachers with opportunities for ongoing reflection; make explicit the connections among contemporary views of science, the rationales for teaching it, and designing equitable lessons; and model this process for preservice teachers.

In the field of elementary science education, there has been a recent and growing scholarly interest to investigate preservice teacher beliefs about working with diverse student populations. Of particular importance are the often unexamined and hidden stereotypes, biases, and other deficit beliefs that preservice teachers have about racialized minority students.

Felicia Moore Mensah (2009) implements a book club in her elementary science methods course with her predominantly White preservice teachers to challenge their cultural biases, assumptions, and stereotypes about racialized minority students. She selects the book club pedagogy because it has been scantly used in science education, particularly for responding to issues of equity, diversity, and multiculturalism. Her book club, which takes place during three class sessions of a semester-long science methods course, focuses on Shirley Brice Heath’s *Ways with Words: Language, Life, and Work in Communities and Classrooms* (Heath, 1983). Heath’s ethnography describes three communities in the desegregated South of the United States from 1969 to 1978: a Black, working-class community; a White, working-class community; and a Black and White middle-class community. Mensah uses this book for its potential to offer cross-
cultural immersion into diversity and its explicit connection to culturally relevant science pedagogy.

Mensah elaborates on three types of learning that are integral for fostering critical, reflective inquiry and effecting ideological change concerning diversity in urban science education. Preservice teachers need to be engaged in a continual process of individual, collaborative, and collective learning. Individually, each participant is responsible for reading the text prior to the book club meeting. During the book club, preservice teachers engage in collaborative learning by discussing the writing prompts in small groups. The prompts are open-ended and designed to elicit critical reflection by asking them to make personal and professional connections to the book and their future students. At the end of the book club session, they engage in collective learning as each group shares “something that was interesting from the small group discussion that you want to share with the whole group” (Mensah, 2009, p. 1047). During the final session, small groups share their learning from the book club experience. According to Mensah, the book club format facilitates cycles of individual, collaborative, and collective group learning that serve as a catalyst for belief change. The book club format with these cycles of learning allows preservice teachers to uncover and confront their deficit beliefs about students from racialized minority and low socioeconomic backgrounds. Preservice teachers are able to think deeply about the roles of language, culture, and race in science teaching, learning, and assessment, and the science pedagogical practices that will meet the needs of diverse student populations.

Inspired by and building upon the increasing scholarly interest in juxtaposing elementary science education with equity, diversity, and multiculturalism, I will now elaborate on my notion of teaching science for social justice that draws from my review of the extant scholarly literature.
Teaching Science for Social Justice

William Tate (2001) contends that a rigorous and relevant science education is a “civil right” that should be accessible to every student. To increase the academic achievement of Aboriginal and racialized minority students who continue to be marginalized in science, scholars have demanded the integration of social justice in science education (Aikenhead & Michell, 2011; Calabrese-Barton, 2003). I conceptualize teaching science for social justice as consisting of three separate, but highly interrelated areas of study: critical nature of science; critical knowledge and pedagogy; and teaching for sociopolitical action. The heuristic diagram below (Figure 2.1) depicts the three dimensions of teaching science for social justice.

Figure 2.1. Three Dimensions of Teaching Science for Social Justice
Critical Nature of Science

The overarching objective of science education is scientific literacy. Although scientific literacy has been deemed as an “ill-defined and diffuse concept” (Laugksch, 2000, p. 71), I define it through the lens of social justice as an understanding of: 1) science content knowledge; 2) science methods, processes, and norms; 3) the impact of science on individuals and society; and 4) the preparation of students for sociopolitical action (Hodson, 2008; Miller, 1983). Conceptualizing and teaching scientific literacy in this manner will equip teachers and students to be social justice oriented citizens who are prepared to challenge school and societal inequities that contribute to the persistent academic underachievement for Aboriginal and racialized minority students.

There is a consensus among science education scholars that understanding the nature of science (NOS) is necessary for scientific literacy (Abd-El-Khalick, 2005; Lederman et al., 2002). NOS is a dynamic area that draws from the history, philosophy, and sociology of science. It has four components: the epistemology of science, or science as a way of knowing; the values and beliefs inherent to scientific knowledge and development; the justification and evolution of scientific knowledge; and the social, political, economic, and moral dilemmas posed by science (Lederman, 1992; Osborne et al., 2003). NOS encourages the interrogation of the epistemic foundations of Western science as well as the values, motives, and ideologies within the field. Studies have demonstrated that students, teachers, and the general public have inaccurate understandings of NOS, which result to low levels of scientific literacy (Abd-El-Khalick & Lederman, 2000).

Critical NOS scholars counter the dominant view of Western science as objective, factual, and evidence-based. They claim that Western science is grounded in a positivist
epistemology which foregrounds careful empirical inquiry to generate theories that explain the “truth” about the natural world (Hodson, 2008). This positivism also views an external reality that can be veraciously studied by dispassionate and value-free researchers. Since Western science is generally depicted as rigorous and objective, it is considered more valid than and superior to other forms of knowledge. On the contrary, critical NOS scholars situate science as a sociopolitical practice that is subjective and value-laden. They pose questions such as: Who does science? What kind of science gets done? Who funds it and for what purpose? Who benefits from scientific advances, and who loses? Whose perspectives and worldviews are present in science and curriculum, and whose are marginalized? What are the dominant beliefs and ideologies in a given society? What current sociopolitical and historical events shape science? For critical NOS scholars, scientific knowledge and epistemology are impacted by individual and community beliefs, values, and norms—all of which influence science. Science does not occur in a vacuum; rather, it reflects not only those who practice it, but also the dominant ideologies of society.

Some scholars have argued that challenging the dominant views of the nature of science is necessary to increase the interest and achievement of Aboriginal and racialized minority students (Hodson & Dennick, 1994; Richmond et al., 1998). Drawing on feminist scholarship, Nancy Brickhouse (1994) urges teachers and students to engage in a critical analysis of the nature of science in order to expose the “human element” of science (p. 406). She positions “women and minority groups [as] outsiders” (p. 403) who have been excluded from Western science because it “serves the interests of an undemocratic, technocratic elite” (p. 404), representing and reinforcing the cultures, beliefs, and values of the community of science who created it—White, middle-class men. Sandra Harding (1991) challenges such an androcentric
epistemology of science, and argues that scientists have made a preposterous claim that they “could tell the one true story about the world that is out there, readymade for their reporting, without listening to women’s accounts or being aware that accounts of nature and social relations have been constructed within men’s control of gender relations” (p. 141). Brickhouse, consequently, urges for the reform of science curriculum to address the following issues: the treatment of women and racialized minorities in scientific institutions; the failure of scientists to address the issues and concerns of women and racialized minorities; how women and racialized minorities have been victimized by science; the sexist language in science; scientists’ failure to adhere to their own standards of justification, consequently producing sexist and racist theories; and the androcentric epistemology of science. Brickhouse contends that such a transformation of the science curriculum “educates students not only in science, but about science” (p. 405). Students, therefore, learn the dominant canon of scientific knowledge, and learn how to evaluate and critique knowledge claims made by scientists.

While Brickhouse (1994) urges for a critical analysis of the nature of science, Gloria Snively and John Corsiglia (2001) take what some scholars call a “radical constructivist” approach to science education reform (Matthews, 1994; Cobern & Loving, 2000). They argue that traditional ecological knowledge (TEK), or the knowledge acquired by indigenous communities due to direct contact with the environment over millennia, is equally valid to the dominant canon of scientific knowledge. Snively and Corsiglia assert that Western modern science (WMS) acts as a gatekeeper for determining what should be included in school curriculum. In other words, WMS’s hegemonic power dismisses indigenous knowledge, and maintains a myopic focus on what is considered science.
Snively and Corsiglia (2001) contend that, since WMS is implicated in many of the world’s ecological disasters and because the “traditional wisdom of TEK is particularly rich in time-tested approaches that foster sustainability and environmental integrity, it is possible that [this] universalist gatekeeper can be seen as increasingly problematic and even counter productive” in contemporary life and wellbeing (p. 6). Hence, they advocate for a cross-cultural perspective to science education that aims to replace some of the canonical knowledge from Western modern science with indigenous concepts and practices from traditional ecological knowledge.

Teaching science for social justice, therefore, requires that teachers and students possess a critical perspective of NOS. Insights from history, philosophy, and sociology of science challenge the dominant narrative of science as neutral, and expose a value-laden practice that has been used to marginalize Aboriginal and racialized minorities, for instance, through scientific racisms. I contend that historical and contemporary acts of injustice should be examined in science to develop in students a critical form of scientific literacy, and subsequently, academic achievement.

**Critical Knowledge and Pedagogy**

Critical science education scholars argue that students’ scientific literacy needs to be linked to their cultures and worldviews (Cobern, 1996). They encourage teachers to build upon their students’ funds of knowledge whereby home and community ideas and practices are utilized as assets and resources for teaching and learning. Working against the deficit approach to teaching Aboriginal and racialized minority students, they find students becoming more engaged and performing better academically through culturally responsive and relevant
pedagogy (Gay, 2000; Ladson-Billings, 1994; Lee & Fradd, 1998). I will highlight scholarly examples on the inter-connection of power and knowledge and the use of culturally congruent instruction to increase student engagement and achievement.

Since Western science remains dominant and hegemonic in school and society, Aboriginal knowledge, cultures, and worldviews have been regarded as “primitive and illegitimate. This condition has led many Aboriginal students to view science as a “foreign culture” and antagonistic towards their way of viewing the natural world (Aikenhead & Jegede, 1999). It is buttressed by mainstream teaching which forces Aboriginal students to enact a form of “cultural border crossing” because it disregards their cultural ontologies and epistemologies. Therefore, for Aboriginal students to become successful in science, Glen Aikenhead and Herman Michell (2011) argue that teachers must build cultural bridges that present science as a combination of both Aboriginal and Western knowledge systems.

Aikenhead and Michell’s (2011) stance resonates with that of critical teacher educator Lisa Delpit (2006) who indicates that mainstream teaching and curriculum has failed to acknowledge that numerous “valid worldviews exist” (p. 151). In her work with African American students, she maintains that schools have functioned to “destroy the heritage, the essence of who and what we are, [and] to destroy their knowledge of themselves” (p. 78). In order to increase the academic engagement and performance and to meet the sociocultural needs of racialized minority students, Delpit argues that teachers must do two things. First, they must possess high expectations and teach the dominant canon of knowledge so that racialized minority students can think critically, compete academically, and be empowered to incite social change. Second, this must be done in a way that does not come at the expense of racialized minority students’ cultural heritages.
Delpit’s argument aligns with that of Annamarie Hatcher and her colleagues (2009) who contend that teachers can bridge Western and Aboriginal scientific ways of knowing through “two-eyed seeing.” Two-eyed seeing is “to see from one eye with the strengths of indigenous ways of knowing, and from the other eye with the strengths of Western ways of knowing, and to use both of these eyes together” (p. 146). Put differently, two-eyed seeing aims to integrate Western and Aboriginal worldviews in a way that recognizes the best from both perspectives. Two-eyed seeing requires teachers to have a strong knowledge of science content as well as the cultural knowledges of their students and other diverse knowledge systems. Ultimately, through this hybrid approach, Aboriginal students “gain cultural capital essential for accessing power as citizens in a Eurocentric dominated world while maintaining their roots in an indigenous wisdom tradition” (Aikenhead & Elliot, 2010, p. 326).

Another effective strategy to bridge science with students’ home cultures and communities is what Eileen Parsons (2008) calls culturally congruent science instruction (CCSI). For Parsons, CCSI is based on Black Cultural Ethos, which purports that African Americans have “a dynamic repertoire” of beliefs, values, traditions, experiences, and practices that are developed through “prolonged participation in cultural communities” and that characterize how they perceive and interact with the world (p. 666). She highlights, in particular, social perspective of time, verve, and rhythmic movement expressiveness as key dimensions of Black Cultural Ethos. In her study of three eighth-grade classes, students who received CCSI demonstrated significant improvement on their achievement tests, while those without CCSI intervention showed a decrease in scores. A further example of addressing the mismatch between school and home/community is what Christopher Emdin (2011) calls reality pedagogy for the hip-hop generation. This form of pedagogy “values who you are, embraces where you came
from, and teaches what has been described as the most challenging subject matter in a way that is engaging, respectful of your culture, and aligned to the way that you see the world” (p. xi). Since hip-hop culture is the reality of today’s urban youth and has its own ways of being and making sense of the world, Emdin urges science teachers to integrate their students’ social realities into curriculum and pedagogy as a way to increase urban students’ science engagement and academic achievement.

The examples above demonstrate that teaching science for social justice requires knowledge of both scientific content and processes as well as student and community cultures. They also reveal that pedagogy which promotes academic achievement includes making science relevant, integrating diverse worldviews, and empowering students. Consequently, teaching science for social justice is activist-oriented and geared toward sociopolitical action.

**Sociopolitical Action**

Critical science scholars argue that doing science can be liberatory for Aboriginal and racialized minority students (Calabrese-Barton, 2003). Sociopolitical science teaching is based on the premise that mainstream science curriculum and instruction reinforces unequal power relations deeply rooted in society. To counter this, scholars advocate for science experiences that develop student agency. Derek Hodson argues for the “politicizing [of] the science curriculum,” and outlines four levels of learning for developing student agency:

*Level 1:* Appreciating the societal impact of scientific and technological change, and recognizing that science and technology are, to some extent, culturally determined.

*Level 2:* Recognizing that decisions about scientific and technological development are taken in pursuit of particular interests, and that benefits accruing to some may be at the expense of others. Recognizing that scientific and technological development are inextricably linked with the distribution of wealth and power.

*Level 3:* Developing one’s own views and establishing one’s own underlying value positions.
Level 4: Preparing for and taking action. (Hodson, 2001, p. 119)

My review of the literature indicates that the vast majority of studies which reflect science teaching for sociopolitical action are geared towards low-income and racialized minority students, are located in urban ecologies, and pertain to community-based concerns (Endreny, 2010; Fusco, 2001). Since sociopolitical science teaching centers on student empowerment and agency, I will highlight two exemplar studies that demonstrate Hodson’s (2001) Level 4 in which students take action concerning local sociopolitical issues.

Angela Calabrese-Barton and Edna Tan’s (2010) study demonstrates how 20 middle school students in an informal community-based learning setting positioned themselves as “community science experts.” The youth assess whether or not their city in Michigan is an urban heat island (UHI). Heat islands occur when urban areas retain energy as a result of infrastructures like buildings and roads, making them warmer than surrounding areas. Detrimental effects of heat islands include increased energy consumption and elevated emissions of air pollutants and greenhouse gases. Students collect community data using video cameras, laser measuring tapes, digital cameras, and thermometers, and create 10-minute documentaries concerning the effects of UHI. Rather than mere recipients, students become both critics and producers of science. Asserting a community science expert identity allows students to become both knowledgeable of the content and take action based on that knowledge.

Teachers of science can also build on their students’ emotional attachments to their local communities to develop a “critical pedagogy of place” (Gruenewald, 2003). In other words, place-based inquiry is a powerful conduit for empowering youth to contest environmental degradation in their neighborhoods. Place-based education seeks to understand how human and natural environments shape each other. For youth growing up in urban, high poverty
neighborhoods, place defines “who [students] are and how they value what matters in science and for the community” (Aikenhead et al., 2006, p. 403). Furthermore, teaching for sociopolitical action involves an understanding of the complex interactions between science content, identity, culture, social position, and geography. An example that highlights the agentic potential of place-based learning is Lisa Bouillion and Louis Gomez’s (2001) community riverbank monitoring project. This study demonstrates the power of “connected science [or]…where real-world problems and school-community partnerships are used as contextual scaffolds for bridging students’ community-based knowledge and school-based knowledge” (p. 878). Such an approach builds upon students’ personal funds of knowledge and engages them in sociopolitical action. Students reach out to organizations, such as the Chicago Academy of Sciences and the Illinois Nature Conservancy, to help them rid their local riverbank of garbage and to promote the health of the ecosystem. They conduct water testing, draft a conservancy plan, and educate the community about the health of the riverbank. They also engage in a letter-writing campaign that successfully convinces the city government to help clear garbage.

These two examples depict how teaching science for sociopolitical action can empower racialized minority youth to make positive changes in their communities. Science education that engages the cultural capital and interests of urban, low-income, racialized minority students not only enables them to become producers and critics of knowledge, but also has the potential to increase both their critical and conventional scientific literacy and achievement in science.

The next section outlines what I am calling a “Critical – Cultural Theoretical Framework” for teaching science of social justice, which draws from my analysis of the scholarly literature on equity, diversity, and multiculturalism and which strongly informs the
focus and format of my elementary science methods course, which I will discuss more in detail in Chapter 3.

**Critical – Cultural Theoretical Framework**

Science education is located within the broader field of curriculum studies. I understand curriculum as a set of beliefs, knowledges, pedagogies, and outcomes in the dynamics of teaching and learning in particular sociohistorical contexts. My proposed research draws on what I am calling a critical – cultural framework of curriculum theorizing. This theoretical framework is most aligned to my study, and was used to inform the development and teaching of the elementary science methods course and analysis that is featured in my thesis study. In this section, I will elaborate on the intellectual underpinnings of the critical – cultural framework and its role in school and society.

Critical – cultural scholars foreground issues of power, oppression, culture, and identity. To address the goal of dismantling structural inequities such as academic achievement gaps, I draw from the works of Michael Apple (2004) and Yatta Kanu (2006). Apple asserts that curriculum is inherently political and that schools are oppressive to non-dominant communities because they reproduce the values, norms, and knowledges of dominant groups, namely those who are White, middle class, heterosexual, and male. Refuting the myth that education acts as the “great equalizer” (Mann, 1848), Apple contends that curriculum is a cultural product that reflects, reinforces, and benefits those in power. To disrupt the reproduction of dominant ideologies, Kanu (2006) proposes the notion of “curriculum as cultural practice.” She argues that culture or the “beliefs, values, and meanings on which different groups draw to make sense of their world” must be at the nexus of curriculum theorizing (p. 4). Like Apple, Kanu posits that
curriculum embodies the values and ideologies of dominant Western culture. Curriculum is much more than content standards or instructional strategies; rather, it also includes practices and ways of doing that are enacted on a daily basis. Hegemonic curriculum practice foregrounds a Eurocentric curriculum that is underpinned by a White supremacist view of Aboriginal and racialized minorities as primitive and inferior, and a civilizing mission to assimilate them into what is deemed as idealized norms. Combined, Apple’s and Kanu’s insights challenge curriculum norms, and form the foundations of the critical – cultural science curriculum for my proposed study.

The critical – cultural theoretical framework is underpinned by multiple strands of thought. Three strands that are relevant to this study are critical pedagogy, critical multiculturalism, and anti-colonial theory. Each strand in my critical – cultural framework is connected to and informs a particular dimension in my model of teaching science for social justice (see Figure 2.2). The three strands are distinct, but highly interrelated whose combined goal, I argue, is to promote critical teachers who challenge and work to reconfigure inequitable systems of power (Freire, 1970). I suggest that these three strands have the potential to increase Aboriginal and racialized minority students’ science participation and achievement. Next, I will highlight each strand and then show how they work in complementary ways to inform the critical – cultural theoretical framework.
Critical Pedagogy

Critical pedagogy is based on the premise that schools are political sites where curriculum, pedagogy, and policy act in the interests of dominant groups while marginalizing non-dominant groups. It urges teachers and students to examine the effects of power, and seeks to dismantle inequities in educational spaces. The most notable scholar in the field of critical pedagogy is Paulo Freire (1970). Freire argues that teachers and students must develop conscientization or a critical awareness of one’s social reality. He contends that critical consciousness would empower oppressed persons to engage in the ultimate goal of education—praxis, a combined reflection-and-action aimed at transforming individuals and their world. For those who belong in dominant groups, praxis requires them to unpack their own biases and
stereotypes and to examine their complicity in a system that serves their interests at the expense of others.

Freire (1970) denounces the “banking model” of education, which privileges a teacher-centered and content-driven form of pedagogy and positions students as empty vessels to be filled. He works against this banking model because it “transforms students into receiving objects. It attempts to control thinking and action, leads men and women to adjust to the world, and inhibits their creative power” (p. 77). He proposes the reconfiguration of the traditional teacher-student hierarchy by situating teachers and students as co-constructors of knowledge. Accordingly, the teacher becomes the student and the student becomes the teacher, thereby minimizing the hierarchy of power between the two entities. To do this, Freire stresses problem posing and dialogue as pedagogical techniques. Dialogue presupposes mutual respect, and allows teachers and students to become partners in the quest for knowledge as they question, analyze, reflect, and solve problems together.

Critical Multiculturalism

Numerous forms of multicultural education have been referenced in the scholarly literature (Kincheloe & Steinburg, 1997). On the one hand, efforts to include multicultural education in school curriculum often take the form of liberal multiculturalism. Liberal multiculturalism aims to provide dominant groups with cultural understanding, tolerance, and respect for non-dominant groups, but ignores issues of cultural, political, and economic inequities. According to political philosopher Will Kymlicka (2010), liberal multiculturalism can be characterized as “a feel-good celebration of ethno-cultural diversity, encouraging citizens to acknowledge and embrace the panoply of customs, traditions, music, and cuisine that exists in a
multi-ethnic society” (p. 33). Such efforts of learning about the Other often promote an essentialized and superficial rendering of culture (Kumashiro, 2000). A simplistic study of “sarís, samosas, and steel drums” (Alibhai-Brown, 2000) presents culture as static, and does not take into consideration the meanings behind cultural expressions or the values and power relationships that mold them. This liberal approach to multiculturalism may promote a superficial understanding of non-dominant cultures, but does little to examine and challenge issues of power, privilege, and oppression.

On the other hand, critical multiculturalism entails a transformative agenda that seeks equity and social justice for all marginalized groups (May & Sleeter, 2010). It “addresses the histories and experiences of people who have been left out of the curriculum” (Miner, 1995, p. 9). Critical multiculturalism not only promotes intercultural respect, but also interrogates issues of individual and systemic discrimination, considers the political and social histories and contexts of marginalized groups, and undertakes an analysis of power relations. According to Peter McLaren (2003), students must understand how “social relationships are distorted and manipulated by relations of power and privilege” (p. 73). Critical multiculturalists see culture as complex, dynamic, intersecting, and flexible, yet still find ways to make their instruction culturally relevant and responsive (Gay, 2000; Ladson-Billings, 1994).

**Anti-Colonial Theory**

Anti-colonial theory is concerned with epistemic oppression that indigenous and Aboriginal communities endure as Western epistemology acts as a tool of hegemony in the guise of “official knowledge” (Apple, 2004). Anti-colonial theory draws from and highlights de-colonizing and anti-racist frameworks (Dei & Kemp, 2006; Dion, 2007, 2009). It seeks to
scrutinize and resist dominant discourses, and “works with the idea of epistemological power of the colonized subjects” (Dei & Kemp, 2006, p. 3). Anti-colonial theory asserts that indigenous epistemologies and ways of knowing are of equal value to Western ways of knowing and should be treated as such when curriculum is developed.

A main goal of anti-colonial theory is to “subvert dominant thinking and re-inscribe colonial and colonizing relations … by challenging the power relations of knowledge production” (Dei & Kemp, 2006, p. 3). Knowledge is of particular interest in anti-colonial theory because Western concepts and ways of knowing have been privileged at the detriment of indigenous knowledge and worldviews. Anti-colonialism resists Western theorizing as the norm by which other knowledges are compared, and advocates that alternative epistemologies be considered valuable (Dion, 2007, 2009). Although critical pedagogy and critical multiculturalism aim to interrogate and interrupt the hegemony of Western knowledge, they fall short in theorizing paradigms that place non-Western knowledge front and center in the curriculum. Anti-colonial theory addresses this gap well by highlighting Aboriginal knowledges and epistemologies, especially in the context of White settler nation-states like Canada.

Common Ground

In spite of their differences, the three strands of the critical – cultural framework have converging interests. They seek to challenge and re-imagine what has been normalized as knowledge of most worth, its corresponding pedagogical practices, and ultimately the goals of education—all of which can have a profound impact on the science participation and achievement of Aboriginal and racialized minority youth. Together these comprise my proposed theoretical framework that is aligned with the three dimensions of teaching science for social
justice (see Figure 2.2). It must be noted that these strand-dimension relationships are not completely exclusive and that strands relate to other dimensions and to each other. However, for heuristic purposes, I will showcase particular alignments.

The anti-colonial strand is aligned with the critical nature of science dimension because it challenges the epistemic origins of knowledge as produced by those with power in society. Consequently, it questions the nature of truth, objectivity, and validity, and recognizes that Aboriginal and racial minority groups have diverse ways of knowing that have been excluded from the dominant canon.

The critical multiculturalism strand is aligned with the critical knowledge and pedagogy dimension since it challenges the hegemony of “official knowledge” as common sense, and understands knowledge itself as a product of cultural, political, and economic struggles between dominant and non-dominant groups. It also challenges content- and teacher-centered pedagogies, and understands that students’ funds of knowledge, lived experiences, ways of knowing, and social realities must be incorporated into the curriculum. Pedagogically, I am suggesting a strategic balance between Western and non-Western forms of knowledge. Rather than envisioning them as antagonistic, I am promoting a hybrid of de-colonizing pedagogies that challenge the dominant conception of knowledge and culturally relevant pedagogies that make Western knowledge meaningful to diverse students. For science, there is potential in drawing from both Aboriginal and Western knowledge systems and exploring the interface between them (Delpit, 2006; Hatcher et al., 2009).

The critical pedagogy strand is aligned with the dimension of teaching for sociopolitical action because both are action-oriented and seek to empower marginalized youth to engage in sociopolitical activity. Traditionally, Aboriginal and racialized minority students have been
alienated from the science community of practice (Gess-Newsome & Lederman, 1999). Teaching science for social justice, therefore, provides students with opportunities to become producers and critics of scientific knowledge because it focuses on issues that are relevant to them. Foregrounding sociopolitical issues in science increases student engagement and achievement, and provides opportunities for the development and expression of student agency.

**Conclusion**

My thesis study responds to the unfulfilled promise of the *science for all* agenda that has been prevalent in science education circles for the past 30 years. Numerous research studies as well as formal assessment results indicate that many Aboriginal, Black, and Latino/a students are disengaging from school science and attaining low levels of science academic achievement. I contend that, for widespread and continued science reform to occur, the catalyst must be in preservice teacher education. Since there is a general scholarly consensus that beliefs are a strong indication of potential action, I am interested in examining preservice teachers’ beliefs about teaching science for social justice. Such a stance to teaching and learning will engage preservice teachers with the three dimensions of teaching science for social justice: critical analysis of the nature of science; critical knowledge and pedagogy; and sociopolitical action. Combined, I argue that these dimensions have the potential to enable preservice teachers to meet the needs of students who have been alienated from science education.

In my review of the relevant scholarly literature, I began by outlining the nature of beliefs and the various theories of belief change. Since many preservice teachers come into teacher education possessing deficit, stereotypical, and even harmful beliefs about Aboriginal and racialized minority students, teacher educators have focused on shifting beliefs that undermine
equity efforts. However, preservice teachers hold on tightly to their beliefs when they are challenged. For example, they enact various strategies of resistance when confronted with issues of diversity, equity, and multiculturalism. They claim to be color-blind, or state that racism is a historical rather than an ongoing and contemporary phenomenon. They also argue that marginalized individuals should work harder to better their circumstances. In response to preservice teacher resistance, teacher educators have mobilized various theoretical and pedagogical frameworks, such as anti-oppressive education. Yet, it must be noted that an element of unpredictability is inherent in challenging and changing preservice teachers’ beliefs about equity, diversity, and multiculturalism.

Research indicates that even one teacher education course on equity, diversity, and multiculturalism can have a positive impact on preservice teacher beliefs. In the field of science education, a couple of examples stand out for their relevant pedagogical insights. Mensah (2009) established a book club with her elementary preservice teachers where they engaged in individual, collaborative, and collective learning experiences that uncovered, challenged, and changed their negative and deficit beliefs about racialized minority children. Bianchini and her colleagues (2003) expanded their secondary preservice teachers’ beliefs about the nature of science by incorporating feminist, anti-racist, and multicultural scholarship into their science methods course. My study seeks to build upon and extend the body of scholarship already established concerning elementary preservice teachers’ beliefs on science and social justice education.

First, I engage in this literature through my analysis and juxtaposition of the scholarship in science education and social justice education, which I subsequently used as the conceptual foundation for my science methods course (which is further detailed in Chapter 3). I posit that
teaching science for social justice requires addressing three separate, but highly interrelated dimensions within a critical – cultural theoretical framework. While a critical analysis of the nature of science is essential (Bianchini et al., 2003), so is preparing preservice teachers with critical knowledge and pedagogy and enabling them (and their future students) to take action on important socioscientific issues. Therefore, all three dimensions within the critical – cultural framework must be addressed in order to fully enact teaching science for social justice.

Second, I engage in the scholarly literature on belief change and teacher education by pursuing a line of inquiry that identifies the “starting” and “end” points of preservice teachers’ beliefs in an elementary science methods course as well as the pedagogical choices that facilitate their belief change. I intend to track the processes and conditions of their shift in beliefs. By determining the pedagogical choices in a science methods course that either promote or constrain change in beliefs, such information can be potentially valuable for other teacher educators who strive to prepare a mainly White preservice teaching force to teach science effectively to Aboriginal and racialized minority students.
CHAPTER 3
RESEARCH METHODOLOGY

In this chapter, I will delineate the methodological design for this research project. First, I will highlight my three central research questions and provide a rationale for my use of qualitative research. Second, I will elaborate on the use of a constructivist grounded theory approach to qualitative inquiry and how it is an appropriate methodology for this study. I will also explain the research context which includes a brief description of the “Science and Technology Education for Elementary School Teaching” (EDU 1450) course featured in this study as well as the profiles of the 11 participants and their corresponding elementary options. Third, I will describe the three primary qualitative methods of data collection. Fourth, I will put constructivist grounded theory to work and detail how I analyzed participant data. Lastly, I will explain how I attempted to ensure validity in this study as well as ethical considerations and limitations.

For this research project, I examined elementary preservice teachers’ beliefs about equity, diversity, and multiculturalism as they engaged in a science methods course with a social justice focus. The course aimed to prepare preservice teachers to effectively teach science to diverse student populations, particularly since research suggests that many Aboriginal, Black, and Latino/a students disengage from school science. The following three research questions guided my research project:

1. What are preservice teachers’ initial beliefs about teaching science for social justice?
2. How do their beliefs about teaching science for social justice shift (if at all) during the course?
3. How do the pedagogical choices made in the course by the teacher educator impact their beliefs about teaching science for social justice?

To answer these questions, I selected a constructivist grounded theory (CGT) approach to qualitative inquiry to examine elementary preservice teachers’ beliefs. Since one of the key philosophical assumptions of qualitative research is that individuals construct their reality as they interact with their social worlds (Merriam, 1998), my work aimed to understand and analyze how preservice teachers made sense of their experiences in the course and how these experiences impacted their beliefs about teaching science for social justice.

Qualitative research intends to “understand situations in their uniqueness as part of a particular context and the interactions there” (Patton, 1990, p. 1). Since qualitative research focuses on “discovery, insight, and understanding from the perspectives of those being studied” (Merriam, 1998, p. 1), it is suitable for a research project with a small number of participants, such as the one I embarked on. However, this type of research requires long-term immersion in a particular setting in order to access nuanced details that can provide multi-dimensionality in the studied phenomenon. These combined characteristics position qualitative research, according to Sharan Merriam (1998), as offering the “greatest promise of making significant contributions to the knowledge base and practice of education” (p. 3).

Although I was both the course instructor and the researcher, this project was not a self-study. My goal was not to focus on myself and my teaching alone. Rather, I intended to better understand the process and practices that preservice teachers undergo as they engage in a science for social justice course and the impact (if any) that the course content and pedagogy may have on their beliefs concerning teaching science for social justice. Hence, my study primarily focused on preservice teachers and their beliefs and learning. With that being said, I must explicitly
locate myself within this study because I am the one who selected the curriculum content and made the pedagogical choices for the course.

Qualitative researchers have used the method of instructor-as-researcher when the content and pedagogies they wish to study are only available in their own courses or contexts (see, e.g., Abd-El-Khalick, 2001; Bianchini et al., 2003; Endreny, 2010; Finney & Orr, 2005; Gess-Newsome, 2002; McDonald, 2010; Mensah, 2009; Rodriguez, 1998). Although two other instructors teach the same elementary science methods course at my institution, they do not explicitly address social justice in their teaching, as defined in this study. One colleague focuses on the theme of inquiry, while the other one addresses environmental sustainability. Since my understanding of social justice concerns the explicit interrogation of power, privilege, and oppression in relation to race, ethnicity, class, and their intersections with other areas of social identity, I utilized the instructor-as-researcher method to examine this teaching and learning phenomenon.

In the following section, I will describe the key tenets of a grounded theory approach to qualitative inquiry and explain why constructivist grounded theory is well suited for this research project. I will also provide details on the context of the study and on the research participants.

**Constructivist Grounded Theory**

First introduced in the 1960s by sociologists Barney Glaser and Anselm Strauss, grounded theory is a “general methodology for developing theory that is grounded in data systematically gathered and analyzed” (Strauss & Corbin, 1998, p. 158). Glaser and Strauss’s (1967) set of systematic and rigorous procedures allowed researchers to develop their own explanations or theories that were grounded in the data. The purpose of grounded theory research
is to provide an interpretive, middle-range theory which, according to Kathy Charmaz (2006), is an “imaginative articulation of the studied phenomenon” (p. 126). Unlike grand theories that explain phenomena at a macro level, grounded theory is a middle-range theory that describes specific situations that are limited to the context and scope of the study (Merton, 1968).

More than fifty years after its introduction, numerous iterations of grounded theory exist (Creswell, 2007; Morse et al., 2009). However, these various versions converge on the following six characteristics: simultaneous data collection and analysis; coding; constant comparative analysis; memo writing; theoretical sampling and saturation; and theory development. In a grounded theory study, data collection and analysis are not seen as separate events, but happen in a synchronous fashion, thereby reciprocally informing each other. This allows researchers to follow interesting findings or leads, and their subsequent data collection works to validate, extend, or dispel an emerging theory. Data are systematically gathered and analyzed by the process of coding, whereby data are sorted into distinct units of meaning (e.g., line by line) to ascertain what the data are about. Synthesizing units of data in this manner not only summarizes each piece of data, but also facilitates the coding of data for their “analytic import” (Charmaz, 2006, p. 42).

The analysis of codes continues with the systematic evaluation and re-evaluation of codes for their inter-relationships, thus enabling the movement of data onto higher levels of abstraction and the creation of broader categories. Through constant comparison, categories are linked to previous codes and new data (Patton, 2002). In other words, every piece of data is compared to other pieces as the researcher moves back and forth between data collection, coding, and categorizing. Constant comparative analysis continues until a few significant categories appear that may constitute an emerging theory that answers the research questions.
As categories emerge, researchers engage in theoretical sampling which is geared to “elaborate and refine the categories constituting [their] theory” (Charmaz, 2006, p. 98). In other words, they look for relevant data that further develop the properties of the categories. This may call for a return to the participants to seek more data or further analysis of data already collected. Data collection ends when researchers reach theoretical saturation, when “additional analysis no longer contributes to discovering anything new about a [theoretical] category” (Mason, 2002, p. 121). In addition, researchers undertake analytic memo-writing throughout the data collection and analysis stages. Memos offer a space to write down important ideas and details, provide a record of analytic progress, and facilitate deep and consistent analysis. According to Charmaz, (2006), “memos catch your thoughts, capture the comparisons and connections you make, and crystallize questions and directions for you to pursue … and [offer] new ideas and insights” during the research process (p. 72). The information contained in memos are integral in guiding analysis and creating theoretical categories.

Although I present grounded theory in a somewhat linear fashion, many steps in this research methodology occur simultaneously. Throughout the research process, researchers continually moved back and forth among data collection, organization, and analysis through coding and constant comparison. They write memos to help further conceptualize ideas. They cluster codes together to make categories which, when saturated, are examined for their relationships to one another. Ultimately, the generated categories from the process of data collection and analysis form the basis of the grounded theory.

According to Anselm Strauss and Juliet Corbin (2007), researchers must choose a research paradigm that is congruent with their beliefs concerning the nature of knowledge and truth. Therefore, for my study, I selected Kathy Charmaz’s (2006) constructivist orientation to
grounded theory (CGT). Charmaz’s CGT refutes the positivist underpinnings of Glaser and Strauss’s (1967) and Strauss and Corbin’s (2007) interpretations, which suggest an external reality that can be entered by an unbiased and value-free researcher. Rather, it posits that there is no singular, objective reality that can be accessed and that neither data nor theories are “discovered.” It contends that there are multiple realities that are continually created as individuals interact with the world around them, and that both data and theories are co-constructed during the interplay between the researcher and the researched.

I am particularly interested in constructivist grounded theory since, under this framework, researchers are not separate disembodied entities from their participants, and reality can only be sufficiently interpreted when researchers examine their own values, perspectives, and views along those of their participants’. In other words, CGT seeks to explicitly locate the researchers in the study rather than minimize their role. Furthermore, for constructivist grounded theorists, concepts such as truth and meaning are social constructions, making the goal of CGT to produce an interpretive portrayal of the studied world rather than an exact picture of it. According to Charmaz (2000), “the grounded theorist’s analysis tells a story about people, social processes, and situations. The researcher composes the story; it does not simply unfold before the eyes of an objective viewer. This story reflects the viewer as well as the viewed” (p. 522). She suggests that CGT is well suited for critical inquiries like mine because it seeks to make explicit, rather than ignore, how sociopolitical, economic, and historical events shape the lives of the researched and the researcher. As the researcher and course instructor using CGT, it is important for me to situate myself in this proposed study and be transparent about my experiences and how they have shaped the development of the science methods course.
Research Context

The Ontario Institute for Studies in Education (OISE) at the University of Toronto is the largest teacher education faculty in the province of Ontario, and offers four pathways to teacher certification. A two-year Master of Teaching (M.T.) program allows individuals to graduate with both a graduate degree and a teaching certificate in elementary or secondary education. The Master of Arts (M.A.) pathway is also a two-year program and includes an elementary teaching certificate. OISE also offers the Concurrent and Consecutive Bachelor of Education (B.Ed.) degree programs. The Concurrent B.Ed. program is a five-year program designed for undergraduate students, while the Consecutive B.Ed. program is a 9-month, post-baccalaureate program for those already possessing a degree. Preservice teachers seeking teacher certification must select one of three divisions for certification: Primary/Junior (grades K-6); Junior/Intermediate (grades 4-10); or Intermediate/Senior (grades 7-12). Those who choose either the Junior/Intermediate or Intermediate/Senior division must also select a teachable or content area specialization (e.g., science, English, geography, or music). Although there are three distinct areas of certification, the elementary division refers to grades K-8 and the secondary division to grades 9-12.

For the past four years from 2009 to 2013, I have taught the “Science and Technology Education for Elementary School Teaching” course (EDU 1450) in the Consecutive B.Ed. Program. The course is a required methods course for all Junior/Intermediate preservice teachers, and meets six times for a total of 18 contact hours over a nine-month period. The OISE Initial Teacher Education Calendar (2012) describes the course as:

The science component is part of the broader Curriculum and Instruction course that enables candidates to understand and apply the knowledge, skills and attitudes necessary for designing and constructing effective programs to meet the diverse needs of every student. Candidates actively participate in integrated, hands-on learning experiences to
gain exposure to the teaching and learning strategies, assessment and evaluation strategies, and planning processes that enable students to achieve desired expectations from the Ontario Curriculum. (p. 36)

To prepare preservice teachers to meet the needs of diverse learners, I elected to bring an explicit social justice orientation to the course. To do this, I turned to the critical – cultural framework of curriculum theorizing (which I explained in Chapter 2), and designed the course so that it is aligned to the three dimensions of teaching science for social justice: critical nature of science, critical knowledge and pedagogy, and sociopolitical action. Doing so challenged preservice teachers to reconsider science teaching and learning, and expanded their curricular and pedagogical understandings of science. In my course, I specifically addressed Canadian contexts by juxtaposing the Ontario Science Curriculum (OME, 2007) and the Ontario Equity and Inclusive Education Strategy (OME, 2009).

During the 2011-2012 academic year, I taught the “Science and Technology Education for Elementary School Teaching” course (EDU 1450) to the three elementary options of Inner City, Doncrest, and Catholic. At OISE, each option has a particular theme, and preservice teachers select one based on their personal interests. For example, the Inner City option works closely with schools and communities in the Toronto District School Board and the Toronto Catholic District School Board, and has a strong emphasis on social justice education through an anti-oppressive framework. The Doncrest option has a focus on the integrative nature of learning, with specific emphasis on brain research and multiple intelligences. The Catholic option centers on preparing preservice teachers to teach in Ontario’s Catholic schools by supporting their spiritual, academic, and professional development.
Research Participants

To identify and select participants for my research project, I utilized purposeful sampling. For purposeful sampling, “the inquirer selects individuals and sites for study because they can purposefully inform an understanding of the research problem and central phenomenon to the study” (Creswell, 2007, p. 125). Since research shows that many Aboriginal and racialized minority students begin to disengage from school science in grades 4 to 8, I purposefully chose to focus on preservice teachers seeking certification and exhibiting a desire to work in these grade levels. My original intent was to select a dozen preservice teachers from a single option who were enrolled in the Junior/Intermediate EDU 1450 course and who had declared science as their teachable. However, due to the low number of elementary preservice teachers who chose science as a teachable, I had to select participants from three options – Catholic, Doncrest, and Inner City. Furthermore, I was only able to recruit eleven preservice teachers who were interested and agreed to participate in my research study. Three participants were from the Catholic option; two from the Doncrest option; and six from the Inner City option. Next I will briefly describe each of the participants in this research project. I have elected to detail the participants based on their educational backgrounds, reasons for entering the teaching profession and future aspirations.

Catholic Option (Carol, Nick, and Tina)

Carol states that she has always wanted to be a teacher. When she was 6 years old, her parents bought her a desk and a chalkboard so that she could teach her neighborhood friends. Carol has a bachelor’s degree in physical education and health, and spends much of her time coaching girls’ volleyball. Although she has a passion for teaching, Carol does not want to be a
classroom teacher at this time because she is young and “wants to live her life.” She would like travel before “settling down” to a permanent occupation.

Although both of Nick’s parents were teachers, he pursued a bachelor’s degree in kinesiology and health science with hopes of becoming a physical therapist. After graduation, he took a marketing position for an auto racing company. Nick refers to himself as a “jack of all trades” because he has many academic interests that include science, European history, English literature, and politics. According to Nick, after his father passed away unexpectedly five years ago, he “grew up” and decided to become a teacher. Nick anticipates teaching in a local Catholic board when he graduates.

Tina describes herself as a “simple gal who loves nature,” and spends much of her time in local parks and waterways. Her love for science fueled her to earn bachelor’s and master’s degrees in biology, and she worked as a professional field biologist before deciding to become a teacher. She has accepted a full-time teaching position with the Toronto District School Board beginning in the Fall of 2012.

**Doncrest Option (Alex and Shiva)**

Alex has excelled from kindergarten through university education, and has many academic awards and honors. He has a bachelor’s degree in psychology and a master’s degree in biology. Although he enjoys his experiences at OISE, University of Toronto, he asserts that it is not “academically rigorous enough.” Alex hopes to teach in a private Jewish school.

Shiva explains that she has always loved science and has always wanted to be a teacher. She prefers learning about physical science rather than life science, and is excited to motivate
and engage her future students in this area. Shiva hopes to teach in a “culturally diverse” school in the greater Toronto area.

**Inner City Option (Ben, Dayja, Frank, Maria, Rebecca, and Walter)**

Ben decided to pursue his teaching certificate after working as a kindergarten classroom assistant for the past five years. He has two bachelor’s degrees in math and science, and refers to himself as a “math and science nerd.” At this time, he is unsure if he wants to enter the teaching profession.

Dayja holds a bachelor’s degree in international development, and has lived in 5 different countries. She elected science as a teachable because she thinks she can motivate girls in the subject. She fondly recalls her mom conducting science experiments with her at their kitchen table when she was young. Dayja is considering taking her newly acquired skillset abroad and teaching in Asia.

Frank has a bachelor’s degree in psychology, but he was unable to find a job in that field. Because of this, he decided to pursue his teaching credentials. He states that he hard a hard time trying to decide between math and science as his teachable area, but figures he has a stronger chance of getting a science teacher position than math. Frank does not want to be a classroom teacher in the Toronto area, and is considering teaching English in Asia.

Maria has a bachelor’s degree in kinesiology, but has tutored elementary aged students in math and science for the past 6 years. This experience has been a catalyst for her desire to become a science teacher. She states that science has always been a strength of hers and she would like to teach in a First Nations school.
Rebecca has always excelled at science since it is her “favorite subject.” She attributes this deep interest to her growing up in a rural area and spending a lot of time outdoors. She has a bachelor’s degree in biology, and considered becoming a medical doctor, but elected to come to OISE, University of Toronto instead. She does not want to become a classroom teacher, but would like to work with kids such as camp counselor in a private organization.

Walter earned a bachelor’s degree in psychology before moving to Korea to teach English. He taught for 8 years, and then moved back to Canada is to attend OISE, University of Toronto. He claims he has always been passionate about teaching science, and has applied for graduate school to pursue science-related research.

**Data Collection**

For my research project, I focused on eleven preservice teachers who were enrolled in my “Science and Technology Education for Elementary School Teaching” course (EDU 1450) during the 2011-2012 academic year. This course is a required science methods course for Junior/Intermediate preservice teachers in the nine-month Consecutive Bachelor of Education program at the Ontario Institute for Studies in Education of the University of Toronto. All eleven participants chose science as their teachable subject. I collected their data through three qualitative methods: 1) initial and year-end, open-ended questionnaires; 2) document analysis of student assignments; and c) semi-structured interviews. In order to examine preservice teachers’ espoused and in-use beliefs (Kane et al., 2002), I focused on the questionnaires and interviews as data on their espoused beliefs, while the assignments provided data on their in-use beliefs. Table 3.1 indicates the three central research questions of this study and the data sources used to answer the questions.
Table 3.1. Research Questions and Data Sources

<table>
<thead>
<tr>
<th>Research Questions</th>
<th>Data Sources</th>
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<tbody>
<tr>
<td>Question #1: What are preservice teachers’ initial beliefs?</td>
<td>beginning and end-of-year questionnaires, interviews</td>
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<tr>
<td>Question #2: How do preservice teachers’ beliefs shift?</td>
<td>end-of-year questionnaires, interviews, assignments</td>
</tr>
<tr>
<td>Question #3: What pedagogical choices impact beliefs?</td>
<td>end-of-year questionnaires, interviews, assignments</td>
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**Questionnaires**

In this study, I created beginning and end-of-the-year, open-ended questionnaires that were designed to gain insights into preservice teachers’ beliefs concerning teaching science for social justice. The beginning-of-the-year questionnaire was comprised of four questions and the end-of-the-year questionnaire contained 12 questions. All preservice teachers enrolled in the course filled out both questionnaires and submitted them electronically to Blackboard. The beginning-of-the-year questionnaire asked about their beliefs concerning science, social justice, and teaching science for social justice (see Appendix B). The end-of-the-year questions were similar, but required deeper reflections given their experiences in class. For example, they required the participants to reflect on the sources of their initial beliefs as well as how their beliefs changed during the year (see Appendix C). David De Vaus (2002) suggests that questionnaires are an excellent method to obtain data concerning participants’ beliefs and experiences. However, Ben Beiske (2007) indicates that a shortcoming of questionnaires is that researchers often do not have the opportunity to follow up on ideas and clarify issues that arise from the questionnaire data. To address this shortcoming, I used interviews as an opportunity to have participants provide further explanations of their responses. Furthermore, following the recommendation of De Vaus (2002), I piloted the end-of-the-year questionnaire with ten
preservice teachers from the Crosstown (Primary/Junior) option to ascertain whether or not it
generated accurate data. Since I taught the Crosstown option science methods course in a similar
manner to EDU 1450, I was comfortable administering the end-of-the-year questionnaire to this
group. Doing so was fruitful because I discovered that I had too many questions and some of
them were redundant. I also used the results of the pilot to fine-tune some wordy and unclear
questions.

**Interviews**

According to Anssi Perakyla (2011), the use of interviews enable researchers to “reach
areas of reality that would otherwise remain inaccessible such as people’s subjective experiences
and attitudes” (p. 869). Generally, there are three different types of qualitative research
interviews: structured, semi-structured, and unstructured (Creswell, 2007). In this study, I used
semi-structured, face-to-face interviews because they possess the flexibility of unstructured
interviews, but provide the direction needed to produce focused data on complex subjective
issues. Semi-structured interviews are positioned between the naturally occurring conversations
that take place in unstructured interviews and the rigid, closed questions associated with
structured interviews. They allow researchers the flexibility to generate a list of guiding
questions in advance and to ask participants for clarification and deeper understanding. Semi-
structured interviews also encourage participants to direct the discussion, and may provide
perspectives or directions not originally anticipated by the researcher.

I interviewed the eleven preservice teachers at the end of the academic year after I
submitted the final course grades to the OISE/UT Registrar’s Office. I asked them to select a
comfortable location, and informed them that the interview would last approximately one hour.
My shortest interview lasted 48 minutes, while the longest took 90 minutes. I interviewed the participants once, following H. Russell Bernard’s (1988) advice that semi-structured interviews are best when the researcher will only have one chance to interview someone. By design, semi-structured interviews allow the researcher the flexibility to adjust and ask probing questions during the interview in order to obtain meaningful data.

I generated a list of questions that fit into five broad themes on preservice teachers’ beliefs regarding teaching science for social justice: 1) former experiences with science; 2) past and current beliefs about teaching science for social justice; 3) in-class factors impacting changes in those beliefs; 4) factors beyond the course impacting beliefs; and 5) future practice (Appendix D). Similar to the piloting of questionnaire data, I also selected participants from the Crosstown (Primary/Junior) option and conducted five pilot interviews. Again, I learned that some of my questions needed reworded for clarity. Also, the experience showed me that I needed to change the order of some of my research questions and begin the interview in a less formal manner. For example, participants were much more comfortable when I began the interview inquiring why they wanted to become teachers and asking them to share their past experiences with science, than when I immediately began asking about the course content and social justice. Furthermore, some of my questions elicited similar responses due to the fact that the questions were inherently parallel. To address this, I integrated some questions and/or reworded them.

**Documents**

In Summer 2011, after teaching the “Science and Technology Education for Elementary School Teaching” course (EDU 1450) for two years, I decided to revise it in order to bring a more explicit emphasis on integrating social justice into the Ontario provincial science
Informed by my review of the scholarly literature, I organized the course readings and designed the assignments using the critical – cultural curriculum framework that I explained in Chapter 2. The three main assignments in my revised course were aligned with specific dimensions and strands (see Figure 3.1). For example, my visual representation assignment, which juxtaposed Aboriginal and Western scientific worldviews, was aligned with the critical nature of science dimension and the anti-colonial strand.

I analyzed the student assignments and written reflections, and compared my findings with their questionnaire and interview data. This type of triangulation (Creswell, 2007) – using three different data sources – provided further understandings of preservice teacher beliefs and the shifts that occurred during the course. Their assignments provided concrete examples of how they understood and applied teaching science for social justice, while their reflections on the learning process and products offered insights into their beliefs as well as their resistance or acceptance of the assignments’ objectives. All assignments were submitted electronically via Blackboard. In the subsections below, I will describe the three course assignments that acted as the main document sources for my study (see Appendix A).

Figure 3.1. Course Assignments Aligned to Dimensions and Strands
Assignment #1: Visual Representation: Aboriginal and Western Worldviews of Science

(Due on the third class session)

For this assignment, I challenged my preservice teachers to reconsider the Eurocentric approach to science by exploring indigenous epistemologies. For example, whereas the West views the natural world as a commodity to be controlled and exploited, indigenous communities possess an intimate relationship with the land based on ecological respect (Cajete, 2000). By understanding the convergences and conflicts between Western and indigenous worldviews, preservice teachers understand science not only as socially constructed, but also politically implicated in dynamics of knowledge and power (Harding, 1991). Toward this end, preservice teachers compared and contrasted Aboriginal and Western worldviews using a visual representation, and considered how these two worldviews of science shape our notions of truth, evidence, and validity. This assignment had two components. First, on an 11” x 17” size paper, they depicted the tensions and similarities between Aboriginal and Western worldviews. Second, they submitted a written reflection that included three components: a description and explanation of their visual representation; an educational position as to the importance (or not) of knowing that different cultural groups may have different worldviews on science; and a delineation of how they might incorporate Aboriginal worldviews in their science teaching.

Assignment #2: Environmental Justice Strategy (Due on the fifth class session)

For this assignment, I asked preservice teachers to consider and reflect on the policies, practices, and impacts of waste dumps, hazardous industries, and other pollutive sources in disadvantaged communities. My objective was to increase their awareness in the area of environmental justice and to have them strategize with students and take action as they assess the
environmental health of local communities (Bouillion & Gomez, 2001). In preparation for this assignment, they read articles and viewed videos on environmental racism and environmental justice at local, national, and international levels. Then they identified an environmental issue that needed to be addressed, and generated a strategy of action that involved pertinent stakeholders. The strategy highlighted the environmental issue, its local impact, and how they would engage students in sociopolitical action concerning the issue.

Assignment #3: Culturally Relevant Lesson Plan (Due on the sixth class session)

For this assignment, I wanted preservice teachers to gain experience using their students’ funds of knowledge and create a science lesson that would be relevant to their students’ lived experiences (Gonzales et al., 2005). My objective was guided by research which indicates that, by making instruction relevant to diverse student populations, science would become accessible to students who have traditionally not been successful in the subject (Ladson-Billings, 2007). In preparation for this assignment, they utilized the culturally relevant and responsive frameworks provided in the course readings and discussions to craft a science lesson plan that this was aligned to the Ontario Science Curriculum (OME, 2007) and that utilized students’ cultural backgrounds (Ladson-Billings, 1995; Villegas & Lucas, 2007). Since this assignment was due on our final class session after they had already undertaken two practicums, they were strongly encouraged to consider the student demographics of their practicum schools for this assignment.

Reflexive Journal

Although a reflexive journal was not a main data source for my study, I maintained a journal throughout the duration of the course. The journal provided a space for personal
reflection and included, but is not limited to, my thinking about preservice teachers’ learning of science, peer interactions, acceptance and/or resistance to course content and discussions, researcher bias and assumptions, preliminary analysis of the data, and memo-writing (Emerson et al., 1995; Merriam, 1998).

Data Analysis

When I began data analysis, it was very important to me to interpret the data in a way that was as true to my participants’ experiences and perspectives as possible (Patton, 2002). To do this, I knew that I needed to immerse myself in the data. This began with the interview transcription. I was able to transcribe nine out of eleven interviews, but hired a professional to transcribe the last two interviews due to time constraints. As I transcribed, I began to get to know my participants more fully and understand their stories. I also read in detail the two interviews transcribed by someone else as part of my pre-analysis of the interview data. After all interviews were transcribed, I downloaded from Blackboard the participants’ beginning and end-of-the-year questionnaires, assignments, and reflections. The participants also provided me with digital photographs of their visual representations. With all the data sources from eleven participants collected, I continued with my data analysis.

For data analysis in constructivist grounded theory, Kathy Charmaz (2006) offers a set of “flexible guidelines” rather than “methodological rules, recipes, and requirements” that I utilized (p. 9). For each data source, I followed Charmaz’s suggestions and began with qualitative coding as the first analytical step. Since coding consists of two stages, initial and focused coding, the initial coding stage focuses on some key questions: “What is this data a study of? What does this data suggest? Pronounce? From whose point of view? What theoretical category might this
specific datum dictate?” (p. 47). I broke down the initial coding stage into four phases, and was mindful of Charmaz’s questions during the entire coding process. During each phase, I followed Charmaz’s four questions as I sifted through the data.

During *Phase One*, I worked solely with the interview data. Here, I read each interview, and coded line-by-line for action and process. In many instances, I found that there were not substantial data to code line-by-line, therefore, I would code fragments of data such as sentences or phrases. Coding with words that reflected action rather than topics was necessary to remain focused on what participants were saying or doing and avoided the pitfall of applying preexisting categories to the data. Categories must earn their way into an emerging theory (Glaser, 1978).

During *Phase Two*, I focused my analysis on the beginning and end-of-the-year questionnaires. Following the same process of initial coding during Phase One, I first coded the beginning-of-the-year questionnaires for action and process, and then coded the end-of-the-year questionnaires.

Analysis during *Phase Three* pertained to the three course assignments: (1) Visual Representation: Aboriginal and Western Worldviews of Science; (2) Environmental Justice Strategy; and (3) Culturally Relevant Lesson Plan. Here, I continued initial coding for the written components of each assignment. I was interested how my participants conceptualized and responded to each assignment. For the visual representation portion, I recorded descriptions and themes in my reflexive journal as memos. At the end of Phase Three, all data sources had been coded.

*Phase Four*: Here, I conducted a second sweep of all data sources to see if the initial codes made sense to me, and I looked for coding possibilities that I may have missed during the first three phases. However, in this phase, I ordered the data differently. In the first three phases,
I coded by *data source* rather than *participant*. In other words, I coded all of the interviews, then all of the questionnaires, and then all of the course assignments. In Phase Four, I coded by participant. For example, I selected a participant in my study and coded all three sources of data for that individual before moving on to the next participant. By breaking up initial coding into four phases, I hoped analysis might reveal both trends across data sources as well as across participants.

After I completed a second sweep of initial coding, I began the process of focused coding as a way to organize my initial codes. Focused coding is the second major stage in coding when the researcher analyzes and compares the most significant and/or frequent codes for their “analytic sense” to generate initial, yet larger categories (Charmaz, 2006, p. 57). The goal of focused coding is to selectively synthesize and integrate large amounts of data into conceptual categories that represent an increased level of abstraction from initial codes. Where initial coding is about laying out the data or breaking it apart to see its contents, focused coding is about putting the data back together in the form of initial categories that represent large chunks of the data. To do this, I scrutinized the numerous initial codes for themes and clustered similar codes together that reflected what was occurring in my data.

For me, focused coding was a lengthy process of ‘getting my hands dirty’ or immersing myself into the data so that I could really work with and focus on it. To do this, I engaged in constant comparative analysis. As I sorted data, I continually compared them to other data, to codes, and to emerging categories. At times, new codes and categories emerged, and weaker ones dissolved. It was this active engagement with the data and constant comparison that led me to raise the level of abstraction necessary for constructivist grounded theory. According to Keith Punch (2009), constant comparison is the “central intellectual activity in analysis” (p. 182). In
other words, coding allowed me to take concrete events and descriptions and move them to theoretical possibilities. After engaging in focused coding and constant comparative analysis, I carefully scrutinized the initial categories represented by the focused codes. Here, I aimed to raise one or some initial categories to theoretical categories that might help answer my central research questions. Since my goal was to understand preservice teachers’ beliefs and their belief changes about teaching science for social justice, I worked with the initial categories that showed promise for this line of inquiry. Furthermore, I engaged in theoretical sampling, or defining and delineating the boundaries and relevance of the categories (Charmaz, 2006). I did this until the theoretical categories were saturated, or data provided no further insights about the category.

Integral to each component of grounded theory research is the act of memo-writing. Memo-writing in my reflexive journal began early in the research process. I would often jot down notes following an interview or stop during transcription to note particular themes or ideas that were emerging. According to Charmaz (2006), memo-writing “is the pivotal intermediate step between data collection and writing drafts of papers” (p. 72). I found memo-writing to be time-consuming yet crucial to my research. While I began with the idea that all memos would be kept in my reflexive journal, in reality, they also took the form of analytic charts, handwritten and typed notes, stream-of-consciousness ideas, and possibilities of emerging categories and themes. The data analysis process may appear linear and neat, as evidenced in the data chapters (Chapters 4, 5, and 6) and in the eventual theory that I propose about belief change in teaching science for social justice (in Chapter 7). However, getting conceptual clarity was quite messy and often uncertain, and much of my analytical work took place in the form of memo-writing. While I coded all my participants’ data using MS Word documents, much of my memo-writing was done by hand in a notebook. I also used post-it notes and created charts, where I was able to
make sense of and expand on codes, develop connections between codes, and note other patterns that surfaced in the data that may not be germane to my theory, but were pertinent to the study such as participants’ former experiences with science in elementary and high school. Ultimately, the iterative process of memo-writing and constant comparison led to the development of three categories that represent my theory of belief change about teaching science for social justice, as delineated in Chapter 7.

In the end, I found that data analysis carried well beyond the time I was stationed at my computer. In fact, I would often find myself thinking about codes, themes, and making mental memos while sitting on the subway or eating meals. In a sense, the data analysis process consumed much of my daily thinking as I strived to analyze and discern what was taking place in my study.

**Validity in Qualitative Research**

Scholars continue to debate the question of validity in qualitative research (Altheide & Johnson, 1994; Atkinson et al., 2003; Creswell & Miller, 2000; Glaser, 1978; Lather, 1993; Lincoln & Guba, 1985; Maxwell, 1992; Merriam, 1998). To ensure that the process and results of my study were valid and could withstand methodological scrutiny, I followed Charmaz’s (2005) four criteria for assessing the validity of constructivist grounded theory studies. Her criteria include credibility, resonance, originality, and usefulness.

Charmaz’s criterion of *credibility* is aligned to Yvonna Lincoln and Egon Guba’s (1985) concepts of credibility and dependability. To meet this criterion, I engaged in three actions: member check; intimate familiarity with research setting; and triangulation of data. According to Lincoln and Guba (1985), member checking is “the most critical technique for establishing
credibility” in qualitative research (p. 314). Member checking is soliciting research participants’ ideas about the collected data and the researchers’ interpretation of the data. I wanted to represent my participants’ experiences and perspectives as accurately as possible, so I sought their input in two distinct phases. First, after all the interviews were transcribed, I emailed their respective interview transcripts for feedback. I asked them to make corrections directly on the documents and return them to me. Overall, the participants made minor changes and clarifications in their transcripts. According to Patti Lather (1986), participants should be allowed a role in negotiation of the final meanings of the research. With this in mind, after completing a solid draft of the thesis’ data findings chapters (Chapters 4, 5, and 6), I sought input from my research participants once again, this time on my data interpretation and analysis. The participants did not request any changes, and were quite happy with how they were portrayed in these chapters as well as my analysis of their beliefs.

In addition, Herbert Blumer (1969) insists that social scientists need to gain an intimate level of familiarity with their studied phenomenon, and argues that an intimate familiarity with research participants and their worlds is imperative for credible research. The very nature of my research setting was, indeed, conducive to establishing this much-needed level of familiarity. First, this was my third year working with preservice teachers and teaching the science methods course. Although I revamped the course for this research study, I had previously made efforts to include aspects of social justice into the course. This history created a level of familiarity with the integration of science and social justice and how preservice teachers’ might respond to such a focus. Second, I created meaningful learning communities in my classes. During each three-hour session, I continually interacted, learned with, and learned from my participants. Lastly, triangulation is a common strategy employed by qualitative researchers to increase the validity of
their work (Denzin & Lincoln, 2005). It is the act of having multiple sources of data to substantiate one’s claims. In this research project, triangulation was achieved by drawing from three sources of participant data: questionnaires, documents, and interviews.

Charmaz’s criterion of resonance is similar to Lincoln and Guba’s (1985) concepts of transferability and confirmability. To meet this criterion, I utilized thick descriptions for depth and context (Geertz, 1993). According to Michael Patton (2002), “thick, rich description provides the foundation for qualitative analysis and reporting. Good description takes the reader into the setting being described” (p. 437). This means the study should “portray the fullness of the studied experience” and offer deep insights into the participants’ “lives and worlds” (Charmaz, 2005, p. 528). I aimed to describe my participants and their insights as richly as possible through “abundant, interconnected details” (Stake, 2010, p. 49). Often, I would rely on participant quotes that illuminated their beliefs about teaching science for social justice. It is my hope that these rich descriptions will allow other elementary science teacher educators to see similarities in their classes and make their own judgements about how this study might resonate or inform their work.

Knowledge production is inherently value-laden because researchers always bring to the process their own beliefs and worldviews (Charmaz, 2005; Guba, 1990). Therefore, the validity criterion of resonance requires researchers to acknowledge how their perspectives and biases might affect the process and results of the research. In the first chapter of this thesis, I situated myself in relation to this study, and elaborated on my life experiences and how they have shaped my personal and professional interests concerning science and social justice. In other words, I had an agenda that I brought to this research and my commitments to teaching science for social justice played a role in the design and implementation of this study. With that being said, I
labored to represent my participants’ realities as fully and truthfully as possible by being mindful of my biases and continually referring to the data to allow “the voices of [my] participants to be heard” (Creswell, 2007, p. 37).

For originality, Charmaz (2005) asks researchers how their projects “challenge, extend, or refine current ideas, concepts, and practices” (p. 528). This research project serves to both challenge and extend current ideas. For example, I challenge both the hegemony of Western science and its role in shaping the way science has been traditionally taught in elementary schools. Instead, I offer a framework of science reform based on three dimensions of teaching science for social justice. I extend the small body of research pertaining to the preparation of elementary science teachers with a social justice focus by addressing specific pedagogical strategies that may have an impact on elementary preservice teachers’ beliefs about teaching science for social justice. There has been limited theoretical discussion concerning belief change and science education concerning equity, diversity and multiculturalism. Therefore, my theory of belief change about teaching science for social justice substantively adds to this body of literature.

Finally, Charmaz’ s validity criterion of usefulness departs from conventional grounded theory, and serves as a productive standard for social justice oriented projects like mine. Charmaz offers four evaluative questions to assess the usefulness of a social justice project: “Does the analysis offer interpretations that people can use in their everyday worlds? Have analytic categories been examined for hidden social justice implications? Can the analysis spark further research in other substantive areas? How does the work contribute to making a better society?” (Charmaz, 2005, p. 528). I believe that this study meets all four requirements of the usefulness criterion. My aim has been to better understand elementary preservice teachers’
beliefs about teaching science for social justice. Ultimately, this explicit attention to social justice has potential to address the unfulfilled promise of the science for all agenda for many Aboriginal and racialized minority students. Understanding elementary preservice teachers’ beliefs about teaching science for social justice and providing a theory of belief change offers hope for greater science engagement for all students. Furthermore, this research project delineates promising pedagogical practices that other elementary science teacher educators might use as they prepare teachers to address the needs of diverse student populations. Lastly, my study potentially impacts and sparks further research in a number of scholarly areas such as elementary education, teacher education, preservice teacher beliefs, preservice teacher resistance, and uncertainty in preparing activist-oriented teachers.

**Ethical Considerations**

Conducting ethical research requires researchers to carefully consider issues of participant risk and vulnerability. With the dual role of being the course instructor and researcher, I was mindful of how to have ethical relationships with my research participants throughout the entire process. During the first class sessions, I discussed my research project to all students enrolled in my “Science and Technology Education for Elementary School Teaching” course (EDU 1450) in the three options (Catholic, Doncrest, and Inner City). I indicated that I was personally and professionally interested in their beliefs about science and social justice, and that I would require them to reflect on their beliefs throughout the course. I also informed them that, after I submitted their final course grades to the OISE/UT Registrar’s Office at the end of the academic year, I would invite some of them to participate in the research study.
During the 2011-12 academic year, there were fifteen preservice teachers in the three options who selected science as their teachable. I invited all fifteen preservice teachers, and eleven agreed to participate in the study. Three declined because they were too busy with transitions at the end of the year and were leaving Toronto for work or to be closer to their families. The fourth preservice teacher declined my invitation, citing lack of interest in my research project. Prior to the interviews, I met individually with the eleven preservice teachers who agreed to participate, and discussed the consent forms with them. All participants signed the consent forms, agreed to be interviewed, and gave me permission to access their questionnaires and assignments from Blackboard for research purposes. Following this protocol, I ensured that the preservice teachers’ participation in my research did not advantage or disadvantage them in my course. Furthermore, to protect participants’ anonymity, I assigned each of them a pseudonym.

Limitations

The findings of my study intend to offer important insights into preservice teachers’ beliefs about teaching science for social justice and the impact that an elementary science methods course can have on those beliefs. But there are limitations that must be accounted for.

Generalizability

My qualitative research project focused on the experiences and perspectives of eleven preservice teachers who were enrolled in a science methods course at a Canadian university located in one of the most diverse cities in the world. According to Patton (2002), qualitative methods “typically produce a wealth of detailed information about a small number of people and
cases. This increases depth of understanding of the cases and situations studied but reduces
generalizability” (p. 14). Drawing on the qualitative research tradition, this study uncovered the
detailed and complex nuances of my participants’ beliefs about teaching science for social justice
and depicted these processes and results in a richly detailed manner. However, with a sample
number of eleven participants within a particular geographical context, the findings are not
generalizable beyond the scope of this study.

**Dynamics Between Teacher Educator and Preservice Teachers**

My dual position as the course instructor and researcher in this study also presents a
unique limitation. As the instructor and ultimately the person in charge of assigning course
grades, there was always the possibility that preservice teachers would tell me what I wanted to
hear or read, rather than respond to the questionnaires and assignments in ways that genuinely
reflected their own beliefs. In my courses, I made efforts to reduce this possibility in two ways.
First, during our first class sessions and in subsequent classes, I reminded my preservice teachers
that my goal was not to indoctrinate them with my beliefs and ideas about science, but rather to
provide a pedagogical space for reflection and re-imagining of science teaching and learning. I
stressed to them that most important to me was that they think critically about science as they
engaged in activities that might provide them opportunities to view science differently. Second, I
used Glen Singleton and Curtis Linton’s (2006) Four Agreements when engaging in courageous
conversations. Singleton and Linton define courageous conversations as those that “sustain and
deepen interracial dialogue about race in order to examine schooling and improve student
achievement” (p. 16). The Four Agreements are: “Stay engaged; Experience discomfort; Speak
your truth; and, Expect and accept non-closure” (p. 17). Since many preservice teachers
experience discomfort when engaging with issues of race and other social identities (Ball & Tyson, 2011), I found their Agreements helpful when I facilitated conversations on race, difference, and science education. These Agreements also allowed preservice teachers to offer their ideas honestly, and motivated them to engage in difficult topics. Although I am aware that the two strategies I used to elicit honest responses from my participants were not full proof, it would become evident in the data findings in Chapters 4 to 6 that my participants felt at ease offering their beliefs and views that were often quite contrary to mine.

Nature of Beliefs and Preservice Teacher Education

Finally, two other important limitations should be noted. First, my research focus on beliefs could be deemed as a limitation since beliefs can only be inferred through what individuals say and/or do. My aim in this study was to understand preservice teachers’ beliefs and how they shifted during an elementary science methods course. To ascertain their beliefs and belief changes (if any), I was limited to their questionnaire responses, interview answers, assignments and written reflections. Moreover, participant responses are indicative of their own personal understandings of beliefs, which may or may not align to those in the scholarly literature.

Since observing participants’ teaching was beyond the scope of this study, I was not able to determine if their espoused beliefs were aligned to their pedagogical practices in the classroom setting (Kane et al., 2002). Furthermore, the relationship between teachers’ beliefs and action is complex. For instance, some science education scholars have found that teacher behaviors are not always consistent with their beliefs (Mansour, 2009). Zhihui Fang (1996) posits that this contradiction may be due to the multifarious nature of a teacher’s work and that particular
structures and contexts may constrain teacher practice. Nonetheless, it should be noted that beliefs can be contradictory and context-dependent.

Second, it should be acknowledged that the eleven preservice teachers in my study came from three different options and were taking other courses in the OISE Initial Teacher Education Program. Therefore, I must be cautious with my claim of my course as the sole cause of their belief change and be cognizant that other instructors and courses may have important roles to play, as well, in my participants’ belief change. I attempted to mediate this limitation by deriving my research participants from one elementary option. However, that was not possible due to the low enrollment of science-focused Junior/Intermediate preservice teachers. Some participants also indicated that the practicum experiences impacted their beliefs about science education and social justice. Since I was not able to observe the eleven participants during their school practicums, I limited my data collection and analysis within the confines of our elementary science methods course unless participants made a link between the practicum and the science course.

**Conclusion**

In this chapter, I have elaborated on the methodological design of my thesis study. I provided rationales for my use of qualitative research methodology and Kathy Charmaz’s (2006) constructivist grounded theory to examine the beliefs of eleven elementary preservice teachers regarding teaching science for social justice. The research took place in a science methods course with a social justice focus during the 2011-12 academic year, where I served the dual roles of course instructor and researcher and the research participants were preservice teachers in my course. I designed the “Science and Technology Education for Elementary School Teaching”
course (EDU 1450) with the critical – cultural framework of curriculum studies, and focused on the three dimensions of teaching science for social justice. Each of these dimensions is informed by a particular theoretical strand and a specific course assignment. I established validity through the consistent use of Charmaz’s criteria for constructivist grounded theory, such as credibility. For instance, I triangulated my findings using three sources of data – the beginning and end-of-the-year questionnaires, the assignments and written reflections, and year-end, semi-structured interviews. Lastly, I explained the ethical concerns and possible limitations of the study. In the next three data chapters that follow, I will explain my findings for each research question regarding beliefs and teaching science for social justice.
CHAPTER 4

INITIAL BELIEFS ABOUT TEACHING SCIENCE FOR SOCIAL JUSTICE

This chapter will address the thesis’ first central research question: What are preservice teachers’ initial beliefs concerning teaching science for social justice? At the beginning of the academic year, all 11 participants stated that they had never considered the fusion of science and social justice. Many of them saw these two areas of study as incompatible. Since the concept of “teaching science for social justice” is quite complex and multi-dimensional, I will unpack my participants’ beliefs using four separate yet intertwined themes in order to peel away these thematic layers for explanatory purposes: (1) their beliefs about science; (2) their beliefs about teaching science; (3) their beliefs about social justice; and, finally, (4) their beliefs about teaching science for social justice. The overwhelming majority of the data for this chapter derived from the beginning-of-the-year questionnaires (BQ). However, I also used data from the individual interviews and the end-of-the-year questionnaires (EQ) to triangulate and further substantiate my analysis.

In this chapter, I will elaborate on a key finding regarding the 11 participants’ initial beliefs: they converged in their relation to the first two themes – beliefs about science and about science teaching; and they diverged in relation to the subsequent two themes – their beliefs about social justice and about teaching science for social justice. On the one hand, their responses at the beginning of the year indicated a shared adherence to a positivistic view of science. All 11 participants believed in positivism, which forwards the idea that carefully controlled and repeatedly tested scientific methods will reveal objective, value-free, and empirical truth about an independent reality (Kuhn, 1970). On the other hand, their responses to the questions on
social justice and on teaching science for social justice indicated a divergence in their beliefs: six participants revealed what can be deemed as “liberal” beliefs, while five participants disclosed what can be deemed as “transformational” beliefs. My use of the terms “liberal” and “transformational” draws from Rick Arnold and his colleagues’ (1991) articulation of the various political approaches to education, which I explained in Chapter 2. However, I prefer to use the term critical, instead of their term transformational, and will use this term throughout the remainder of the thesis. Liberal beliefs can be characterized as those concerned with intercultural respect, education as a means to success, and an emphasis on individuals and attitudes rather than social systems and oppression. In contrast, critical beliefs are concerned with systemic and institutional inequities, and aim to reposition power relations and transform schools and societies. As a quick overview, Table 4.1 lists all 11 participants, under the liberal and critical categories.

Table 4.1. Participants and Social Justice Beliefs

<table>
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<th>Participant</th>
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<td>Alex</td>
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<td>Frank</td>
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<td>Nick</td>
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Beliefs About Science

In this section, I will examine preservice teachers’ beliefs about science. Although science has a variety of definitions, it generally refers to content, process, and impact (Hodson, 2008; OME, 2007). In other words, science is the body of knowledge of the natural and human designed worlds, the activities that give rise to that knowledge, and the impact of that knowledge on society and the environment. Overall, my participants’ responses were consistent with this definition of science. As I will show, all 11 research participants converged in their understanding of science as a body of knowledge that objectively explains the truth about the natural world through a positivistic process of inquiry and is utilized to enhance the quality of human life. They also shared in the belief that science consists of particular content and process that generate objective truth with significant impact on individuals and society.

Curriculum Content: According to my participants, science curriculum content describes the physical world through the applied and life sciences of biology, chemistry, and physics. It pertains to both concrete and theoretical concepts regarding how humans understand the universe and how living and non-living things interact and are connected to one another.

Process of Scientific Inquiry: The science process of inquiry is geared towards understanding the world or how the world works (Miller, 1983). It can start simply by “asking questions and seeking answers to them” (Dayja, BQ, 9/23/11). At a more abstract level, it “lays the framework for how to decide if something is true using experimentation and reasoning” (Frank, BQ, 9/23/11). The process of inquiry is based on the scientific method as “the main tool [to] gather data and prove or disprove a hypothesis” (Walter, BQ, 9/23/11). Consequently, if the scientific method of experimentation and reasoning is properly used based on “what we can control and what we can measure” (Shiva, BQ, 9/30/11), then its results would be proven and,
therefore, considered to be true. Since my participants believe that this particular science process is “the best tool for understanding the world” (Alex, BQ, 9/30/11), they want to teach it in “a fun, engaging, and stimulating way” (Rebecca, BQ, 9/23/11). Ultimately, for Carol, it ought to “stimulate a sense of wonder and joy of discovery” and to “perpetuate curiosity about the natural world” (BQ, 9/19/11).

Objective Truth: My participants believed that strict adherence to the scientific method would produce factual knowledge and objective truth. They held up science as “the holy grail of truth and knowledge” (Walter, BQ, 9/23/11). It is a “black or white subject” with the irrefutable power to depict “the proven truth about the natural world” (Nick, BQ, 9/19/11). For my participants, if something is not or cannot be proven through the scientific method, then “it’s not truly science” (Frank, BQ, 9/23/11). Since the scientific method is conventionally viewed as a neutral, value-free enterprise (Abd-El-Khalick, 2005), science is deemed factual and objective, setting itself apart from other bodies of knowledge “like philosophy, religion, and the social sciences that are based on opinions and feelings” (Maria, Interview, 6/8/12). In one of his responses to the beginning-of-the-year questionnaire, Ben disclosed not only his belief regarding the power of science, but also his irritation to what he viewed as my relativistic use of science: “I am genuinely irritated that you used the phrase, ‘there are no right or wrong answers’ about science. I believe that science gives us right and wrong answers” (9/23/11).

Impact of Science: Science is significant because, according to Tina, it “touches every single aspect of our lives” (BQ, 9/19/11). She elaborates on this idea by indicating, “What could be more important than science? It is everywhere, all around us. It’s in the sky, the lakes, the ground. It’s in our computers and hospitals. Really, if you think about it, science is everywhere” (Ibid.). Linked to the significance of science is its impact everywhere in nature and in the human-
designed worlds of computers and hospitals. Frank noted the impact of science because “science is application heavy. What is most important is that it helps our lives. If I am sick, I count on science” (BQ, 9/23/11).

My participants’ definitions of and beliefs about science, particularly the objectivity of science, are aligned with previous studies concerning preservice teachers’ beliefs about the nature of science (Abd-El-Khalick & Lederman, 2000; Borda, et al., 2009; Southerland & Gess-Newsome, 1999). Like my participants, many preservice and practicing teachers hold a dominant view of science as positivistic. According to Glen Aikenhead and Masakata Ogawaw (2007), positivism:

> passionately emphasizes inductive and deductive logic applied impartially to theory-neutral observations and strict empirical and experimental methodologies, all of which yield objective, value-free, secure knowledge…. Positivists consider their scientific thinking to be the ultimate measure of rationality and therefore, positivists’ knowledge singularly represents the fidelity of a true word. (p. 550)

A positivistic focus on strict and impersonal procedures gives credence to the scientific method as the best way of understanding reality.

The belief in the positivistic procedures of the scientific method is one of the most pervasive hallmarks of Western science (Aikenhead & Michell, 2011; Hodson, 2008). All my participants shared a strong faith in the scientific method as a set of prescribed steps to make observations, ask questions, form hypotheses, conduct tests or experiments, collect data, and draw conclusions. Carol recalled that “Doing science always begins with an observation. This prompts a scientist or student to form a hypothesis and to do the scientific method (BQ, 9/23/11). By adhering to its impersonal and empirical steps, the scientific method is able to produce objective facts about the world. Nick indicated that “When I think of science, I think of
information that is verifiable, reliable and valid…. science provides us with facts about the world…. You cannot argue with the facts” (BQ, 9/19/11).

Since science content as “facts” and “truths” derives from careful and methodical investigation, its results are considered universal. Universalism is presumed by a positivistic epistemology which asserts that scientific knowledge is verifiable information that depicts one true image of reality (Brickhouse, 1994; Stanley & Brickhouse, 1994). Shiva confirmed this position by stating that “Science is the same everywhere you go. The sun rises on one side of the world and sets on the other” (BQ, 9/30/11). She also believed that “There is good and bad science. Good science has gone through peer review and has been rigorously tested. Therefore, I don’t really believe gender, race, class, etc. have anything to do with science” (Ibid.). Shiva’s response represents my research participants’ general universalist perspective of science. Her response indicates a faith in the objective power of science to produce value-free knowledge that is so generalizable that only one universalized result is possible. Furthermore, her focus on peer review and rigorous testing situates science as solid, irrefutable knowledge.

Beliefs About Teaching Science

In this section, I will focus on how preservice teachers envisioned science instruction and how their vision was shaped and informed by their past experiences as students of science. All 11 participants articulated a personal vision for science instruction in response to the ways in which they were taught science during their elementary and high school years. Individually and collectively, they rejected the science pedagogies of their former teachers, and sought to re-imagine how science can and ought to be taught when they become teachers. All but one of the participants in this study completed their K-12 and university education in the greater Toronto
area. The sole exception, Shiva, attended elementary school in Iran, but went to high school and university in Toronto.

In response to questions regarding their elementary school science experiences, participants unanimously referred to “transmission style learning … based on a textbook and lots of memorization” (Tina, Interview, 5/3/12). They described the importance of the scientific method (Hodson, 2001), which was taught in elementary school, but only two participants recalled actually using it to conduct experiments. For the most part, as Frank recalled, “the scientific method was up on the wall and I can still remember the steps to this day, but we only discussed the process [and] never engaged with it” (Interview, 4/28/12). Their experiences with science teaching continued in high school, which they described as “boring” (Alex, Interview, 6/7/12) and “textbook heavy” (Maria, Interview, 6/8/12) with “a lot of rote memorization” (Ben, Interview, 4/27/12). Consequently, their previous K-12 school experiences generated a love/hate relationship with science. Dayja confessed, “I loved science. I loved reading about science. I loved exploring the park by my house. But school science almost did me in. In fact, my high school science classes nearly killed my love of science” (Interview, 5/4/12).

All 11 participants described their personal vision of teaching science as rooted in the curiosity of their students. They shared the belief that “Children are curious. We need to capitalize on this, … feed their curiosities, and teach them so much more than just facts about the world…. They need to understand the processes of science and experience science with their hands and minds” (Rebecca, BQ, 9/23/11). Dayja lamented, “It is sad really. Science can be so much fun, but I never had a single teacher make it fun. I have always loved spiders, and in grade three we did a spiders unit. The teacher could have brought in spiders or something, … [but] we just read from the textbook. That’s not science” (Interview, 5/4/12). Rejecting the transmission
style of learning that they were subjected to as students (Freire, 1970), participants espoused a vision of science pedagogy as relevant, engaging, and stimulating that incorporates investigation and exploration. Their rejection of the transmission style of science instruction was also linked to their concern regarding how it does not allow students to develop critical thinking skills. Alex maintained that “Teaching science is about teaching students to think critically and to engage with the scientific method and the skills associated with it in a hands-on way…. Our future students should be taught to think, not just be sponges who absorb information” (BQ, 9/30/11). Decrying the methods by which they experienced science, participants asserted that students must engage with the scientific method in a hands-on way so that they could develop critical thinking skills. Participants envisioned their own classrooms where students are actively engaged in activities and experiments that pique their individual interests, utilizing the scientific method to discover scientific truths and in general enjoying science.

Beliefs About Social Justice

Whereas all 11 participants converged and shared similar beliefs about science and teaching science, they diverged in their beliefs about social justice. My analysis reveals two types of initial beliefs: liberal and critical beliefs about social justice. Out of the 11 preservice teachers in this study, six espoused liberal beliefs about social justice at the beginning of the year. Those with liberal beliefs stressed the need for intercultural understanding and respect. They indicated that diversity in school and society should be celebrated by bringing in multicultural examples of science through what James and Cherry Banks (2010) refer to as a “contributions approach” or “the insertion of ethnic heroes/heroines and discrete cultural artifacts
in to the curriculum” (p. 237). They referred to “cultural groups” when discussing diversity, but made no reference to specific races or ethnicities.

On the other hand, five preservice teachers espoused critical beliefs about social justice that recognized and challenged multiple forms of systemic oppression in schools. They believed that teachers must engage in critical pedagogy (May & Sleeter, 2010; McLaren, 2003) and involve students in explicit conversations about injustice concerning issues of race, class, gender, and sexuality. They made explicit references to issues of power, privilege, and marginalization. However, these preservice teachers’ beliefs depicted a contradiction. While they possessed beliefs that aimed to challenge systemic inequities, they still possessed a positivistic view of science. In other words, although they occupied the critical category when it came to social justice issues, they did not challenge the content and inquiry process of science. My analysis of the questionnaires, supplemented by the individual interviews, indicates clear distinctions between those with liberal beliefs in comparison to those with critical beliefs. These distinctions manifest in the three main themes of their definitions of social justice, the sources of their social justice beliefs, and the role of the teacher, which I will further explain below.

**Definitions of Social Justice**

*Liberal:* Participants with liberal beliefs emphasized the values of freedom, democracy, and equality for all when discussing social justice. They also used the terms “diversity” and “culture” in their responses about social justice, but with very rare exceptions, did not mention specific social locations or identities in relation to race, class, or gender. They consistently referred to Canada’s multicultural policies as a cornerstone of this country’s social justice commitment (Carr & Lund, 2007). Nick elaborated on this position by stating “I am glad that I
am Canadian because we view diversity as a strength rather than a detriment… We are all equal anyway” (Interview, 6/9/12). His response drew upon a belief of equality that was based on individuals and their actions, but accounted for neither systems of marginalization, nor a macro-view of oppression in schooling. Alex also shared a belief about social justice that primarily pertained to individuals, rather than structures that privileged some and worked against others. He said,

I’m Jewish, so I know that sometimes people will make stereotypical comments. Social justice happens when we develop an awareness about other cultures [and] then hopefully snide comments [will] cease. But at the end of the day, it’s about my responsibility to not let those comments bother me. (Interview, 6/7/12)

These statements support the need for intercultural awareness and harmony through learning “about the other” (Kumashiro, 2000; Kymlicka, 2010). They also take an individualistic approach to addressing and not addressing social justice issues in schooling, thereby failing to recognize various forms of systemic and institutional oppression.

**Critical:** Whereas those with liberal beliefs described social justice by bringing about equality through cultural awareness of others, participants with critical beliefs defined social justice as acknowledging and challenging multiple forms of systemic oppression in school and society (McCready, 2010). Tina’s comments represented the critical group when she said,

Social justice comes from making an effort to recognize and then address inequities in the classroom, community, and society as a whole. For instance, discrimination around race, religion, gender, sexuality, intellectual and physical ability, and language are themes from which social justice issues stem. (Interview, 9/19/11)

Whereas the liberal group indicated only learning about the other, the critical group combined learning about and acting upon the oppression of others. All five critical participants pointed out the shortcoming of liberal perspectives, and contrasted their view of social justice as action-oriented. For example, Dayja adamantly opposed a liberal approach to social justice: “Making
students aware of racism and other forms of discrimination does not get to the root of the problem…. It’s just barely scratching the surface of social justice work” (Interview, 5/4/12).

**Sources of Social Justice Beliefs**

There are clear demarcations between the liberal and critical groups concerning social justice in schooling. The liberal group’s agenda of social awareness and tolerance was seen as superficial and counterproductive by the critical group that urged to take into consideration power structures in the dynamics of schools and society. My analysis of the individual interview data uncovers notable transformative experiences in the lives of my participants in the critical group that might explain important sources of their social justice beliefs. All five critical participants shared experiences of disempowerment related to their respective social locations and identities as racialized, ethnicized, gendered, and classed individuals. They pointed out these experiences as instrumental in their development of social justice beliefs. Meanwhile, the liberal participants did not explicitly disclose particular personal experiences of disempowerment and/or transformation, or how their social locations and identities mattered in their daily interactions in school and society.

*Liberal:* While those who possessed critical beliefs about social justice could explicitly describe instances of disempowerment and/or transformation, the six participants with liberal beliefs did not. Rather, they described overall positive experiences in school and society. Two of the liberal participants self-identified as visible minorities: Frank is of Chinese descent, and Shiva is of Iranian descent. Both Frank and Shiva come from upper-middle class families living in the Toronto suburbs that were predominantly White. They recalled a few instances of being teased when they were growing up due to their “cultural” differences, but attributed them to
“kids being kids” rather than racial discrimination (Frank, Interview, 4/28/12). There was another racialized minority in the group, Carol who is of Argentinean descent and can easily pass as White. She did not self-identify as a visible minority and did not disclose any experience of marginalization. The three other liberal participants – Nick, Alex, and Rebecca self-identified as Italian, Jewish, and Caucasian, respectively – offered no examples or minimized instances of discrimination in school and society.

Critical: The five critical participants shared details of personal marginalization due to their race, class, and/or gender, and considered these experiences as pivotal in their development of social justice beliefs. Dayja, who self-identified as Black Canadian and grew up in a poor, single-mother home in the Jane and Finch area of Toronto\(^1\), recounted her unease while shopping outside of her community: “I know how I am viewed as Black…. We’re not trusted…. All my life, I have hated shopping in downtown Toronto. If our city was truly multicultural, the women who work in those stores wouldn’t glare at me and follow me around” (Interview, 5/4/12). Her comment countered the mainstream liberal pride in Canada’s multicultural policy. While many proudly state that racial diversity is welcomed in Canada due to its official policy which claims that “diversity is a national asset” (Citizenship and Immigration Canada, 2012), Dayja’s experience as a racialized minority proved otherwise.

Ben shared Dayja’s concern about the failure of the multiculturalism policy by describing his own experiences of racial discrimination. Like Dayja, Ben grew up in the Jane and Finch area of Toronto. Born to Black parents and adopted at birth by White parents, he self-identified as “half Black and half White.” He recalled being “called the ‘N-word’ and other profanities. Teachers have thought I was dumb because I process slowly, and being 6’4” with a big afro, you

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\(^1\) James and Haig-Brown (2001) refer to the Jane and Finch community as a “low-income area of metropolitan Toronto characterized by diversity in ethnicity, race, and religion” (p. 230).
can imagine how people steer clear of me on the street… One time, I couldn’t even get into a club for a friend’s birthday party. I was so embarrassed” (Interview, 4/27/12). Even though Ben self-identified as “half Black and half White” due to his particular circumstances, his daily encounters assured him that school and society saw him as Black.

Walter, a second-generation Korean Canadian, who grew up in a middle class neighborhood in Toronto, shared his concerns regarding the media and education’s role in perpetuating negative stereotypes about Asians (Lee, 2009). During his interview, he said, “I have always been uncomfortable with how Asians are portrayed in the media. As an Asian man, I have never really felt masculine enough. The media feminizes Asian guys and it makes me feel very unattractive…. I still battle this” (Walter, Interview, 4/25/12). He was also keenly aware of the model minority stereotype that many educators have of Asian students. He stated that, “I have seen it for years and even in my practicums. Teachers believe Asians are super smart and obedient…. If they don’t act that way, they think something is wrong with the kid. I just want to say ‘Hold up. Not all Asians are good at math.’ It’s painful” (Ibid.). He expressed dismay that particular individuals and groups in society are expected to perform in particular ways and subsequently receive different expectations. He recognized the media and educational systems’ constructions of Asians in negative and detrimental ways and how these constructions play out as stereotypes in society. For Walter, these depictions “can be dangerous for Asian students” (Ibid.), and served as an impetus for his social justice beliefs.

Tina became aware of injustice growing up as the only female and the youngest of four siblings in a “traditional Italian” family that was steeped in the Catholic faith. She indicated that

In our culture, the men make all the decisions because they are biblically the head of the household. My mother saw her role as serving my father and my brothers…. My brothers had many opportunities that I did not have because I was female. I don’t care if it’s cultural or not, I am not going to put up with that. (Interview, 5/3/12)
Tina shared many stories about going “toe to toe” with her father and brothers and that she was considered a “radical feminist” by her family. She asserted that “I was rebellious. But if standing up for equal rights makes me a rebel, then I am proud to be one” (Ibid.).

All five participants in the critical group shared personal narratives of real-life experiences of marginalization, which they attributed as crucial in shaping their beliefs concerning social justice and their subsequent commitments and actions to disrupt systems of power in school and society. Yet, interestingly, these experiences did not alter their positivistic view about science as a body of knowledge and about the teaching of science.

**Role of Teacher**

*Liberal:* Participants with liberal beliefs viewed teachers as facilitators of harmonious and tolerant learning communities. They believed that all students are “equal and essentially the same” and that they should be taught to respect individual differences (Alex, BQ, 9/30/11). Doing so could create a classroom that fostered a strong sense of community. According to Carol, “Teaching for social justice is about promoting a positive and accepting learning environment. I mean, there are cultural differences between students, and we have to learn to respect these differences…. After all, this is Canada” (Interview, 9/19/11). Liberal participants addressed student achievement by focusing on students’ variety of learning styles and making learning exciting. Nick stated, “All students can reach their full potential if their teacher is socially just during instruction…. This means being aware which students need auditory, visual, or kinesthetic activities” (BQ, 9/19/11). Rebecca also said, “Some students do not reach their full potential, so a teacher must stimulate the interests of her students by making learning exciting”
All six participants in this group described the importance of making learning interesting and subsequently increasing engagement and student success.

Critical: Participants with critical beliefs described the role of teacher differently in comparison to those with liberal beliefs. Whereas the liberal group purported that inter-cultural harmony was possible through awareness and tolerance, Maria stated that teaching for social justice was far more complex: “At the root of all action and interaction is power. Some [people] have it and some don’t. How can marginalized students have equal footing in the classroom? Unless we look at who has power and who doesn’t, we can never teach for social justice” (BQ, 6/8/12). Hence, for Tina, the role of teaching for social justice included a “moral aspect” that interrogated dynamics of power and privilege (BQ, 9/19/11). Even though those with liberal beliefs stressed the inclusion of all students, they did not explicitly address the social structures and hierarchies present in school and society, how these disadvantage particular students, and how teachers might engage themselves and students to dismantle them. For Ben, a key element in this critical process was reflection combined with action, similar to what Paulo Freire (1970) terms as praxis. Ben maintained that “We all have biases and prejudices. Teaching for social justice requires the teacher to know his/her biases and then help his/her students understand theirs, as well” (BQ, 9/23/11). This self-understanding, then, needed to be linked to social action, and vice versa, in order to connect personal reflection to societal and systemic change.

Beliefs about Teaching Science for Social Justice

In this section, I will delineate preservice teachers’ initial beliefs about teaching science for social justice. Similar to the previous section, my analysis shows that my research participants’ beliefs continued to diverge along liberal and critical lines. In other words, those
with liberal beliefs held similar perspectives regarding teaching science for social justice, and those with critical beliefs did the same. All 11 participants in this study indicated that they have never considered the integration of science and social justice and that they viewed the two areas of study as incompatible. Not surprisingly, in comparison to their written responses to questions about science and about social justice in the beginning-of-the-year questionnaires, their formulation of teaching science for social justice was less developed. To elaborate further on their answers and the divergence between those with liberal and critical beliefs, this section will focus on the two main themes of the relationship between science and society and the role of the teacher.

**Relationship Between Science and Society**

*Liberal:* Participants with liberal beliefs asserted that science could be used for the “greater good” (Shiva, BQ, 9/30/11) and to “improve the lives of humanity” (Frank, BQ, 9/23/11). For example, Alex stated that, “Teaching science for social justice is using scientific and technological breakthroughs to improve the lives of those who lack access to basic needs like food, health, and safety” (BQ, 9/23/11). Carol further explained through an example of using science to solve local issues: elementary students could learn the “science behind” food nutrition, making healthy eating choices and engaging in social justice at the same time (BQ, 9/19/11). While learning science, students could “make sandwiches for hungry children in the neighborhood, hand them out,” and direct families to local food banks. While this activity engages students in science and “doing something good for society” (Ibid.), in my view it perpetuates a charity model of social justice. In this charity model, science is utilized by those who possess resources, and social justice is done to the marginalized. Liberal participants
promote using science to benefit individuals; however, they do not account for issues of systemic marginalization, power, and privilege.

Critical: Participants with critical beliefs depicted a different relationship between science and society in comparison to those with liberal beliefs. Even though they also advocated for the use of science to support disenfranchised individuals, their responses reflected a more meaningful understanding of power and social change. Tina urged for the use of science to “improve people’s livelihoods” that were rooted in inequities and complicities in Canada and beyond: “Medicine without Borders is a clear example of how science and the practice of science and scientific tools and methodologies are used for social change…. However, we need to look at Canada’s role in the economic turmoil of third world countries…. We are not guilt free” (Tina, BQ, 9/19/11). Like Tina, both Maria’s and Dayja’s responses also indicated analysis of unequal power relationships as they addressed Canada’s role in the extraction and depletion of resources from developing nations for our country’s economic and material gain. They offered insightful examples of the use of science to fuel rampant consumerism and the relationship between science and capitalism.

Ben viewed teaching science for social justice as preparing students to use science to address their local community concerns and to advocate for social change. He argued that “teaching should be through investigation, experimentation and discovery and how to challenge and ultimately illuminate injustice in our society…. It might look like asking the class what are some issues that concern them that science could address” (Ben, BQ, 9/23/11). During our interview session, I asked Ben to elaborate on this statement. He responded, “I mean any issue that might be important to urban students … engaging and empowering them to make positive changes in their own communities … like issues of environmental racism” (his emphasis;
Ben believed that marginalized students ought to simultaneously learn science and engage in social justice efforts that affect their own neighborhoods. His critical view sharply contrasts with Carol’s liberal perspective because, in Ben’s case, students become both producers of science and agents of social change.

**Role of Teacher**

Liberal and critical participants continued to exhibit diverging beliefs regarding the teacher’s role in teaching science for social justice. Their beliefs reflected and were an extension of their initial beliefs about social justice.

*Liberal:* Participants who possessed liberal beliefs focused on creating a classroom environment that would be conducive to learning science. Such an environment would be “welcoming and would encourage scientific exploration” (Carol, BQ, 9/19/11). Rebecca stated that teachers should “share their passion for science with young children and youth in a safe, comfortable, welcoming environment … and model respect in the classroom while teaching science, respecting each other and our earth” (BQ, 9/23/11). Liberal participants stressed the need for a cohesive classroom community. Pedagogically, they emphasized the importance of making science learning both fun and meaningful for their students. For Alex, “teaching science for social justice means we need to make science relevant to [students’] daily lives…. They must be shown the applicability of science … in a hands-on way” (BQ, 9/30/11). They all believed that scientists from many cultures should be incorporated into the curriculum to make science relevant. Nick asserted the importance of “mak[ing] students aware of the contributions of scientists across the globe” as a means to teach science for social justice (BQ, 9/19/11). While
liberal participants stressed a contributions approach to science education, it was still based on
the premise that that these contributions adhered to a Western, positivistic notion of science.

Critical: Participants with critical beliefs were similarly committed to teaching science
for social justice which would integrate enthusiasm and relevance. However, their views also
included a desire to “even-ing the playing field” by attending to issues of power and privilege
(Maria, BQ, 9/23/11). In the context of science, Walter said, “Students should be given the
capacity not only to explore, investigate, and make sense of the world, but to also critically
evaluate, question, and deconstruct the oppressive structures in it” (BQ, 9/23/11). This explicit
attention to unequal power relations was not evident in any of the responses from participants
with liberal beliefs. In addition, even though both liberal and critical participants urged teachers
to select curriculum that would represent non-European and non-dominant scientists and groups,
only those with critical beliefs interrogated why particular voices were left out of official
textbooks and curriculum. For example, Dayja suggested that teaching science for social justice
must incorporate issues of colonialism:

Teachers must teach about discoveries from individuals that are not European and by
teaching about environments, practices, events and habitats outside of North America…. After all, science as it is taught represents the accomplishments of White men, who have
exploited others and stole their accomplishments…. My students will know why
particular stories are told and others left out…. That is fusing science with social justice.
(Dayja, BQ, 9/23/11)

Conclusion

In this chapter, I have examined preservice teachers’ initial beliefs concerning teaching
science for social justice. Since their beliefs were complex and multi-layered, I unpacked them
using the following themes based on their questionnaire and interview responses: (1) their beliefs
about science; (2) their beliefs about science teaching; (3) their beliefs about social justice; and,
lastly, (4) their beliefs about teaching science for social justice. My analysis indicates that all 11 participants shared converging beliefs about science and science teaching. They considered science as consisting of particular content and process that would generate objective truth with significant impact. They also rejected their former teachers’ transmission style of science pedagogy when they were elementary and high school students, and consequently were committed to grounding their future teaching based on the curiosity of their students. However, participants diverged into two categories concerning their beliefs about social justice and teaching science for social justice. At the beginning of the year, six participants espoused liberal beliefs, and five participants held critical beliefs. Their differences manifested in their definitions of social justice, the sources of their social justice beliefs, the relationship between science and society, and the role of the teacher in integrating science and social justice. In the critical group, all five participants were unaware of a contradiction inherent in their beliefs. While they stressed the need to challenge multiple forms of oppression in school and society, they did not question the hegemonic positivism of science. Further distinctions between the liberal and critical participants will become evident in the next chapter, which will discuss the shifts in their beliefs throughout and at the end of the academic year.
CHAPTER 5

CHANGES IN BELIEFS ABOUT TEACHING SCIENCE FOR SOCIAL JUSTICE

This chapter will focus on the thesis’ second central research question: *How have preservice teachers’ beliefs concerning teaching science for social justice shifted during the course?* I will address this question by building upon a key finding in the previous chapter where two groups of participants emerged at the beginning of the year: those who generally possessed liberal beliefs and those who generally held critical beliefs. On the one hand, liberal participants emphasized awareness and tolerance of social differences. Although humanistic in intent, their approach of celebrating differences did not interrogate inequities revolving around race, ethnicity, gender, class, and other markers of social difference inherent in school and society (Arnold et al., 1991). On the other hand, critical participants espoused strong beliefs that foregrounded issues of power and oppression prevalent in society and subsequently mirrored in schools. Those with critical beliefs were explicit that teachers should possess a transformative agenda that would challenge dominant ideologies and dismantle unequal power structures. For my analysis in this chapter, I closely scrutinized the participants in each group to ascertain any shift in their beliefs throughout and at the end of the elementary science methods course. In particular, I examined their responses to the individual interviews and end-of-the-year questionnaires as well as their course documents in the form of assignments and written reflections.

In this chapter, I will elaborate on a major finding regarding the participants’ changes in beliefs about teaching science for social justice. At the end of the year, all 11 preservice teachers in this study demonstrated shifts in their initial beliefs. They demonstrated three types or degrees
of shifts – minimal, substantial, and refined. More specifically, four participants with liberal views showed minimal shifts in their beliefs about teaching science for social justice; the other two participants with liberal views showed substantial shifts; and all five participants with critical views showed refined shifts in their beliefs.

In order to determine these changes, I explored the preservice teachers’ beliefs in response to the three dimensions of teaching science for social justice, which served as the guiding foundation for my “Science and Technology Education for Elementary School Teaching” course (EDU 1450). These three dimensions were critical nature of science (CNOS), critical knowledge and pedagogy (CKP), and sociopolitical action (SPA).

**Dimensions and Changes**

This section will provide an overview of the three dimensions of teaching science for social justice (which was fully explained in Chapter 2) and of the changes in beliefs shown by participants by the end of the year.

*Critical Nature of Science (CNOS):* Since the nature of science refers to the epistemology of science or science as a way of knowing, a *critical* analysis of the nature of science situates this epistemological foundation or way of knowing within power relations (Brickhouse, 1994). In my course, I asked my students to interrogate the ideologies, beliefs, politics, and conditions of knowledge production. I posed questions, such as: What kind of science gets done? Who funds it, and for what purpose? Whose perspectives are present, and whose are not? What sociopolitical and historical conditions shape science and its teaching and learning? We explored these questions by reading and discussing texts from the history, philosophy, and sociology of science and on Aboriginal worldviews and knowledges. Critical nature of science, therefore,
challenges the positivistic and allegedly neutral ways in which science and science education have been constructed, and aims to embrace new ways of teaching science through diverse epistemologies (Aikenhead & Michell, 2011).

**Critical Knowledge and Pedagogy (CKP):** The next dimension refers to the knowledges and pedagogies that teachers draw upon in order to make science relevant to racially and culturally diverse learners and to enhance their academic achievement (Gay, 2000; Ladson-Billings; 1994). In my course, I asked preservice teachers to consider questions, such as: How does the curriculum represent (or not) the lived experiences of my students? How do I build on my students’ funds of knowledge for teaching and learning? Am I prepared to explicitly address issues of racism and other forms of oppression in my classroom? I posed these questions in order to situate teaching and learning as sites of power where dominant beliefs and ways of being are reproduced in schools. I wanted them to consider what we know not only about our students, but also about ourselves. Since marginalized students are often viewed from a deficit perspective, this dimension urges us to utilize students’ funds of knowledge from their home and community as assets and resources in education (Gonzales et al., 2005).

**Sociopolitical Action (SPA):** The last dimension is broadly concerned with the impact of science and technology on society and the environment (STSE) and with the development of advocates who will use science to benefit marginalized communities and address socioscientific issues (Pedretti & Nazir, 2011; Calabrese-Barton, 2003). Of particular interest to me in this dimension is the empowerment of racialized minority and low-income students who live in urban ecologies to become critics and producers of science as they work towards transforming their local communities (Calabrese-Barton & Tan, 2010). In my course, I asked preservice teachers to grapple with questions, such as: How do I encourage my students to become agents of change?
What are the enablers and barriers to becoming change agents? What different forms of advocacy are appropriate for elementary school students? When I selected environmental justice as a topic that they needed to address, especially in relation to the “winners and losers” of scientific innovation and globalization, I posed additional questions, such as: What happens to highly toxic electronic waste? Which communities are generally sites for hazardous waste disposal? What are the local and global costs when resources are extracted from developing nations? What changes can be made to our rampant consumerism? Ultimately, I urged preservice teachers to enact science pedagogy that incorporated sociopolitical action that alerts students to various injustices and prepares them for age-appropriate action.

Out of the six participants who began the year with liberal beliefs concerning teaching science for social justice, four of them – Alex, Carol, Frank, and Nick – experienced a minimal shift in their beliefs. My analysis of their data revealed that their change only took place in the first dimension of critical nature of science. They demonstrated no changes in the other two dimensions of critical knowledge and pedagogy and sociopolitical action. Therefore, they began and ended the course with liberal beliefs. However, two participants who began the year with liberal beliefs showed substantial shifts. For this study, I defined “substantial” as change occurring in more than one dimension of teaching science for social justice. Rebecca and Shiva demonstrated shifts in all three dimensions, consequently moving their beliefs from liberal to critical. By the end of the year, both of them shared beliefs that explicitly engaged with issues of power and privilege, that critically interrogated curriculum, teaching, and learning, and that urgently called for addressing injustice in a socially stratified society. Finally, all five participants – Ben, Dayja, Maria, Tina, and Walter – who espoused critical beliefs concerning teaching science for social justice demonstrated a refinement in their initial beliefs by the end of
the year. They indicated that the course fine-tuned or polished the beliefs that they held at the beginning of the year.

For the remainder of this chapter, I will further elaborate on the three types or degrees of changes in beliefs – minimal, substantial, and refined – in relation to the three dimensions of critical nature of science, critical knowledge and pedagogy, and sociopolitical action. The next section will focus on liberal participants who showed a minimal shift, followed by those who experienced substantial shifts, and ending with the critical participants who demonstrated refinement in their beliefs.

Participants with Liberal Beliefs Who Made Minimal Shifts

Four participants with initial liberal beliefs demonstrated a minimal shift by the end of the year. More specifically, Alex, Carol, Frank, and Nick experienced a slight shift only in one dimension, the critical nature of science. There were no discernible shifts in the other two dimensions. All four participants held firmly to their positivistic view of reality that was grounded in the dominant Western science framework. They remained consistent in their shared belief that science and social justice were greatly incompatible. They were determined in the preservation of scientific knowledge, and saw the juxtaposition of science and social justice as a threat to the integrity of science. For example, Alex argued that science would be “water[ed] down” and that students would not receive its full benefit by incorporating social justice issues (Interview, 6/7/12). He explained that “Social justice is soft science. It’s not like biology or chemistry … [that] are hard sciences. If we dilute science with social justice, our students are going to miss out on content…. That’s a disservice to kids” (Ibid.). Ultimately, my analysis of the data from the liberal participants with minimal shift reveals that they sought to maintain or
reinforce the status quo and, in some cases, resisted my pedagogical efforts. This occurred in all three dimensions, which I will further elaborate below.

**Critical Nature of Science**

Since a critical analysis of the nature of science challenges the epistemology of science, it interrogates the positivist foundations of science by questioning its objectivity and ability to depict the one ‘truth’ about the natural world. Doing so makes way for possible engagements with diverse, non-Western worldviews and ways of knowing (Harding, 1991). I explicitly countered the dominant view of science in our “Science and Technology Education for Elementary School Teaching” course (EDU 1450) by situating science as a critical-cultural practice, which I explained in detail in Chapter 2. Since science is produced, circulated, and made meaningful by humans, I maintained in my teaching that it cannot be absolutely objective and is therefore value-laden. However, these four participants firmly held to their positivist beliefs concerning the nature of science, and did not embrace my constructivist view of science.

With that being said, these participants demonstrated a *slight* interest to consider a variety of cultural worldviews for their future teaching as long as they reflected Western science and were underpinned by positivism. For example, Frank said, “I do believe that empirical data gathered by peoples all over the world throughout the course of times holds value. But it will only be as valuable as our scientific principles if it is derived empirically, objectively, and can be reproduced” (Interview, 4/28/12). His statement reflected both a firm reliance on science that was rooted in positivism and a somewhat willingness to incorporate diverse perspectives so long as they were aligned with the positivist tradition. This view of accepting diverse viewpoints, while remaining within the dominant science framework, was generally shared by others in the
group. Carol also believed that “Science is an objective body of facts … [with] right and wrong answers,” yet she indicated an interest to integrate Aboriginal perspectives into science (Interview, 5/5/12). Similar to Carol, Nick in his assignment reflection wrote: “While I appreciated the readings on Aboriginal perspectives, I have a hard time calling them science. In this day and age, I find it hard to fathom that Aboriginal perspectives carry the same weight as Western science” (Assignment #1, 11/29/11).

**Critical Knowledge and Pedagogy**

The critical knowledge and pedagogy dimension demands that science instruction ought to be linked to students’ cultures and worldviews. Working against the deficit approach, teachers need to access students’ funds of knowledge and engage in culturally relevant pedagogy (Ladson-Billings, 1995). However, in this dimension, the four liberal participants demonstrated no discernible shift in their initial beliefs. My analysis of their data suggests that their lack of change was greatly due to a shared belief that minimized the role of race, ethnicity, and culture in the science teaching and learning process.

These participants claimed that culturally relevant pedagogy was dangerous because it could end up stereotyping students, and instead favored a color-blind pedagogy (Derman-Sparks & Phillips, 1997; Pennington et al., 2012) that “treated all students as individuals” (Nick, EQ, 2/7/12). Carol said, “I believe we should look at individual students and not make generalizations about groups of students. CRP [culturally relevant pedagogy] reinforces stereotypes, and I am not comfortable with that” (Interview, 5/5/12). Further highlighting the value of individualism and meritocracy (Rosenberg, 2004; Solomon et al., 2005), Frank stated, “I am going to select good lessons because they are good lessons, not because they are culturally specific, but because
they encourage critical thinking’” (Interview, 4/28/12). Focusing on students’ racial and cultural attributes, for Frank, was a form of “babying certain students” (Ibid.). Since it would be impossible for a teacher to “attend to every culture,” highlighting a racial or cultural group over others would be, in his eyes, a form of unjust privileging (Ibid.).

These beliefs were also evident in the participants’ course documents. For example, Assignment #3 required them to create a Culturally Relevant Science Lesson Plan, which included a written reflection on the product and their process of completing it. My analysis of their lesson plans and reflections suggests a discomfort and even resistance to following the assignment’s guidelines due to their belief concerning the irrelevance of race, ethnicity, and culture in science and science education (Case & Hemmings, 2005). For instance, neither Frank nor Carol made any reference to student identity or social location in their assignment. Instead, Frank’s lesson plan required students to create a Rube Goldberg Machine2, a common Grade 6 task in the Understanding Structures and Mechanisms strand of the Ontario Curriculum. To make the lesson supposedly culturally relevant, Frank wrote that “the students will use relevant school supplies to build the Rube Goldberg Machine” (Assignment #3, 4/5/12). During the interview, I inquired what he meant by “relevant” school supplies. He responded with “things like wood, nails, rulers, and graph paper” (4/28/12). When pressed further, he indicated, “I did not go the racial route because doing so leaves some kids behind. It’s not treating them equally or equitably” (Ibid.). Similarly, Carol’s lesson plan focused on having students create a classroom compost bin. Her rationale for the lesson’s culturally relevance was: “environmentalism is relevant to every student because it affects us all” (Assignment #3, 2/7/12).

2 Named after American cartoonist and inventor Rube Goldberg (1883–1970), a Rube Goldberg Machine is a deliberately over-designed machine that performs a very simple task in a very complex fashion that usually includes a chain reaction.
Sociopolitical Action

Sociopolitical science teaching seeks to produce teacher and student activists. It examines the effects of science on society and the environment and how they intersect with race and class (Brickhouse, 1994). In this dimension, the four liberal participants did not exhibit any discernable shift in their beliefs. While they believed that science should incite critical thinking in students, they were adamantly opposed to addressing sociopolitical issues in their classrooms. They were adamant that teachers should not engage in activism or teach their students to become activists. Doing so, they argued, would be a form of “indoctrination” that should be avoided (Nick, Interview, 6/9/12). Frank indicated that “We cannot teach students to be activists without telling them what to think. I would rather teach them to be curious and to think critically. They can make up their own minds about these issues” (Interview, 4/28/12). The participants also expressed the belief that controversial issues should only be addressed if students brought them up and that teachers, according to Carol, should not “open a can of worms” or be a catalyst for learning about controversial issues (Interview, 2/7/12). Alex maintained that social justice should be kept to a minimum in science teaching because it had the potential to “impede individual progress” (Interview, 6/7/12). Each person should be responsible for overcoming obstacles, and “too much social justice” would not empower the oppressed to “better themselves” (Ibid.). Alex’s beliefs resonated with Frank’s earlier statement about “babying certain students” in that incorporating controversial issues, such as race and culture, into the classroom may impede motivation for success. Overall, this group’s individual and collective responses displayed a firm belief in a meritocratic society where individuals would have the opportunity and ability to overcome social obstacles if they worked hard enough (Feagin, 2001).
To address the sociopolitical action dimension, Assignment #2 in my course asked preservice teachers to create an Environmental Justice Strategy that would use science to benefit marginalized communities or that would enable marginalized students to use science to address local concerns. For this assignment, I encouraged them to explore various age-appropriate ways for elementary students to take the role of activists. Frank and Alex created strategies that were related to a case study that I presented in class concerning the detrimental impact of industrialization on Aboriginal communities in Sarnia, Ontario. They both selected letter writing as their approach to student activism. In their written reflections for this assignment, they shared their unhappiness with engaging students as activists. For example, Frank wrote, “Although what happened in Sarnia is wrong and I don’t agree with it, we cannot use our students as political instruments. It is beyond a teacher’s responsibility and wrong to do so” (Assignment #3, 2/10/12). Meanwhile, Carol and Nick selected landfills and ozone depletion, respectively, as issues for their Environmental Justice Strategies. However, neither one of them connected the environmental justice topics to particular communities. Instead, they claimed to have selected issues that had a “global effect on everyone on the planet” (Nick, Assignment #3, 1/17/12).

Participants with Liberal Beliefs Who Made Substantial Shifts

By the end of the year, two participants with initial liberal views exhibited substantial shifts in their beliefs about teaching science for social justice. Both Rebecca and Shiva experienced changes in all three dimensions, thus consequently moving from the liberal to the critical category. They both shared beliefs that explicitly engaged with issues of power and privilege, that critically interrogated curriculum, teaching, and learning, and that urgently called for addressing injustice in school and society. In their interviews, they recognized the changes in
their beliefs, and displayed unease and embarrassment concerning their initial beliefs. In order to delve deeply into their changes, I will focus on Shiva for the first dimension of critical nature of science, on both Rebecca and Shiva for the second dimension of critical knowledge and pedagogy, and on Rebecca for the third dimension of sociopolitical action. Although both of these participants experienced substantial changes in all three dimensions, I selected these particular examples because they offer rich depictions of belief changes.

**Critical Nature of Science**

Shiva began the year stating that she “passionately” believed in the need for social justice work (BQ, 9/30/11). She expressed that her experiences living in various countries and her social identity as a Muslim female shaped her understanding of the importance of addressing social justice issues in school and society. However, as the year progressed, Shiva explained that the new knowledge she encountered in the course challenged her beliefs about social justice. She confessed, “I mean, I began this journey thinking that I knew it all. I even thought equality was the same thing as equity. I hadn’t even scratched the surface of social justice…. This [course] was a humbling experience” (Interview, 6/9/12). Shiva’s change of belief in this dimension was evident in Assignment #1 where she reflected on Aboriginal knowledges in science:

> I had never thought of the possibility of there being different sciences. I thought science was factual…. I never saw a grey area with science, just black or white…. However, in the classroom, social justice cannot occur if the environment is dominated by long established thought paradigms, such as what science is, how scientific knowledge is gained, and how it is accepted…. We must break through these established paradigms. (Shiva, Assignment #1, 12/13/11)

By the end of the year, Shiva intended to challenge the long-held tradition that Western science is the single and best way to understand the world, and demonstrated a critical understanding of the nature of science as imperative to teaching science for social justice. In her words:
We must teach our students to accept the relativity of our understanding of the world around us. The subjectivity of what we consider truth and knowledge, and the ability to see other truths just as valid as our own, exist. This may be the very essence of teaching science for social justice. (Shiva, EQ, 4/10/12)

Shiva’s response indicates a marked contrast to her beginning-of-the-year beliefs reflecting a singular, objective, and universal science steeped in the positivist tradition.

**Critical Knowledge and Pedagogy**

At the beginning of the year, neither Shiva nor Rebecca believed that an analysis of race, ethnicity, or culture was relevant to science and science education because they thought that all students should be treated equally. However, by the end of the year, both participants supported the need for culturally relevant instruction and for the development of students’ critical consciousness. According to Shiva,

> At the beginning of the year, I thought just showing my students a few examples of Islamic science was sufficient. I now believe [that] this is weak social justice at best. I must make instruction culturally relevant to my students, and that means teaching them in a way that develops their own critical consciousness about all the content…. I mean content itself is culture. It represents the dominant culture! (Shiva, Interview, 6/9/12)

Shiva’s commitment to critical consciousness was also evident in her Culturally Relevant Lesson Plan (Assignment #3). In this assignment, she juxtaposed social justice outcomes with a Grade 6 space unit that she taught during her school practicum in a racially diverse classroom. She began the unit by having her students Draw-an-Astronaut, which was an adaptation of the Draw-a-Scientist activity that I used in our course (Chambers, 1983). From this activity, she troubled the view of White men dominating the field of Astronomy and the stereotypes prevalent in school and society regarding astronauts and scientists. Next, her students selected a country to research on their contributions to space science. Shiva intended this lesson to “promote cultural competence as [students] understand the global contributions of space programs” (Shiva,
Assignment # 3, 4/10/12). She also urged her students to think critically about global power and social inequity as they explored “the unequal opportunity for countries to contribute to their space program and its effects on society” (Ibid.).

While the dimension of critical knowledge and pedagogy seeks to address the racial and cultural knowledge of students, it also encourages teachers to engage in self-reflexive work in order to understand how their own social identity and location figures into the science classroom (Rodriguez, 2005). By the end of the year, Rebecca stated,

One of the first things I think about before teaching is my students’ race and culture, and it’s terrifying that teachers do not consider these things when planning. I never saw race as important to teaching, but now I believe it’s all intertwined…. How can I make my lessons culturally relevant if I don’t really know my students and the cultural attributes they bring to school? (Rebecca, Interview, 6/8/12)

Not only did Rebecca believe that students’ funds of knowledge should be utilized and built upon in science education, but she also saw how important knowledge of oneself was in teaching and learning (McClaren, 2003).

I always think about my social location now. What does it mean to be a White female teacher? I believe it’s so important that every single day, every single interaction you have with a student, to be aware of your location and the impact you’re having on a student. So what experiences you’ve had that shaped the way you are. What kind of privileges you’ve had, what opportunities you’ve had, or maybe haven’t had. (Rebecca, Interview, 6/8/12)

At the beginning of the year, Rebecca believed that “kids are kids” and that “they are all the same” (BQ, 9/23/11). However, in our interview at the end of the year, she displayed a dramatic shift in beliefs, one that spoke to the complex role that race and culture played in the classroom.
Sociopolitical Action

For the sociopolitical action dimension in my course, I wanted preservice teachers to examine environmental issues and to connect them to issues of power that manifest in a society stratified by race, ethnicity, and class. Rebecca “stumbled on” the case of Africville, Nova Scotia, while researching an idea for Assignment #2, the Environmental Justice Strategy (Interview, 6/8/12). She was “distraught” that she had never heard of this example from Canadian history, and chose to pursue it as a means to integrate the history of science as it intersects with issues of race and class (Ibid.). Located on the southern shore of the Bedford Basin in Halifax, Africville was mainly populated by Black Nova Scotians, and was targeted and ultimately destroyed in the name of public interest and urbanization (Nelson, 2009).

For Rebecca, it was imperative for her students to understand this environmental justice issue because she herself had never heard of it.

Here I am 25 years old and have never heard of Africville, and this happened here in Canada! Our kids need to understand how this community was dumped on. The environmental pollution in Africville was excruciating to read about…. The well waters were contaminated, the city dump was there, a fecal waste depository…. They never had proper roads, street lamps and electricity. All because they were Black and poor … and this happened in Canada. How could my teachers forget to teach this? (Rebecca, Interview, 6/8/12)

According to Rebecca, there is an ethos in Canada that “racism is an American thing” (Rebecca, Assignment #2, 2/10/12), and consequently racism in Canada is dismissed (Carr & Lund, 2007). Rebecca’s analysis of the curricular exclusion of Africville resonates with what Susan Dion describes as a form of historical amnesia. Dion argues that “if justice for Aboriginal people lies in remembering, but forgetting serves the supposed needs of the Canadian nation, where are the possibilities for accomplishing justice to be found?” (Dion, 2009, p. 3). Rebecca’s outrage at the historical and contemporary forgetting of Africville added to her belief that “we must empower
all students to fight for equitable treatment of all communities regardless of race and class”
(Rebecca, EQ, 4/5/12).

Participants with Critical Beliefs Who Made Refined Shifts

Ben, Dayja, Maria, Tina, and Walter began the year with critical beliefs concerning teaching science for social justice, and indicated that the course refined their initial beliefs. At the beginning of the year, they already had an in-depth knowledge of social justice concerns, and were willing to take issues of power, privilege, and difference towards new and challenging levels. One important aspect of their shift was they began to question science as a body of knowledge. In this section, I will highlight the first dimension of critical nature of science, since it was in this dimension that these five participants made a significant shift from a positivist to a constructivist orientation of science. A constructivist orientation of science challenges the positivistic underpinnings of objectivity and universalism and depicts science as a human product that is specific to culture, time, and place (Brickhouse, 1994). I will also delve into the other two dimensions, but in a less detailed way, to showcase their refinement of beliefs.

Critical Nature of Science

My analysis of the beginning-of-the-year data, as detailed in the previous chapter, shows that this group questioned neither science as a body of knowledge nor the source of scientific knowledge itself. Rather, like participants who possessed liberal beliefs, they held positivist notions of science knowledge and science knowledge production. For example, even though these participants challenged the dominance of White males in science curriculum and careers as well as the use of science to oppress particular social groups, they did not interrogate the practice
of science itself. By the end of the course, all five participants not only challenged the way
science has been used to marginalize particular communities, but also the source of scientific
knowledge and the values behind scientific investigation. For example, they drew from diverse
ways of knowing from Asia and Aboriginal populations in Canada to trouble the Eurocentric
science curriculum. For Walter,

Teaching science for social justice is, first, not being part of the existing systemic
oppression by using engaging, representative, diverse, and inclusive curriculum, as
opposed to biased, unrepresentative, ethnocentric curriculum. It is teaching that science,
like anything, can be co-opted. Science has been historically used to justify [various]
agendas, from justifying slavery to the oppression of women. Even now, science is co-
opted not only through the personal biases of the researchers, but also through which
types of research get funded and the agenda of the organizations that do the funding.
(Walter, EQ, 4/5/12)

Critical participants noted that, when other forms of science were included in the school
curriculum, they were generally presented as inferior, thus contributing to the hegemony of
Western scientific knowledge. Maria made power explicit when describing her beliefs about
teaching science for social justice:

Any form of knowledge is power, and oftentimes science can be used as facts to persuade
the greater public towards one argument while silencing the possibility of different
perspectives. For example, research … can conclude the superiority of certain races,
sexes, and sexual orientations without ever having considered the context which serves a
significant confounding variable in these types of studies…. Rather than using science to
further oppress certain truths and marginalize individuals, it should be utilized as a tool to
enlighten the greater masses…. It is susceptible to either oppressive or emancipatory
goals. (Maria, EQ, 4/5/12)

All five participants confessed that they had “never been forced” or provided with opportunities
to think about science in critical ways (Tina, EQ, 2/7/12). For this dimension, my analysis of
their data indicates that the participants moved away from a positivist orientation and embraced a
constructivist view that acknowledged multiple perspectives of science and science education.
Consequently, they displayed a significant shift in this dimension.
Critical Knowledge and Pedagogy

Two of the critical participants shared their school practicum experiences that refined their initial beliefs. While Maria and Ben began the year understanding the roles that race and ethnicity played in school and society, they explained that their practicum allowed them to make clearer linkages between what they learned in our course and what they taught to their students. During her interview, Maria shared that,

A group of students wanted to know my last name and I told them. They immediately wanted to know if I spoke Spanish because they recognized my name as Hispanic…. I spoke Spanish to them and told them I was from Chile. One of them was from Chile, too. I forged a strong relationship with those four students. It was like they knew I understood them or something. It was special. (6/8/12)

For Maria, this experience enabled her to further interrogate her social location as a Latina, the importance of being a Latina teacher, and how this identity impacted her relationships with students.

Similarly, during his interview, Ben elaborated on his practicum experience in which he felt his identity as a Black man allowed him to bond with his Black male students. He completed his second practicum in a school located in a low-income, immigrant community in Toronto. He described his class as “mainly Somali students who come from difficult circumstances” (4/27/12). When I asked him what he meant by “difficult circumstances,” he responded, “It’s a very poor community that is riddled with drugs and crime. Even some of my sixth graders were experimenting with drugs and in trouble with the law.” He continued that many students were “really good kids that society just does not understand … what it means to be Black and growing up in the inner city.” Although Ben reiterated that he was “not a very good Black role model” and was “culturally not very Black” because he was raised by White parents, he did recognize that, in his students’ eyes, he represented someone who shared their racialized conditions (Ibid.).
Through his reflection of the school practicum, Ben considered that it was advantageous for him to share his racialized experiences with his students.

**Sociopolitical Action**

Critical participants already held initial beliefs with a strong dedication for creating activities that would develop their students’ critical consciousness and agency. For the Environmental Justice Strategy assignment, they took additional steps to create activities that were culturally relevant with local and global connections. For his first school practicum, Walter was placed in a classroom with a large number of first- and second-generation Filipino Canadian fifth graders. He developed a strategy that linked North American water pollution to the aquatic health of the coastal areas of the Philippines. He wanted to make connections between his students’ environmental habits in Canada and the economic and social wellbeing of their families and relatives in the Philippines through their dependence on marine life as a main form of living and employment sustenance.

The assignment was also an opportunity for Maria to make environmental issues relevant for her classroom of mainly Latino students by focusing on the degradation of the Ecuadorian rainforest in South America as a result of “North Americans’ addiction to oil” (Maria, Assignment #2, 2/10/12). In her assignment rationale, Maria described the strategy as:

Focusing on how oil giants like Chevron and Texaco, for the past three decades, have poisoned the land, air and water of the Amazon Rainforest in Ecuador. Moreover, it focuses on the subsequent health repercussions felt by indigenous inhabitants of the area that include increased rates of cancer, leukemia, birth defects and a multitude of other health problems. To add to this, their indigenous ways of being and living have been drastically suppresses and destroyed due to the environmental and health degradation that surrounds them. (Ibid.)
Although some of her students were from Ecuador and many were from South America, she was shocked that they were not familiar with this case. However, due to the relevance of the Environmental Justice Strategy, her students were willing to learn more and “became very excited” during the lessons (Ibid.).

According to Maria, one particular component of the Environmental Justice Strategy became “an eye opener,” which dramatically affected her beliefs about teaching science for social justice (Ibid.). During her lesson, she asked her students to take and argue various perspectives of different stakeholders in the rainforest devastation. She noticed that her White and male students dominated the discussions, and her Latino and female students were quiet and marginalized. During our individual interview, Maria shared,

Although there were more Latina students in the classroom than any other group, during the activity they were talked over, dismissed, and silenced, regardless of the role or perspective they were playing…. The debates were heavily skewed due to one side having the power and authority to silence and marginalize voices. (Maria, Interview, 6/8/12)

Maria became visibly upset as she recounted this experience. She described it as a “learning experience,” but readily admitted that she was left grappling with the event since she did not have a clear solution to resolve the dilemma of how to empower her racialized minority female students (Ibid.).

Ultimately, the five participants with critical beliefs indicated that the course acted to deepen and affirm their initial beliefs about teaching science for social justice, and empowered them approach science and science education differently. Dayja disclosed that,

I’m realizing that my beliefs don’t have to be just my own, or my secret…. I feel like I have been given permission to intertwine the two [science and social justice] and bring social justice issues into science. That is what the course did for me. It gave me the liberty and courage to expand the way I look at teaching science. (Interview, 5/4/12)
Conclusion

In this chapter, I have examined how preservice teachers’ initial beliefs concerning teaching science for social justice shifted during the course. My analysis indicates that participants demonstrated three degrees or kinds of shifts – minimal, substantial, and refined. Four participants with liberal views showed minimal shifts in their beliefs about teaching science for social justice; the other two participants with liberal views showed substantial shifts; and all five participants with critical views showed refined shifts in their beliefs. Liberal participants who demonstrated a minimal shift did so somewhat slightly in the critical nature of science dimension. While they held tight to their positivistic views of science, they were willing to incorporate Aboriginal perspectives into the science curriculum. Their views are in line with Banks and Banks’ (2010) contributions approach to multicultural education. Liberal participants who experienced substantial shifts challenged and shed their view on positivism, and moved towards a constructivist framework concerning the nature of science, which included the incorporation of Aboriginal knowledges. They also adopted beliefs that accounted for the complex roles that race and culture play in teaching and learning and that embraced the urgency to prepare students for sociopolitical action. For those who began the year with critical perspectives, their beliefs became more refined in all three dimensions of teaching science for social justice. What was consistent across all participants was their shift in the critical nature of science dimension. This was the case for the critical participants, as well. They moved from their initial beliefs in positivism to a constructivist orientation, and were affirmed in the two other dimensions of critical knowledge and pedagogy and sociopolitical action. In addressing this chapter’s research question, I have specifically delineated participants’ belief shifts concerning teaching science for social justice, which is a unique contribution to the literature on beliefs and
belief change. Furthermore, research data demonstrate an element of unpredictability concerning changing preservice teachers’ beliefs. Even though all eleven preservice teachers underwent the same course with the same readings, lessons, and assignments, they demonstrated different degrees of shifts in beliefs. Hence, an anti-oppressive pedagogy can produce a variety of responses and effects (Goldstein, in press; Kumashiro, 2000). The unpredictability in teaching science for social justice can also be gleaned in the next chapter where I discuss a specific lesson on “The Mystery of Maple Leaf Creek” and how participants’ understanding of and engagement with the lesson were strongly influenced by their initial beliefs and potential for belief change. In the next chapter, I will discuss in-depth the pedagogical choices that the participants indicated as crucial in their belief change.
CHAPTER 6

PEDAGOGICAL CHOICES THAT IMPACTED PRESERVICE TEACHERS’ BELIEFS

This chapter will respond to the thesis’ third and final central research question:

*According to the participants, which pedagogical choices made in the course by the teacher educator impacted their beliefs about teaching science for social justice?* My objective will be to better understand the pedagogical choices that promoted changes in beliefs from the perspective of the participants themselves. Consequently, this chapter ought not to be construed as a self-study of my teaching, although admittedly its findings will have implications for teacher education in general and for my own science pedagogy in particular. In this chapter, I will use the term “pedagogy” to broadly include, but not be limited to, course assignments, readings, in-class investigations, case studies, and written reflections. For my analysis, I focused primarily on the end-of-the-year questionnaire and individual interview data, especially as they made reference to specific instructional strategies, materials, and experiences.

This chapter will build upon the previous chapter’s key finding, which indicates that preservice teachers demonstrated three degrees or kinds of shifts in their initial beliefs about teaching science for social justice. By the end of the year, they experienced either minimal, substantial, and refined changes in their beliefs. These shifts were evident in one or more of the three dimensions of critical nature of science, critical knowledge and pedagogy, and sociopolitical action. In this chapter, my analysis of the three dimensions and what participants indicated as key pedagogical choices revealed that six enabling factors emerged as crucial in changing their initial beliefs. The participants’ belief change in the dimension of critical nature of science took place when they engaged with diverse perspectives in science, especially with
Aboriginal knowledges, and when they challenged the positivism of science. Their belief change in the dimension of critical knowledge and pedagogy occurred when they recognized their own social location as preservice teachers and incorporated the role of race and culture in teaching and learning. Their belief change in sociopolitical action manifested when they recognized and acted upon the development of their students’ critical consciousness and agency. Table 6.1 shows how these six factors correspond to the three dimensions of teaching science for social justice.

Table 6.1. Dimensions and Enabling Factors of Teaching Science for Social Justice

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<tr>
<th>Dimensions</th>
<th>Enabling Factors</th>
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<tr>
<td>Critical Nature of Science</td>
<td>Engage with diverse (e.g., Aboriginal) knowledges</td>
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<td></td>
<td>Challenge the positivism of science</td>
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<tr>
<td>Critical Knowledge and Pedagogy</td>
<td>Recognize teachers’ social location</td>
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<td></td>
<td>Incorporate race and culture in teaching and learning</td>
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<tr>
<td>Sociopolitical Action</td>
<td>Develop students’ critical consciousness</td>
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<td>Encourage student agency</td>
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In this chapter, I will elaborate on the pedagogical choices that the participants noted as crucial in their belief change, and will link them to their corresponding dimensions and enabling factors. Toward these ends, I will divide the chapter into two main sections. In the first section, I will focus on two participants – Rebecca and Shiva – who began the year with liberal beliefs about teaching science for social justice, expressed substantial shifts in all three dimensions, and by the end of the year, transformed into possessing critical beliefs. I chose to delve into their belief change more fully for two reasons. They provided the most robust and comprehensive data about belief change and pedagogical choices based on their questionnaires, interviews, and
course documents. What was striking about their data was the way in which they articulated their transformation in genuinely self-reflexive ways (Rodriguez, 2005). I also focused on participants with substantial belief change due to the rather limited body of scholarship that offered insights into pedagogies that promoted shifts in teacher education, science education, and social justice (Bianchini et al., 2003). The large majority of the literature in these areas account for the overt and covert resistance of preservice teachers to lessons of equity, diversity and multiculturalism (Case & Hemmings, 2005; Ullucci & Battey, 2011). Hence, I will contribute to these scholarly discussions by providing an in-depth analysis of specific pedagogies that enabled substantial changes in beliefs for some students about teaching science for social justice.

In the second section, I will closely examine a specific lesson in order to argue that any pedagogy directed to teaching science for social justice will be unpredictable and that it will understood, interpreted, and acted upon based on the beliefs that preservice teachers already possess (Goldstein, in press). In short, the pedagogical choices made by teacher educators will always be filtered and mediated by the beliefs held by preservice teachers, thereby creating a constant element of uncertainty when teaching for social justice. I will center my analysis on a lesson called “The Mystery of Maple Leaf Creek,” which I developed to highlight the compatibility of science and social justice. I will use this lesson to delineate more insights into the processes and conditions of belief change for all 11 participants in this study. More specifically, participants with substantial belief change considered this lesson as a transformative, epiphanic moment in their teacher education program. Those with minimal belief change ended up what I am calling “de-criticalizing” the lesson’s social justice perspective and implication. And those who experienced refinement in their initial beliefs, recognized the value
of the lesson, but raised concerns and reservations with the integration of science and Aboriginal perspectives.

Therefore, my goal for this chapter will be to provide rich details into the pedagogical choices that promoted substantial changes in preservice teachers’ beliefs and into the varying responses of preservice teachers to a specific science pedagogy based on their beliefs.

**Pedagogical Choices that Promoted Substantial Changes**

This section will focus on Rebecca and Shiva, the two participants with initial liberal beliefs, who experienced substantial changes by the end of the year. I will analyze their changes by specifically describing the pedagogical choices that they noted as crucial in their shifts. I will frame these choices under their respective dimensions concerning teaching science for social justice. Subsequently, I will extrapolate the enabling factors corresponding to these choices.

**Critical Nature of Science**

Under the critical nature of science dimension, Rebecca and Shiva identified the pedagogical choices of Aboriginal readings, Assignment #1 (Aboriginal and Western Scientific Worldviews), and case studies pertaining to scientific racisms as crucial in their belief change. These choices can be extrapolated into two enabling factors: they engaged with diverse (e.g., Aboriginal) knowledges; and they challenged the positivism of science. Table 6.2 lists the specific readings, assignment, and case studies for the critical nature of science pedagogies and their corresponding enabling factors.

In my course, the dimension of critical nature of science included having students engage with diverse perspectives in the science curriculum. I considered the examination of Aboriginal
worldviews as a powerful way of rethinking what and how we know science (Aikenhead & Michell, 2011; Kanu, 2011; Snively & Corsiglia, 2001). I urged preservice teachers to interrogate what constituted scientific knowledge, what were its limits, and of what value were Aboriginal knowledges to understanding the natural and human designed worlds. To this end, I required four readings on Aboriginal knowledges and ways of living in nature. The readings provided background knowledge for Assignment #1, entitled “Visual Representation of Aboriginal and Western Worldviews of Science” (see Appendix A). For this assignment, preservice teachers explored the tensions and similarities between Aboriginal and Western worldviews of science through a visual representation and a written reflection on their final product and the process of completing it.

Table 6.2. Critical Nature of Science, Pedagogical Choices, and Enabling Factors

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<tr>
<th>Dimension</th>
<th>Pedagogical Choices</th>
<th>Enabling Factors</th>
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<tbody>
<tr>
<td><strong>Critical Nature of Science</strong></td>
<td>Readings • “Our words, our ways: Teaching First Nations, Metis, and Inuit learners” (Alberta Education, 2005) • “Indigenous knowledge and science revisited” (Aikenhead &amp; Ogawa, 2007) • “Eurocentric science” (Aikenhead &amp; Michell, 2011) • “Building bridges: Pitfalls to avoid” (Aikenhead &amp; Michell, 2011) Assignment #1: Visual representation of Aboriginal and Western worldviews of science Case studies: Scientific racisms</td>
<td>Engage with diverse (e.g., Aboriginal) knowledges Challenge the positivism of science</td>
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Rebecca and Shiva described the course readings as engaging, well-written, and easy to understand. They attributed the relative accessibility of the readings as important to holding their interest and to clearly describing the foundations of Aboriginal and Western science as espoused by scholars and practitioners alike. Rebecca stated, “I had never considered that there could be different sciences. The Aboriginal readings were amazing. They really laid out, in understandable terms, the differences between Eurocentric and Aboriginal sciences” (Interview, 6/8/12). However, with this new learning came unease. Shiva felt “cheated” by her previous science education (Interview, 6/9/12). She asked, “Where was this information when I was in Grade 6? How come I am only learning this now?” (Ibid.). According to Shiva, the readings prompted her to deepen her knowledge on Aboriginal worldviews and share them with others. During her second practicum, she coordinated an Aboriginality assembly for the entire school. She attributed her dedication to exposing students to alternative perspectives to her disdain that she did not receive such an education when she was younger.

Both Rebecca and Shiva asserted that Assignment #1 was instrumental in shifting their beliefs concerning teaching science for social justice. They claimed that it provided a strong foundation of Aboriginal and Western science worldviews, brought an awareness of how the media perpetuated stereotypes of Aboriginal peoples, and challenged their initial positivistic beliefs about science. The visual representation portion of this assignment allowed them a large degree of flexibility in depicting Aboriginal and Western worldviews. Both participants remarked in their written reflections and individual interviews that searching for images to highlight Aboriginal worldviews became problematic. Rebecca was especially upset: “Everywhere I looked, I found stereotypical pictures that represented Aboriginal peoples…. It was so frustrating realizing that young people are constantly bombarded with these images daily”
This dilemma led Rebecca to depict Aboriginal worldviews with words rather than images. Her visual representation included terms, such as “co-exist,” “harmony,” “passion,” “beautiful,” “mystery,” “truth,” and “life.” She then used these terms as cornerstones for the assignment’s written portion. In reference to the term “POWER” displayed prominently on her artifact, she wrote, “As opposed to the anthropocentric view of Western science, where nature can be seen as a servant to humankind… Aboriginal worldview promotes a non-hierarchical and egalitarian relationship with nature” (Assignment #1, 12/8/11). This marks Rebecca’s understanding that Western science often exhibits power over nature, whereas an Aboriginal worldview consists of “power with” assumption. In other words, Western scientists seek to understand the world in order to manipulate and control it and to exercise power over nature and people. This starkly contrasts with Aboriginal goals of living with the natural world in a biocentric and harmonious way (Laudine, 2009).

Similarly, critical participants shared the same concerns of stereotyping and appropriation in their Assignment #1 reflections. To minimize this, they elected to complete the visual representation portion of the assignment in different ways. For example, Ben chose to place a large medicine wheel in the center of his assignment, and his reflection focused on the role of the medicine wheel in Aboriginal culture and how it contrasted with Western science. Tina created her project using needlepoint with simple shapes, such as rocket, sun, beakers, and fish, and linked them Aboriginal and Western worldviews. Hence, the two initial liberal participants who made substantial shifts and the five critical participants went to great lengths to depict Aboriginal peoples and worldviews of science in appropriate and respectful ways.

In contrast, liberal participants who made minimal shifts in their beliefs created visual representations that used objects, such as feathers, totem poles, and scenes of cowboys and
Indians. Their assignments included photos and drawings of Aboriginal people as relegated to the past, instead of existing in and engaging with the modern present. They produced what Susan Dion (2007) calls “molded images” of Aboriginal peoples, which depict reductive and dehumanized representations and perpetuate a “discourse of the romantic, mythical other” (Dion, 2009, p. 5). Furthermore the written reflections of liberal participants did not address the harmful knowledges prevalent in society concerning Aboriginal individuals and communities (Kumashiro, 2000). Whereas participants who experienced substantial and refined shifts in their beliefs did not incorporate harmful images of Aboriginal peoples and explicitly wrote against their use, participants who demonstrated minimal shifts failed to recognize how their visual representations promoted problematic cultural appropriation.

For the critical nature of science dimension, I also used case studies of scientific racisms in order to provide preservice teachers with a deeper understanding of the subjective nature of science. I selected cases that detailed various problems, dilemmas, and patterns of injustice with the use of science in historical and contemporary periods. For instance, during our first class session, I provided a lesson that covered topics, ranging from eugenics, craniometry, IQ testing, and the biology of race, to current research on K-12 student attitudes, achievement, and career trajectory in science. For Rebecca and Shiva, the case study analysis provided concrete examples that challenged their ideas about the positivist nature of science. Shiva explained, “The case studies during our first class really got to me. I never thought that science had a cultural component…. I always saw it as neutral … but it’s a product of mankind, so it is not free of emotion and agenda” (Interview, 6/9/12). Shiva came to realize science was a value-laden process and product that did not proceed in a purely objective and impersonal manner. Rather, scientists’ observations and interpretations depended on their own backgrounds and prior
experiences. In other words, their beliefs, social locations, and educational training—all of which were determined by a myriad of social and cultural factors—played a role in shaping the collection and interpretation of empirical data. As Robert Young (1987) claims, “a racist society will have a racist science” (p. 16).

**Critical Knowledge and Pedagogy**

Under the critical knowledge and pedagogy dimension, Rebecca and Shiva indicated that the pedagogical choices of Draw-a-Scientist (Chambers, 1983) and the readings and lesson plan assignment on culturally relevant teaching as important in their belief change. These choices can be extrapolated into two enabling factors: they recognized teacher’s social location; and they incorporated the role of race and culture in teaching and learning. Table 6.3 shows the in-class activity, course readings, and assignment for these pedagogies and their corresponding enabling factors.

Table 6.3. Critical Knowledge and Pedagogy, Pedagogical Choices, and Enabling Factors

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<tr>
<th>Dimension</th>
<th>Pedagogical Choices</th>
<th>Enabling Factors</th>
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<tr>
<td><strong>Critical Knowledge and Pedagogy</strong></td>
<td>In-Class Activity: Draw-a-Scientist</td>
<td>Recognize teachers’ social location</td>
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<td></td>
<td>Readings</td>
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<td></td>
<td>• “Creating culturally responsive schools” (Bazron et al., 2005)</td>
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<td></td>
<td>• “The culturally responsive teacher” (Villegas &amp; Lucas, 2007)</td>
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<tr>
<td></td>
<td>• “But that’s just good teaching” (Ladson-Billings, 1995)</td>
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<tr>
<td></td>
<td>Assignment #3: Culturally relevant lesson plan</td>
<td>Incorporate race and culture in teaching and learning</td>
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For the critical knowledge and pedagogy dimension, I began the first class session of the year with the Draw-a-Scientist activity. This activity has been used by numerous researchers to evaluate both K-12 students’ and preservice teachers’ perceptions and mental images of science and scientists. In this activity, I first asked preservice teachers to visualize a scientist, and then using a blank paper, crayons, and markers, to draw that image with as many details as possible. Next, I had them share their drawings in small groups and note commonalities and differences among the drawings. Through this process, they realized that the vast majority drew stereotypical portrayals of scientists, depicting White men working in laboratories and wearing eyeglasses and white lab coats. Then, I posed the following questions for individual reflection and small group discussion: Why did you draw that image? What effect might this image have on females, Aboriginal, and racialized minority students? As a teacher, how might you challenge this dominant narrative? Lastly, I shared current data on the science participation, engagement, and achievement of Aboriginal, Black, Latino/a, and female students (Brown & Sinay, 2008).

This activity was an eye-opener for Rebecca and Shiva. It enabled both of them to realize their own perceptions and stereotypical ideas about scientists and how they and their students’ social identities may impact the teaching and learning of science. Shiva was troubled that her drawing depicted a scientist working in a lab with test tubes and a chemistry equation scribbled on a blackboard behind him. In our individual interview, she recalled the activity and how it humbled her by making her realize that she did not know as much as she initially thought about social justice.

That was my reflective moment and I will never forget it and I have shared this with many people. That I realized that no matter how forefront thinking I think I am, I’m not. I drew a White scientist and thought nothing about it…. Even though I am a visible minority, I’m not immune to the media and such. I realized I was still at the beginning on this journey. (Shiva, Interview, 6/9/12)
Shiva revealed tremendous vulnerability with her realization that she was not “immune” to the many social influences bombarding us daily. Consequently she understood that her responsibility as an elementary science educator was teaching more than academic content and process. She stated, “Oh my God, it’s not about [our students] learning about the scientific method and how to do experiments and all that stuff. It’s about them being able to see themselves as scientists or doing science. How will they enjoy science if they cannot see themselves in it” (Ibid.)? Shiva speculated that the affective domain of teaching was important to science learning in order to increase marginalized students’ perceptions and attitudes toward the subject (Alsop, 2005). She indicated that the Draw-a-Scientist activity should be done with students and that “they need to know about this dominant narrative too…. They are never too young to learn” (Ibid.). Furthermore, she extended her action to working with adults: “We need to let parents know that we are sending negative messages to some students about science. I bet they have never even considered it” (Ibid.).

For Rebecca, drawing a stereotypical scientist and learning about research on the science achievement of female, Aboriginal, and racialized minority students created an intense disequilibrium that impacted her beliefs about science and her approach to teaching science. She realized that “science is packaged for and by White males” and accepted her responsibility in challenging this dominant practice (Rebecca, Interview, 6/8/12).

I was always one of the few females in my science classes, but I never really thought about why this was the case. By never reflecting on this, I was part of something that disadvantages the very children I want to teach…. To be painfully honest, I guess I bought into it and maybe never even thought of certain individuals being scientists…. Teaching science is much more than making [science] exciting or even relevant. It’s about connecting one’s identity to it. (Ibid.)
Rebecca’s reflection on the Draw-a-Scientist activity depicted her previously unconscious complicity to the hegemony of who does science in society. At the beginning of the year, she even exclaimed that science teachers ought to deliver the content in a fun and engaging manner. However, by the end of the year, Rebecca thought that teaching science needed to involve challenging dominant science discourses evident in the media and official curriculum, so that students who traditionally did not see themselves as doing science could do so. She wanted to make science engaging and create opportunities for students to enact and embody identities that would be conducive to becoming do-ers of science (Calabrese-Barton, 2003).

For the critical knowledge and pedagogy dimension, I also assigned academic readings on culturally relevant teaching, which provided background knowledge for Assignment #3, a Culturally Relevant Science Lesson Plan (see Appendix A). Both Rebecca and Shiva indicated that this assignment was an opportunity to take “research and apply it in a practical manner,” thereby bridging theory and practice (Shiva, Interview, 6/9/12). Rebecca created a lesson plan, entitled “The Great Oil Pipeline Debate” for Grade 8 students, which met the Ontario curriculum expectations in the Understanding Earth and Space Systems strand. For the enduring understanding of the lesson plan, Rebecca wrote:

This activity explores the impact of human-induced environmental disasters to the communities they affect. This demonstrates the benefits and the costs of offshore drilling for oil and building pipelines and the people whose voices are heard in the decision-making process. This demonstrates our interconnectedness to the environment and our influence with respect to resource extraction. The students can explore the science method in a student-centered, experiential, collaborative way while considering Aboriginal ways of knowing. The students are reminded of the different ways to view science and the importance of sustainable living and respecting the environment, especially among Aboriginal populations. Students will start to understand who is involved in making these decisions and how their voices can be heard in regards to determining whether or not to build an oil rig or pipeline across Western Canada. (Rebecca, Assignment #3, 4/5/12)
Rebecca’s lesson plan demonstrated a strong commitment both to the official science curriculum and to social justice. It addressed the following Overall Expectations of the curriculum: “1) assess the impact of human activities and technologies on the sustainability of water resources; 2) investigate factors that affect local water quality; and 3) demonstrate an understanding of the characteristics of the earth’s water systems and the influence of water systems on a specific region” (OME, 2007).

Rebecca’s lesson plan met these expectations by engaging her students with readings and media depictions of the ongoing oil pipeline debate in Canada, urging them to develop an inquiry-based, oil spill cleanup and then write a culminating essay. Her lesson plan also incorporated social justice by having her students examine how the pipeline would affect Aboriginal communities, engage in research, and present various viewpoints for a mock debate in the classroom. Rebecca extended the aspect of water quality in the Safe Drinking Water for First Nations Act, and explicitly taught the unjust practices that allowed different regulations for water quality in urban settings in comparison to that in Aboriginal communities. She provided information about long-standing boil advisories and “power imbalances” that marginalized Aboriginal communities (Rebecca, Assignment #3, 4/5/12). The lesson plan ended with students participating in sociopolitical action by writing letters to the Canadian government and creating posters to be displayed on school walls.

Rebecca developed a strong belief that race and culture, especially Aboriginal worldviews, should be incorporated into the science curriculum, and created avenues for such in her lesson plan. Her write-up indicated that

The students will be introduced to Aboriginal worldviews. First, the importance of the cycle, referring back to the lesson on the water cycle and how science is very relationship based. They will be asked to consider the different views of science and progress with respect to the building of the pipeline by comparing Aboriginal ways of living in nature
and the focus on sustainability versus Eurocentric science, which is often neutral to sustainability favoring instead entitlement and progress. The students will consider the costs and benefits of both views and be encouraged to find a common ground or two-eyed solution. (Rebecca, Assignment #3, 4/5/12)

Rebecca sought to challenge two presuppositions of Western science: rectilinear time and anthropocentrism. Whereas Western time moves uniformly and limitlessly in a linear fashion from past to present, Aboriginal time “harmonizes with the myriad of cycles observed in nature. Time has no beginning and no end. It reveals patterns, cycles and rhythms. What goes around literally comes around” (Aikenhead & Michell, 2011, p. 87). Rebecca used the water cycle as a means to engage her students with this temporal worldview. Next, she indicated that the anthropocentric nature of Western science has resulted in the need for greater ecological sustainability. Anthropocentrism establishes a hierarchy of importance within nature, and positions animals, plants, and nonliving things as servants to humankind—oftentimes having detrimental effects on the environment in the name of progress (Taylor, 2011). Rebecca urges her students, instead, to adopt “two-eyed seeing.” Two-eyed seeing requires students to evaluate a phenomenon through Aboriginal and Western lenses and to make informed environmental decisions utilizing the strength of both worldviews (Hatcher et al., 2009).

**Sociopolitical Action**

In the sociopolitical action dimension, Rebecca and Shiva considered the pedagogical choices of the case studies on environmental racism and the Environmental Justice Strategy assignment as vital to their belief change. These choices can be extrapolated into two enabling factors: they facilitated the development of students’ critical consciousness; and they engaged student agency to address socioscientific issues. Table 6.4 shows the case studies and assignment for the sociopolitical action pedagogies and their corresponding enabling factors.
For the sociopolitical action dimension, I used case studies of environmental racisms to provide preservice teachers with a deeper understanding of the intersection of science, environment, race, and class. Environmental racism is a form of discrimination against racialized minority and poor communities that “involves such practices as the siting of hazardous or toxic waste dumps inhabited primarily by people of color, or hiring racialized minorities to work in hazardous industries, or even exporting toxic waste to impoverished countries” (Westra, 1999, p. 103). I selected both historical and current examples of environmental racisms in developed countries like Canada and the United States and in developing countries such as India and the Philippines, as well as successful efforts of resistance and mobilization. Both Rebecca and Shiva pointed to this session as having a strong impact on their initial beliefs and emotions.

Table 6.4. Sociopolitical Action, Pedagogical Choices, and Enabling Factors

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<th>Pedagogical Choices</th>
<th>Enabling Factors</th>
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<tbody>
<tr>
<td>Sociopolitical Action</td>
<td>Case studies: Environmental racisms</td>
<td>Develop students’ critical consciousness</td>
</tr>
<tr>
<td></td>
<td>Assignment #2: Environmental Justice Strategy</td>
<td>Engage student agency</td>
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During our interview, Rebecca explained that learning about “how Canada treats its Aboriginal population was the most shocking and upsetting” (Rebecca, Interview, 6/8/12). I was surprised by her statement due to the various media depictions of the unjust ways Aboriginal groups had been and continue to be treated. When I probed further, tears began to roll down her cheeks when she said,

I have always heard that Aboriginals get lots of government hand-outs like free college tuition … and that they are never happy. I think I dismissed a lot of the bad things
[examples of injustice] that I was hearing because, I’m so ashamed now, I think I believed that on some level and that shielded me from ever really taking it seriously. I mean, I know so much has happened to them, so much pain and suffering, but I guess I thought we were beyond that. (Ibid.)

Rebecca shuffled her feet as she shared feelings of shame, guilt and anger, which she directed at herself. She continued, “I have clean drinking water. I don’t suffer from the negative health effects brought on by toxic dumps in my backyard. I am not stereotyped by everyone” (Ibid).

Rebecca’s reflexivity in this issue demonstrates a growth in her own critical consciousness regarding systemic oppression. This contrasts with her initial beliefs which centered on individuals. “Although I knew the conditions of residential schools were bad, I never thought they could affect a community to this extent. I really thought people could get over these things. I realize now, that these experiences are deeply embedded in identity and culture and ways of being…. I was foolish for even thinking that before” (Ibid.).

Shiva stated that the case studies of environmental racisms should be “posted on billboards all over town” as a way to “keep this knowledge fresh in our minds” (Shiva, EQ, 4/10/12). Too often, things become “out of sight, out of mind.” Environmental justice could not occur if we didn’t continually “bring these issues up, all the time, to everyone” (Ibid.). She recognized that she was guilty of doing just that:

I don’t live near a reservation and I have never been on a reservation. It really is something very foreign to me. However, the class that day reminded me that Aboriginals, Black people, and other minority groups are treated badly all the time. Whether we live near them or not is not what matters. What matters is we keep this information front and center, so people have to act on it…. It’s racism, pure and simple. (Shiva, Interview, 6/9/12)

Shiva’s remarks suggest that she is moving beyond the position of what Susan Dion (2007) calls the “perfect stranger” in regards to her knowledge of and relationship with Aboriginals peoples. Dion’s concept of the perfect stranger refers to the beliefs and discourses that non-Aboriginal
individuals internalize and enact so that they are perceived as innocent of and not complicit to structures and practices of discrimination. Consequently, they can avoid taking responsibility for engaging in teaching for social justice. For example, preservice teachers may claim that they lack awareness about Aboriginal peoples, histories, cultures, and conditions or that they are ignorant of the effects of settler colonialism, racism, and institutionalized oppression. Dion posits that the perfect stranger is a complex subject position that is “informed simultaneously by what teachers know, what they want to know, and what they refuse to know” (p. 331).

Shiva also shared that the case studies also made her reflect on her own social location as a visible minority: “What happens if they were to come for people who look like me next? Overall, people who look like me don’t hold a lot of clout in society, and this is about power. It’s about vulnerable populations not being part of a larger decision making process” (Ibid.). Rebecca and Shiva’s statements indicated that their end-of-the-year beliefs took into consideration the complex dynamics of systemic oppression, privilege, and one’s social location.

After examining numerous cases of environmental racisms, I had preservice teachers complete Assignment #2, an Environmental Justice Strategy. I asked them to create one, especially in relation to the communities of their practicum schools. Their tasks included identifying an environmental issue, explaining its impact on society, and describing how they would teach the issue and engage students as activists. Shiva and Rebecca generated strategies that focused, respectively, on a local problem linked with developing countries and a Canadian concern targeting a racialized minority community. Although both of them were initially resistant to sociopolitical science teaching, through this assignment they began to realize that “age appropriate action is necessary in all content areas” (Rebecca, Interview, 6/8/12).
Shiva selected topsoil depletion as the main focus for her environmental justice strategy. She decided on this topic because she noticed during her first practicum that students did not use the compost bins in the classrooms. When food scraps were not disposed in compost bins, they entered landfills, became contaminated, and were not composted. For the goals of her strategy, Shiva wrote: “1) to have students investigate how the amount of compostable food waste we lose in landfills every day can be reduced; 2) to teach students the ease of vermicomposting; and 3) to educate fellow students, parents and the community on the benefits of composting” (Shiva, Assignment #2, 4/10/12). She addressed social justice in her strategy by addressing global resource distribution with her students. She continued:

Many fruits and vegetables are grown in developing countries. When they are imported to Canada, we are depleting the nutrient value of the soil in the country of origin. When the waste from these fruits and vegetables ends up in landfills, they can never be recovered. By composting, we ensure that the nutrients remain available to the food growth cycle … and most importantly, student activism in composting will empower them begin growing their own fruits and/or vegetables therefore reducing our dependence on other nations. (Ibid.)

Shiva believed that composting might lead students to growing their own foods, thereby lessening the soil burden in developing countries. While I did not deem this strategy as fully representing environmental justice locally and providing adequate rationale to address the issue, I did recognize a shift in Shiva’s beliefs concerning engaging students in sociopolitical action. She offered numerous avenues of activism that included developing a learning wall, convening a school-wide assembly, establishing a garden club, teaching parents during a Vermiculture Night in school, and advertising in community newspapers.

For her Environmental Justice Strategy, Rebecca addressed the intersections of race, class, and science using the example of Africville in Nova Scotia, which I described in Chapter 4. During our individual interview, she elaborated on her feelings of anger and sadness
concerning the ways Africville residents were treated. She indicated that, prior to my Elementary Science course, she had “never really thought about the connection between politics and science” (Rebecca, Interview, 6/8/12). She selected the case of Africville to tell “the untold story of a Black community that was targeted and ultimately destroyed in the name of public interest” (Assignment #2, 2/10/12). Rebecca was determined to develop her own and her students’ critical consciousness. She herself had not heard of Africville, and passionately indicated that “we [Canadians] must become more aware of these injustices in our backyard” (Interview, 6/8/12). Her assignment integrated various content areas using the following activities to increase students’ critical consciousness:

1. Research the history of Africville, Nova Scotia
2. Write in role as a person who has a particular perspective during the Africville time
3. Compare the community of Africville to your own/other Canadian community (e.g. Attawapiskat). What are the opportunities and challenges that each community endures?
4. Create an image or poster that depicts what a safe and healthy community has (Assignment #2, 2/10/12)

Here, Rebecca brought science and social justice together by focusing on a Canadian case of environmental racism and the consequences of human-made pollution. Her activity aligned with the Relating and Technology to Society and the Environment goal of the Ontario Curriculum for Grades 1-8 (OME, 2007). Rebecca viewed her unit as “necessary…. Teaching our students about injustice and preparing them to make positive change in the world all while doing science should be mandatory” (Ibid.).

In this section, I have delineated the different pedagogical choices I had made in the Elementary Science course that Rebecca and Shiva attributed as important in their belief change. From these pedagogical choices, I extrapolated six enabling factors that were crucial for belief change. In Shiva’s and Rebecca’s cases, they demonstrated substantial shifts from liberal beliefs at the beginning of the year to critical beliefs at the end. In the next section, I will provide a
detailed account of an activity that both of them stated had a powerful impact on their beliefs and their responses to it. I will then compare their responses to the other two groups – the liberal participants with minimal shifts and the critical participants with refined shifts. My goal for the next section will be to delineate the varying responses to a particular lesson on teaching science for social justice and the uncertain and unpredictable ways in which beliefs mediated or filtered how preservice teachers understood or made meaning of the lesson.

**The Mystery of Maple Leaf Creek**

Research participants stated that my in-class modeling of pedagogies which explicitly integrated science and social justice played a vital role in shifting their beliefs. According to Ben, “I really appreciated the way you demonstrated how to teach science for social justice by modeling it for us in class” (EQ, 4/5/2012). In fact, all eleven participants referred to the Mystery of Maple Leaf Creek as particularly important in their belief development.

I constructed the Mystery of Maple Leaf Creek lesson (hereby referred to as Mystery) to address the Understanding Life Systems strand of the Ontario Science Curriculum (OME, 2007) and to incorporate diverse and, more specifically, Aboriginal worldviews and knowledges. I presented this activity to preservice teachers as a mystery that I needed their help to solve. I chose the third class session for this lesson because preservice teachers had just completed the readings for and the visual representation assignment of Aboriginal and Western worldviews of science. Below is the story that I shared on this lesson:

Maple Leaf Creek is a stream that flows through a rural area known as Pineville. Residents of Pineville are farmers who rely on their own produce as well as plants and animals from local forests and waterways for food. A health official from New Port City—an urban area south of Pineville where Maple Leaf Creek meets Grand River—arrives with disturbing news about a young boy who has fallen ill in New Port City.
Medical tests concluded a dangerous level of pesticide in the boy’s bloodstream. Only residents of Pineville use this particular pesticide.

New Port City’s drinking water was tested, and not a trace of the pesticide was found. The unfiltered water from Grand River was tested, and a minute amount of pesticide was detected, but this is expected due to surface run-off from Pineville farms. Pineville residents are concerned about their responsibility in the matter, but cite that none of their residents have gotten ill, and they frequently swim, fish, and eat crops grown in Pineville. (Eslinger, 2013)

In this lesson, preservice teachers enacted roles of organisms that lived in the ecosystems of Pineville and New Port City as they worked together to solve the mystery. They learned what could happen when toxins such as pesticide entered ecosystems and became part of the food webs and the potential impact they could have on various organisms. In this case, a young boy ate a fish that was contaminated with a large amount of pesticide through a process known as bioaccumulation, the build-up of pollutants as they passed through food webs. This activity enabled preservice teachers to see how plants such as cattails, while engaging in photosynthesis, could take in trace amounts of toxic material which could be transferred from plants to fish and then to humans throughout a food web.

In this lesson, I infused an Aboriginal perspective on the role of circle in nature, a foundational concept in Aboriginal philosophies, values, and cultures. The circle underpins a way of life, and is both a familiar and sacred symbol of wholeness, inclusiveness, and cycles in nature. Aboriginal scholar Michael Tlanusta Garrett (2003) explains that the circle is a symbol of power, relation, peace, and unity. He states, “It serves as a reminder of the sacred relationship we share with all living things in this world and of our responsibility as a helper and contributor to the flow of the Circle of Life by living in harmony and balance with all our relations” (Garrett, et al., 2003, p. 227). With this in mind, I drew upon the circle in a couple of ways in Mystery.

I began the lesson with all preservice teachers sitting in a circle formation. A circle formation for communication is rooted in the traditional practices of Aboriginal people. The
talking circle is useful pedagogically because it establishes a style of communication that is different from that of the Western tradition (Kanu, 2011). Rather than debating, challenging, and talking-to others, the talking circle creates a safe, non-hierarchical setting where students have the opportunity to speak without interruption. It allows students to share their viewpoints and ideas and to explore issues, solve problems, and celebrate successes. Rather than reading the mystery scenario to them, I engaged them in storytelling, another common practice in Aboriginal communities (Ibid.). After telling the story, I asked preservice teachers to sit in smaller talking circles with six people in each circle. I provided a stone to each circle, and mandated that only the holder of the stone could speak. In their groups, preservice teachers shared their ideas about who or what caused the New Port City boy to fall ill.

Afterwards, I facilitated the role-playing portion of the lesson where they took roles as organisms, such as snails, fish, plants, muskrats, mice, and birds. Role-playing depicted two interconnected and fundamental attributes of Aboriginal worldviews – nature as holistic and relationality. Holism stresses the need to understand a phenomenon in its entirety, rather than by breaking it down into discrete parts. In other words, the lesson was only meaningful as a whole view of nature and not by piecemeal. By taking the roles of various plants and animals, preservice teachers could see the connections of all living things in the circle of life. Marie Battiste and James Youngblood Henderson (2000) point out that holism leads to “harmony as a dynamic and multidimensional balancing of interrelationships in [Aboriginal] ecologies” (p. 43). When these interrelationships are disturbed, disharmony ensues. Therefore, the addition of pesticide to a food web had detrimental consequences for all of the organisms within the web, including humans. Closely related to holism is the attribute of relationality. To Aboriginal people, living and non-living things are related, and relationships require both attachment and
responsibility due to the delicate balance among all things. One should be emotionally connected to nature and the world because “existence is made up of a web of interrelationships” (Aikenhead & Michell, 2011, p. 79). The Mystery lesson depicted the holistic and relational nature of life, and implicated the personal responsibility of humans.

Although all 11 participants in the study indicated in the interviews or the end-of-the-year questionnaires that the Mystery lesson was responsible for shifting their beliefs, each of the three groups offered diverging perspectives. Liberal participants who had substantial shifts in beliefs fully embraced the lesson, and considered it to be epiphanic in their belief change. Critical participants who demonstrated refinement in beliefs accepted the activity as important, but disclosed some reservations. Lastly, liberal participants who exhibited minimal belief changes avoided the lesson’s social justice components altogether.

**Participants with Liberal Beliefs Who Made Substantial Shifts**

For Rebecca and Shiva, the Mystery lesson allowed them to bridge the “divide between theory and practice” (Shiva, Interview, 6/9/12). Rebecca elaborated, “Much of what we do here at OISE is research heavy, and I am left to my own devices in figuring out how to apply that knowledge practically” (Rebecca, Interview, 6/8/12). She went on that the disconnect between theory and practice would often leave her frustrated and be admittedly “not really invested in figuring out how to reconcile the two” (Ibid.). Therefore, Mystery provided an avenue through which she could reconcile this dilemma. “The way you modeled the activities in class was powerful…. The best was the Mystery of Maple Leaf Creek. You had us do the talking circle and then explicitly used Aboriginal worldviews…. Seeing it done really had a profound impact on me” (Rebecca, EQ, 4/5/12). When I asked Rebecca to elaborate during the interview, she
indicated that it “helped me connect the dots” by providing a way to integrate Aboriginal worldviews and knowledges into the science curriculum (Rebecca, Interview, 6/8/12). Shiva echoed Rebecca’s statements concerning the merit of the lesson. “All of the Aboriginal readings were great, but I kept wondering what this would look like in my future classroom…. The Maple Creek activity really empowered me…. Seeing how to infuse the two made me want to teach it in my practicum” (Shiva, Interview, 6/9/12).

For these participants, the Mystery lesson both inspired and motivated them to integrate science and diverse worldviews, and provided them with a vision for future integration. Mystery served as an epiphanic moment, or a particular moment in time that leaves a “significant mark on people’s lives by altering or strongly confirming their fundamental meaning structures” (Hyland, 2010, p. 390). They did not question the activity or its implications, but embraced it as one way to teach science for social justice. Although Rebecca and Shiva did not offer critical or analytical commentary pertaining to Mystery, for those with initial critical beliefs, Mystery provoked skepticism and reservation.

**Participants with Critical Beliefs Who Made Refined Shifts**

Critical participants who experienced a refinement in their beliefs demonstrated reserved acceptance of Mystery. For them, the lesson was “a great example of teaching science for social justice” (Tina, EQ, 2/7/12). However, their persistent tenacity for interrogating power and privilege – based on their initial beliefs about social justice – raised concerns about integrating diverse perspectives in science. Both Maria and Tina stressed the need for “fair and non-stereotypical representation” of Aboriginal people and perspectives when teaching lessons like
Mystery due to their fears of reifying negative stereotypes of Aboriginal people (Tina, Interview, 5/3/12). According to Maria,

In Canada, Aboriginals may be the most oppressed in our society. Everywhere you go, you hear troubling discourse that is full of negative generalizations, stereotypes, and racist beliefs. I think as teachers we have a responsibility to make sure that, when we include Aboriginal worldviews, we do so in a way that does not perpetuate [stereotypes]…. It’s our responsibility. (Maria, Interview, 6/8/12)

Tina furthered this idea by acknowledging the limitations of her Italian background and upbringing. “I was never around Aboriginal people and that puts me at a disadvantage … due to my lack of understanding. I need to approach this [integrating Aboriginal knowledges] carefully … in a way that is respectful” (Tina, Interview, 5/3/12). By no means did Tina believe that teachers should not incorporate diverse worldviews and knowledges into the curriculum, but she realized her particular limitations and the need to present Aboriginal worldviews authentically.

Walter and Dayja expressed beliefs that showcased their understanding of the relationship between language and power. Walter shared, “I mean really, at a basic level, the language we use to explain and understand Aboriginal worldviews creates a false sense of comprehension. We are using English and a Eurocentric framework to interpret Aboriginal worldviews. That in itself is problematic, right?” (Walter, Interview, 4/25/12). Dayja posed the dilemma, “I wonder how much is lost in translation when we try to learn how to incorporate diverse worldviews…. I am not sure how to reconcile that … but I do know we need to be cognizant of it” (Dayja, Interview, 5/4/12). While all of the critical participants noted that Mystery was an effective way to combine Aboriginal and Western scientific worldviews, it did act as a catalyst to further think about stereotyping, cultural appropriation, and oppressive discourse.
Although liberal participants with substantial shifts did not challenge the limitations, implications, or assumptions behind Mystery, the critical group posed questions and concerns pertaining to language, social location, and possible limitations of similar lessons. In other words, the critical group assessed the role that power and privilege may play when engaging diverse perspectives. However, although they highlighted these concerns, everyone in this group was adamant that teachers must engage in self-reflection and ongoing learning (Kumashiro, 2000; Rodriguez, 2005) to successfully integrate Aboriginal worldviews and knowledges in the science curriculum.

**Participants with Liberal Beliefs Who Made Minimal Shifts**

Throughout the year, liberal participants with minimal shift in beliefs would often engage in what I call “de-criticalizing” a lesson’s social justice perspectives and implications. In other words, their beliefs mediated Mystery in such a way that dismissed entirely its social justice components. My analysis of the data reveals that the phenomenon of de-criticalizing occurred in all the participants in this category – Alex, Carol, Frank, and Nick. Although I made explicit the social justice focus and implications in Mystery, their responses reveal that they found the most value in the activity’s elements that were most aligned to their initial and unyielding beliefs.

In Chapter 4, I outlined the liberal group’s initial beliefs on teaching science. They consistently stressed the importance of developing critical thinking, fostering a welcoming classroom climate, and addressing students’ learning styles. For liberal participants with minimal shift, these beliefs remained unchanged throughout the course of the year, and acted to filter how they perceived Mystery. Alex stated, “The creek activity was my favorite because it required so much critical thinking to solve the mystery you posed. I cannot wait to do this with my
students…. Critical thinking is the main goal of science” (Alex, EQ, 4/10/12). Similarly, Frank claimed that Mystery “was so engaging and fun that students will love it…. It really challenges students to engage in higher order thinking” (Frank, Interview, 4/28/12).

For liberal participants with minimal belief change, teachers must create a positive learning environment for their students. Carol noted that Mystery could potentially assist in meeting this goal through the teamwork aspect of the lesson: “The Mystery of Maple Leaf Creek is one of the most important activities of the year…. It required us to work together to solve the dilemma…. I will use it in my future classroom because it’s also a great community building activity because we had to work as a team” (Carol, Interview, 4/28/12). Frank remarked that Mystery’s “strength, besides science, is its focus on cooperation” (Frank, EQ, 4/5/12). While the Mystery lesson certainly stressed cooperation over competition, Aboriginal worldviews and knowledges were not mentioned and, thereby, dismissed by the participants.

Consistent with the liberal belief on the importance of differentiating instruction to meet diverse learning styles, two participants detailed how Mystery accomplished this. According to Alex, “It meets many learning styles. For the kinesthetic, it gets them up and moving. For the auditory, they get to hear the mystery out loud, and the map and name-tags for the students who require visual learning…. Really, it’s good for everyone” (Alex, Interview, 6/7/12). Nick also praised Mystery for “addressing multiple learning modalities” (Nick, Interview, 6/9/12). While a teacher ought to establish an welcoming, respectful, student-centered classroom and to provide instruction that fosters higher order thinking skills while meeting students’ diverse learning needs, this group’s conviction to such beliefs worked to sieve out the social justice components of the lesson. This filtering process contributes to the element of unpredictability of teaching science for social justice, and is congruent with findings by Goldstein (in press).
In this chapter’s second section, I described how the three groups of preservice teachers responded to my in-class modeling of the Mystery of Maple Leaf Creek, a pedagogical activity designed to integrate science content with social justice and Aboriginal worldviews and knowledges. I wanted to demonstrate the different ways participants’ prior beliefs filtered and shaped understanding of new information. For example, preservice teachers with initial liberal beliefs who underwent substantial shift showed complete acceptance of the activity as a way to teach science for social justice. The lesson gave them confidence, and motivated them to want to practice such integration. Those with initial critical beliefs who displayed refinement recognized the positive value and impact of the activity. But they raised critiques regarding potential stereotypical assumptions in the activity and the effect of their own social locations on teaching and learning. Finally, those with initial liberal beliefs who experienced minimal change completely de-criticalized the activity of its social justice implications. They considered the most valuable components of the lesson to be those that were already aligned to their initial liberal views, such as critical thinking, multiple intelligences, and teamwork.

**Conclusion**

In this chapter, I examined which pedagogical choices made by the teacher educator impacted preservice teachers’ beliefs about teaching science for social justice. My analysis indicates that, according to my participants, three sets of pedagogical choices were vital to their belief changes. These choices corresponded to six enabling factors. In other words, for belief change to take place, preservice teachers need to: 1) engage with diverse (e.g. Aboriginal knowledges; 2) challenge the positivism of science; 3) recognize their own social locations as educators; 4) incorporate race and culture in teaching and learning; 5) develop students’ critical
consciousness; and 6) encourage student agency. Furthermore, I provided an example of how preservice teachers with varying beliefs and shifts – initial liberal with substantial shift, initial liberal with minimal shift, and initial critical with refined shift – perceived a specific pedagogical activity. Although I taught the lesson to all participants in the same way, my analysis of their data suggests that their initial beliefs functioned as a filter or sieve to how they understood the activity, what they found as valuable, and how it may be used for their future practice. In the following concluding chapter, I will synthesize my findings from Chapters 4, 5, and 6 to construct a theory of belief change about teaching science for social justice.
CHAPTER 7

TOWARDS A THEORY OF BELIEF CHANGE ABOUT
TEACHING SCIENCE FOR SOCIAL JUSTICE

My thesis addressed three central research questions. As elementary preservice teachers take a science methods course with a social justice focus: What are their initial beliefs concerning teaching science for social justice? How do their beliefs about teaching science for social justice shift (if at all) during the course? And lastly, how do the pedagogical choices made in the course by the teacher educator impact their beliefs about teaching science for social justice? I decided to pursue a research project on beliefs and belief changes because there is general scholarly consensus that beliefs are precursor to actions (Pajares, 1992). However, as I noted in the limitation section of Chapter 3 there is not always a direct correlation between preservice teachers’ espoused beliefs and their actions. In other words, beliefs can be contradictory and context-specific. The findings in this thesis should be considered in light of this limitation.

Beliefs are an important area of study because a substantial body of research indicates that many preservice teachers possess beliefs that are not conducive to the tenets and goals of equity, diversity, and multiculturalism. These teachers discount the role of race and culture in teaching and learning, take a banking approach to education, have low expectations for their students, and do not encourage their students to address and take action on socioscientific issues that shape their lives and communities. In turn, their students become passive recipients of knowledge, focus on rote memorization and basic skills, do not make connections between school and society, and disengage from curricular material that is not culturally relevant (Hollins
& Guzman, 2005). Consequently, for many of these students, their interest in science wanes, thereby negatively impacting their academic engagement and achievement in science. I also selected to undertake this research project in the context of my elementary science methods course at OISE, University of Toronto, since there are limited empirical studies on the integration of science and teacher education for social justice.

Siding with scholars who suggest that even a single social justice oriented course in teacher education can shift the beliefs of preservice teachers, I revised my course to reflect my review and synthesis of the scholarly literature on teaching science for social justice. Hence, by analyzing beliefs and belief changes in the context of teacher preparation in elementary science education within a social justice framework, I hope that my research can significantly contribute to the preparation of the predominantly White preservice teacher population to meet the needs of racially, culturally, and linguistically diverse students. As a result, the unfulfilled promise of the science for all agenda can be realized through the academic success in science of Aboriginal, Black, and Latino/a students.

I explored my central research questions by conducting a constructivist grounded theory approach to qualitative inquiry that focused on 11 preservice teachers who took my “Science and Technology Education for Elementary School Teaching” (EDU 1450) course during the 2011-12 academic year at OISE, University of Toronto. Using purposeful sampling, I selected participants who declared science as their teachable content area and aspired to teach science in grades four through eight. From these participants, I collected and analyzed three sets of data, which served to triangulate my findings and bolster the validity of my study. Research data included written responses to the questionnaires that I distributed to all preservice teachers at the beginning and at the end of the year, their verbal and transcribed responses to individual
interviews at the end of the year, and their submitted assignments and written reflections throughout the course. Although my research project possessed elements of self-study and action research, I intended this study to be not about me. Admittedly, as the course instructor, I was responsible for the course objectives and pedagogical choices. However, my research focus was on preservice teachers, their beliefs and belief changes, and their experiences and perspectives on the elementary science methods course.

As required in a grounded theory approach to research, I analyzed the qualitative data using a constructivist grounded theory (CGT) method, as developed by Kathy Charmaz (2006). CGT seemed more appropriate for my study than the more positivistic iterations of grounded theory for two reasons. First, it rejects the notion that a neutral observer enters into a research setting and discovers the truth about a singular reality. Second, it acknowledges and values the researcher’s role in the research process. CGT embraces the empirical and analytical position that findings represent the researcher’s own values and interpretations of the data. In other words, I, as the researcher and the perspectives that I bring to the study become central to the research process. As both the researcher and the course instructor, CGT accounts for my beliefs about social justice, and my curricular and pedagogical choices for the course. My personal and professional backgrounds certainly played a significant role not only in the choice of the research topic, but also in the conduct of the research process.

As a White male who grew up in the southern rural area of the United States, I was immersed and took pleasure in the natural world, which gave me a strong foundation and love for science. Early on, I wanted to be an elementary school teacher, so that I could share my passion for science with children. However, when I became a teacher, I was challenged by many of my racialized minority students who were disinterested in science, and I struggled to make
science come alive and relevant to them. Like many White liberals who held the belief that all kids are the same and therefore ought to be treated equally, I failed to recognize students’ intersectional attributes of race, class, and culture that are different from mainstream norms. I did not understand how schools privileged certain identities and marginalized others and how processes and structures of privilege and oppression were intricately tied to students’ academic learning and accomplishment.

By addressing the three central research questions, my ultimate goal is to generate a theory of belief change about teaching science for social justice. In this final chapter, I will elaborate on the process, results, and implications of my theory-generating endeavor in the following manner. First, I will explain, through my extensive review of the scholarly literature on teaching science for social justice, how I developed the elementary science methods course. Based on my literature review, I conceptualized a critical – cultural framework that served as the overarching lens for the course, and designed the course to foreground the three dimensions of critical nature of science, critical knowledge and pedagogy, and sociopolitical action. The development of an elementary science methods course with a social justice orientation is, in fact, an important scholarly and practical contribution to science education since only a handful of published studies address the preparation of teachers in an elementary science methods course with a social justice emphasis.

Second, I will delineate through my empirical study how preservice teachers’ beliefs about teaching science and social justice were impacted by the elementary science methods course. My analysis and findings of the qualitative data through constructivist grounded theory have been thoroughly explored in Chapters 4, 5, and 6, which responded to each central research question in detail. Another scholarly and practical contribution to science education can also be
gleaned especially in Chapter 6, which explains effective pedagogical strategies that impact belief change from the vantage point of preservice teachers. My analysis culminates in this chapter where I develop a theory of belief change about teaching science for social justice. This theory includes three components: recognizing the relationship between science and society; recognizing the relationship between individuals and society; and recognizing the importance of activist-oriented science education. I will close this chapter – and my thesis – by describing the contributions of this research project as well as directions for future research.

**Integrating Science and Social Justice**

In Fall 2009, I began teaching the mandatory elementary science methods course called “Science and Technology Education for Elementary School Teaching” (EDU 1450) for preservice teachers who wanted to obtain a teaching certification in the Junior/Intermediate division (Grades 4-10) at OISE, University of Toronto. Initially, I conceptualized the course to include issues of equity, diversity, and multiculturalism based on my experiences as a 10-year veteran educator of urban elementary schools. Dissatisfied with the process and results of my university teaching, I searched for an overarching conceptual framework that would integrate science education and social justice more seamlessly. Unfortunately, this investigation left me empty-handed. As a result, when I began my doctoral studies in Fall 2010 in Curriculum Studies and Teacher Development at OISE, University of Toronto, I set out to create my own framework through an extensive review of the scholarly literature. My literature review enabled me to develop a critical – cultural theoretical framework to teaching science for social justice, which includes three dimensions: critical nature of science, critical knowledge and pedagogy, and
sociopolitical action. These dimensions subsequently served as the curricular and pedagogical pillars for my elementary science methods course.

The critical – cultural framework that I developed for the science methods course recognizes the complex roles that power plays in school teaching and learning. It points out and challenges the multiple and overlapping forms of privilege and oppression in school and society. For science education in particular, it interrogates the knowledge production and mobilization of science, and positions science as a cultural practice that reflects the beliefs and practices of dominant groups, while dismissing the diverse knowledges and worldviews of other groups as inferior and irrelevant. My critical – cultural curricular framework is informed by three distinct, but highly interrelated theoretical strands: anti-colonial theory, critical multiculturalism, and critical pedagogy.

Anti-colonial theory argues that dominant knowledges are a product of colonial histories and legacies, and represent Eurocentric ontologies, epistemologies, and methodologies. Through Eurocentric hegemony, indigenous knowledges and ways of knowing are suppressed, misappropriated, and rejected (Dei & Kemp, 2006; Dion, 2007, 2009). Critical multiculturalism counters the liberal form of multiculturalism that highlights and celebrates difference without accounting for the systemic and structural operations of power. It takes into account the intersection of social locations and identities in relation to race, class, gender, language, sexuality, and ability as they shape and manifest in school and society (May & Sleeter, 2010). Finally, critical pedagogy facilitates the reading of the word and the world, in which literacy is grounded in scrutinizing the relationship between education and society at large. It encourages teachers and students to be active participants, to pose questions and address relevant social issues, and to utilize education for individual and institutional transformations (Freire, 1970).
Each dimension of teaching science for social justice is grounded in a particular theoretical strand: the dimension of critical nature of science is grounded in anti-colonial theory; the dimension of critical knowledge and pedagogy is grounded in the theoretical strand of critical multiculturalism; and the dimension of sociopolitical action is grounded in the theoretical strand of critical pedagogy. Figure 7.1 (the same as Figure 2.2) demonstrates the overarching critical – cultural perspective of the elementary science methods course, which includes the three dimensions and their corresponding theoretical strands.

Figure 7.1. Dimensions and Theoretical Strands of Teaching Science for Social Justice

Starting in Fall 2011, I began teaching a revised “Science and Technology Education for Elementary School Teaching” (EDU 1450) course using this framework. In the next subsections, I will elaborate on the dimensions in the elementary science methods course by giving specific examples of corresponding readings, in-class activities, and assignments. Following my
commitment for research to have scholarly and practical contributions, my explanations here are intended for other elementary science teacher educators in regards to how to develop a methods course that puts at the center teaching science for social justice.

**Critical Nature of Science**

The dimension of critical nature of science is informed by the theoretical strand of anti-colonial theory, which challenges the Eurocentric objectives and production of scientific knowledge as well as the uses and outcomes of this knowledge. Teaching science for social justice requires a critical analysis of the nature of science, or science as a way of knowing. It encourages the interrogation of the epistemic foundations of Western science as well as its ideologies, operations, and effects. It challenges science as the sole authoritative body of knowledge by exposing its social, political, and economic roots and routes. Therefore, the dimension of critical nature of science endorses a constructivist epistemology rather than a blind faith in positivism.

In my elementary science methods course, I wanted to trouble my preservice teachers’ faith in positivism and have them engage with Aboriginal knowledges and worldviews of science. Early in the course, I presented numerous case studies depicting historical and contemporary incidences of scientific racisms. Through small and large group discussions, I urged preservice teachers to see science as a human endeavor driven by social, cultural, political, and economic motives and conditions. Later in the course, we read scholarly articles that compared and contrasted Western and Aboriginal worldviews of science. As one of their major assignments, preservice teachers were required to create a visual representation depicting their interpretation of the dynamics between Western and Aboriginal worldviews and knowledges and
to submit a written reflection on their final product and their process of creation. Through in-class presentations and discussions, course readings, and assignments, preservice teachers began to see the hegemony of Western science and the negative effects it has had on Aboriginal people, racialized minorities, poor communities, and girls and women. My analysis of what my research participants indicated as transformative pedagogical choices reveals that, within the dimension of critical nature of science, two enabling factors helped shift their beliefs: engaging with diverse perspectives, especially Aboriginal epistemologies; and challenging the positivism of science.

**Critical Knowledge and Pedagogy**

The dimension of critical knowledge and pedagogy is informed by the theoretical strand of critical multiculturalism, which makes explicit issues of systemic oppression and power relations based on race, gender, class, sexuality, and other markers of social difference. In my elementary science methods course, I explored the complex roles that race and culture play in teaching and learning science and the relevant pedagogies that aim to meet the needs of racially, culturally, and linguistically diverse students. I also urged my preservice teachers to examine their own social locations and identities and how these may impact science content, their interactions with students, and their views on marginalized families and communities. During the first class session, I asked preservice teachers to complete the Draw-a-Scientist activity to explore their perceptions of science and scientists. This activity led them to deeply examine their own social locations, the beliefs they held about what is science and who does science, and the potential implications for different kinds of students. I also required preservice teachers to create a Culturally Relevant Science Lesson Plan based on their school practicum experiences, which allowed them to apply the principles of culturally relevant pedagogy to the practical demands of
lesson planning. My analysis of what my research participants indicated as transformative pedagogical choices reveals that, within the dimension of critical knowledge and pedagogy, two enabling factors helped shift their beliefs: recognizing their own social location; and incorporating race and culture in teaching and learning.

**Sociopolitical Action**

The dimension of sociopolitical action is informed by the theoretical strand of critical pedagogy, which empowers teachers and students to analyze and challenge dominant systems of power in schools and society. The goal of critical pedagogy is for us to understand the relationship between knowledge and power and to take constructive action for progressive change. Therefore, the dimension of sociopolitical action is broadly concerned with the impact of science and technology on society and the environment and with the development of advocates who will use science to benefit marginalized communities and address socioscientific issues. In my elementary science methods course, I drew from numerous Canadian and international case studies of environmental racism to demonstrate how marginalized and disenfranchised communities are saddled with more environmental burdens than privileged communities. As another major assignment, I required preservice teachers to construct an Environmental Justice Strategy based on a local, national, or global issue of their choosing. I also urged them to ensure that their strategy incorporates age-appropriate actions for elementary students, so that both teachers and students can work together to resolve a socioscientific, environmental concern. My analysis of what my research participants indicated as transformative pedagogical choices reveals that, within the dimension of sociopolitical action, there were two enabling factors that
promoted belief change: developing students’ critical consciousness; and encouraging student agency.

Drawing from the critical – cultural theoretical framework, I used the three dimensions of teaching science for social justice as the conceptual lens for my “Science and Technology Education for Elementary School Teaching” course. In a course that only met for six class sessions for a total of 18 contact hours during a nine-month teacher education program, I recognized and understood the challenge of providing science education content and pedagogical content knowledge, while incorporating concepts, strategies, and assignments centered on social justice. Frankly, it was not an easy task. However, I was driven by a scholarly, professional, and even personal commitment to integrate science education and social justice in meaningful ways. My former elementary student Tyrell whose quip “don’t you know only White kids like science?” continues to resonate with me and is present on every page of this thesis. He reminds me of the importance of this research project and how much more I need to learn and do.

Towards a Theory of Belief Change about Teaching Science for Social Justice

My “Science and Technology Education for Elementary School Teaching” course (EDU 1450) heavily drew from my extensive review and synthesis of the scholarly literature that enabled me to integrate science education and social justice and to apply these insights onto curriculum development and teaching strategies. My research interest in preservice teachers’ beliefs and belief changes emerged quite separately. In fact, it emerged after I had already developed my critical – cultural framework during my first year of doctoral studies in the 2010-11 academic year. In the Summer 2011, when I began exploring potential thesis research topics and questions, I started becoming curious about teacher beliefs and belief changes based on my
readings of critical scholars of teacher education. After seriously considering the two scholarly areas of teaching science for social justice and of preservice teachers’ beliefs and belief change, I decided to bring them together to develop a theory of belief change about teaching science for social justice.

Chapters 4, 5, and 6 provide more detailed explanations on the research data, analyses, and findings that built on each other and facilitated the development of my theory of belief change about teaching science for social justice. In summary, at the beginning of the academic year, the 11 preservice teachers in the study can be categorized as holding two types of beliefs about teaching science for social justice: six participants possessed liberal beliefs, while five others had critical beliefs. Those with liberal beliefs espoused the need for intercultural respect and valued learning about “the other.” Those with critical beliefs stressed the need to challenge structural inequities in school and society based on social markers of difference, such as race and class. By the end of the year, all research participants experienced one of three types or degrees of belief change about teaching science for social justice – minimal, substantial, or refined. Four of the six participants with initial liberal beliefs demonstrated a minimal change in beliefs by the end of the year, showing a slight shift in the critical nature of science dimension only. The other two participants with initial liberal beliefs exhibited a substantial change in beliefs, moving towards the critical category in all three dimensions by the end of the year. Lastly, the five participants with initial critical beliefs showed a refined change in beliefs, alongside a significant shift in the critical nature of science dimension.

In my study, the first research question enabled me to identify two types of initial beliefs – liberal and critical – that preservice teachers possessed regarding teaching science for social justice. The second research question provided insights into the three differing ways in which
these beliefs changed – minimal, substantial, or refined – by the end of the year after the participants took my elementary science methods course. The third research question provided the participants’ perspectives on the specific course pedagogies which facilitated their belief change. These pedagogical choices that were identified by the participants were then extrapolated to delineate six enabling factors in teaching science for social justice: (1) engaging diverse (e.g., Aboriginal) worldviews in science; (2) challenging the positivism of science; (3) recognizing teachers’ social location; (4) incorporating race and culture in teaching and learning; (5) developing students’ critical consciousness; and, (6) encouraging student agency. My analysis of the data for the three research questions has facilitated the development of my theory of belief change about teaching science for social justice.

Table 7.1 below offers an overview that delineates the development and components of the theory of belief change about teaching science for social justice.

Table 7.1. Overview of Teaching Science for Social Justice

<table>
<thead>
<tr>
<th>Science Methods Course from the Literature Review</th>
<th>Theoretical Strands</th>
<th>Empirical Study from the Research Participant Data</th>
<th>Constructivist Grounded Theory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions</td>
<td></td>
<td>Pedagogical Choices</td>
<td>Enrollment Factors</td>
</tr>
<tr>
<td>Critical Nature of Science</td>
<td>Anti-Colonial Theory</td>
<td>Aboriginal readings and visual representation</td>
<td>Engage with diverse (e.g., Aboriginal) worldviews</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Case studies: Scientific racisms</td>
<td>Challenge the positivism of science</td>
</tr>
<tr>
<td>Critical Knowledge and Pedagogy</td>
<td>Critical Multiculturalism</td>
<td>Draw-a-Scientist</td>
<td>Recognize teachers’ social location</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Culturally relevant pedagogy readings and lesson plan</td>
<td>Incorporate race and culture in teaching and learning</td>
</tr>
</tbody>
</table>
The table can be read along vertical and horizontal planes. Along the vertical planes, the elementary science methods course was constructed based on my extensive review and synthesis of the scholarly literature which enabled me to identify three theoretical strands that informed their respective dimensions of teaching science for social justice. The empirical study was grounded in the qualitative data from the 11 participants, who identified particular pedagogical choices from my course that were then extrapolated to their corresponding enabling factors. Along the horizontal planes, each dimension was informed by a theoretical strand which served as a foundational pillar for teaching science for social justice. The dimension and theoretical strand were linked to particular pedagogical choices selected by the participants as crucial in their belief change. For instance, the dimension of critical nature of science heavily drew from anti-colonial theory in the way that I conceptualized the course. The participants overwhelmingly pointed to the Aboriginal readings and visual representation assignment as vital pedagogical choices that facilitated their belief change in regards to engaging with diverse perspectives in science. Ultimately, the empirical study, which derives from the participants’ qualitative data, is interconnected with the course that I developed through my literature review. In other words, the empirical through my research and the theoretical through my literature review are inextricably intertwined in the formulation of my theory of belief change about teaching science for social justice.
Analytically and methodologically, constructivist grounded theory (Charmaz, 2006) has enabled me to focus on the empirical data from my qualitative research and derive my emerging theory from it, without completely disregarding various theoretical strands and previous studies that may inform the new theory. Based on my research, which was informed by and grounded in my elementary science methods course, I forward my theory of belief change about teaching science for social justice as a theoretical framework underpinned by three teaching and learning conditions. I theorize that preservice teachers may experience belief change when they recognize (1) the relationship between science and society, (2) the relationship between individuals and society, and (3) the importance of taking action on socioscientific issues. The degree of belief change, as my research demonstrates, will heavily depend on the initial beliefs of preservice teachers and to what extent they meet the three conditions. For instance, when they meet all three conditions, preservice teachers will most likely show substantial or refined change in their beliefs about teaching science for social justice. However, when they are not all met, they will most likely show minimal or no change at all. In sum, clearly identifying preservice teachers’ initial beliefs and explicitly enacting the three teaching and learning conditions are tremendously significant for teacher educators to promote belief change within preservice teachers to teach science for social justice.

In the next sub-sections, I will elaborate on the three teaching and learning conditions that underpin my theory of belief change about teaching science for social justice. For the first teaching and learning condition of recognizing the relationship between science and society, I will draw from data from all of 11 research participants since this condition generally (but not entirely) falls in the critical nature of science dimension and all participants experienced shifts of varying degrees in this dimension. For the next two teaching and learning conditions of
recognizing the relationship between individuals and society and the importance of taking action on socioscientific issues, I will focus on data from two participants, Rebecca and Shiva, since they experienced substantial shifts in beliefs in regards to teaching science for social justice. The other four participants with initial liberal beliefs showed no change at all in the dimensions of critical knowledge and pedagogy and sociopolitical action. The five participants with initial critical beliefs demonstrated some refinement in these two dimensions. Hence, I decided to emphasize the transformation of the participants with substantial belief changes for the last two teaching and learning conditions since they provided the most informative data.

**Recognizing the Relationship between Science and Society**

The first teaching and learning condition of recognizing the relationship between science and society is a crucial starting point when promoting belief change about teaching science for social justice. Without this fundamental condition, the hegemonic regime of science in teacher education, school curriculum, and social consciousness will most likely continue to reign supreme. At the beginning of the academic year, all 11 participants in this research project placed an intense faith in the power of science and its methods to produce genuine factual knowledge about the world. According to my participants, science is “the holy grail of truth and knowledge” (Walter, BQ, 9/23/11). It is considered objective because “it deals with facts” (Ben, BQ, 9/23/2011) and “scientists follow rigid procedures so that their results are valid” (Shiva, BQ, 9/30/2011). Such beliefs position science as “beyond reproach,” and make it a value-free and universal practice (Dayja, Interview, 5/4/12). My participants’ initial beliefs strongly resonate with research assessing preservice and practicing teachers’ beliefs about the nature of science (Abd-El-Khalick & Lederman, 2000). There is a general consensus that science is a body of
knowledge that is produced by an academic elite through a rigorous scientific method that yields objective facts about the world. Consequently, the belief in an objective and authoritative science has permeated our social consciousness, and has conferred scientific knowledge a privileged status in school and society.

By the end of the year, all 11 preservice teachers recognized the important relationship between science and society, the only teaching and learning condition that all research participants met. For those who demonstrated substantial belief change from a liberal to a critical position (Rebecca and Shiva), they challenged the universal notion of Western science, saw science as a human endeavor motivated by many contextual factors, and reconsidered diverse epistemologies as being relevant to science teaching and learning. Similarly, for those who already had critical beliefs yet exhibited a refined change (Ben, Dayja, Maria, Tina, and Walter), they also made great strides in their understandings of the nature of science and took aim at science as body of knowledge. For those who started with liberal beliefs and showed minimal change (Alex, Carol, Frank, and Nick), they demonstrated only a slight shift in the dimension of critical nature of science, generally where the relationship between science and society was most evident. They began to consider the possibility of including diverse perspectives into the science curriculum, but held on strongly to their notions of Western science as a superior form of knowledge. The liberal participants who demonstrated minimal belief change held perspectives that are considered problematic by scholars of history, sociology and philosophy of science (Aikenhead & Michell, 2011; Brickhouse, 1994; Harding, 1991). These scholars claim that scientism, or the dogmatic reverence of science as the basis and method of absolute knowledge, is problematic for a numbers of reasons. First, it elevates science to such a high status that it is beyond critique or reproach. Second, scientism constrains the possibility of engaging with
diverse epistemological perspectives. Third, it perpetuates a mythical faith in what science can and cannot tell us about the natural and human-made worlds. My research indicates that belief change occurs in regards to teaching science for social justice when preservice teachers recognize the relationship between science and society, especially when they view science as a cultural phenomenon and when they unlearn positivism.

*Science as a cultural phenomenon:* Science as a cultural phenomenon responds to the overarching questions: What is science? And, who does science? Participants who made substantial and refined shifts in their beliefs during the year understood the nature of science from a critical perspective. For example, they questioned long-standing beliefs about the nature of scientific knowledge and the effects of science on society. Rebecca stated, “I never considered science [as] a cultural practice. I have been taught that it is a cultural … something that is above and beyond culture” (Interview, 6/8/12). She added, “many different groups have their own way of explaining the natural world, and they [diverse sciences] stand in the shadow of Western science” (Ibid.). Here, preservice teachers see the hegemonic influence of Western science and its exclusion of diverse ways of knowing the world. Walter bluntly shared,

To be honest, Western science is very arrogant, isn’t it? I mean, it acts as if it’s the only way to know things and disregards the sciences that have been present in multiple indigenous communities, China, Africa, and the Islamic nations for centuries…. We talk about multiculturalism, but science, as far as I can see, is not multicultural at all. (Walter, Interview, 4/25/12)

Participants noted that science defined by Eurocentric standards acts to exclude, diminish, and deem inferior other ways of understanding that have guided many non-European societies (Hodson, 1993).

As previously mentioned, all 11 participants in this study expressed that the Aboriginal readings and visual representation assignment were extremely important pedagogical choices in
facilitating their belief change concerning teaching science for social justice. These activities created a space for preservice teachers to engage with diverse epistemological perspectives, shedding light on the importance of recognizing science as a cultural activity and such acknowledgment was crucial to belief change. For example, Shiva remarked in her interview, “content [science] is culture, it represents the dominant culture” (6/9/12). She continues, “We must teach our students to accept the relativity of our understanding of the world around us. The subjectivity of what we consider truth and knowledge, and the ability to see other truths just as valid as our own, exist” (EQ, 4/10/12). Shiva demonstrates an understanding of what another participant indicated: there are “numerous sciences that are culturally specific” (Ben, EQ, 4/5/12).

Unlearning positivism. The second, and closely related, tenet of the teaching and learning condition of recognizing the relationship between science and society is unlearning positivism. Participants with substantial and refined shifts moved away from a firm belief of positivism, and moved towards a constructivist orientation of reality. At the beginning of the year, participants espoused that “facts speak for themselves” (Dayja, BQ, 9/23/11) and “what could be more important [in explaining the world] than science?” (Tina, BQ, 9/19/11). Their beliefs are steeped in the tradition of positivism that has dominated science and science education. Scientists claim that the rigorous methods in empirical investigation produce neutral knowledge. Such a belief is embedded in the philosophical orientation of positivism. Positivism indicates that there is a singular, external world, which we can come to know through careful experimentation (Aikenhead & Michell, 2011). Moreover, strict adherence to these methods produces irrefutable knowledge. In other words, science produces highly reliable knowledge. Positivists assert that the “culture, gender, race, ethnicity, or sexual orientation of the knower is irrelevant to scientific
knowledge” (Stanley & Brickhouse, 1994, p. 388). They also claim that science is an “intellectual activity whose truth-finding goal is not, in principle, affected by national, class, racial or other differences” (Matthews, 1994, p. 182).

Unlearning positivism urges preservice teachers to see science as a human activity that is not immune to human emotions, agendas, or biases. Since science does not occur in a social vacuum, it is not purely objective or neutral. Rather, it represents the ideologies, values, and beliefs of the dominant culture (Harding, 1991). Participants who experienced substantial and refined shifts recalled how our first class session when I challenged dominant notions of science “was a powerful and eye-opening experience” (Shiva, BQ, 9/30/11). Ben recalled, “That class made me so uneasy. There you were, challenging my favorite subject” (Interview, 4/27/12). Maria remembered feeling angry when I shared a PowerPoint slide with the original, full title of Charles Darwin’s (1859) famous book, On the Origin of the Species by Means of Natural Selection or the Preservation of the Favoured Races in the Struggle for Life. During her interview, she confessed,

As a Latina, I suddenly knew where you were headed with the conversation and it made me sick to my stomach. I knew the group of people who look like me were not the favoured groups Darwin was referring to … and I got mad because even though I took all these science classes, I never knew the title or anything about the social context in which Darwin lived. (Maria, Interview, 6/8/12)

My participants’ engagement with anti-racist and feminist critiques of science as well as case studies of scientific racisms encouraged a greater recognition of the relationship between science and society. They started seeing science, its purposes, and its products differently, and how various social, economic, and political factors influence science, further unlearning positivism. Shiva stated,

On the first day of class, you had us think about the question, “Who benefits and who loses with scientific advancements?” Then you shared all those horrible examples of how
science has been used to further racist and sexist motives and ideas…. It really made me think. I never considered how science could be used to uphold the superiority of Whites and males. (Shiva, Interview, 6/9/12)

By the end of the year, this group saw science “as a human activity that is a part of, not separated from, the rest of society” (Tina, EQ, 2/7/12) in which “scientists produce knowledge that is either oppressive or emancipatory” (Maria, Interview, 6/8/12), therefore moving towards a constructivist understanding of science. Maria shared, “I bought into the stereotype of the unemotional and value-free scientist who simply wants to make the world a better place…. But all of these guys, like Linneaus, Morton, Watson and the others you shared with us, created science that was based on their own beliefs” (Maria, Interview, 6/8/12). When preservice teachers engaged with case studies of scientific racisms, such as IQ assessments, medical testing on racialized bodies, and environmental racisms, they could no longer avoid seeing the relationship between science and society. Rebecca said, “The cases revealed a nasty side to science…. I never saw science as being bad, but science is done by humans and sometimes humans do bad things” (Interview, 6/8/12).

**Recognizing the Relationship between Individuals and Society**

The second teaching and learning condition that is necessary for belief change to teaching science for social justice is recognizing the relationship between individuals and society. For this condition, I will focus on Rebecca and Shiva, who began the academic year with liberal beliefs and experienced substantial belief changes. Through their belief change, they began to see dynamics in school and society beyond the individual level and how the self is tied to social categories of difference, such as race, class and gender that are part of larger systems of privilege and oppression. They started acknowledging the complex and intersecting roles that social
differences play in teaching and learning and how they are implicated in structures and hierarchies of power. Through this recognition, their prior beliefs about equality, individualism, and meritocracy were dramatically challenged.

At the beginning of the academic year, Rebecca and Shiva possessed liberal beliefs and espoused that “all students are equal” (Shiva, BQ, 9/30/11) and that teachers who engage in social justice “treat all students the same” (Rebecca, BQ, 9/23/11). Although they acknowledged differences among students, they believed that social justice meant providing equal instruction to all students. They also did not account for systemic and institutional inequity and for the history and legacy of discrimination that students from marginalized communities continue to experience. Both Rebecca and Shiva indicated that the Draw-a-Scientist activity was important in their belief change. They both drew White males. Rebecca had “never thought about why” she was one of the few females in her science courses in high school and university (Rebecca, Interview, 6/8/12). She realized that not reflecting on this disparity was disadvantageous to female and racialized minority students because they do not see role models and do not see themselves as doing science. She came to understand that teaching science is “about connecting one’s identity to it” (Ibid.). Similarly, Shiva stated that she “was not immune to the media” message that only certain racialized (White) and gendered (male) individuals “get to become scientists” (Shiva, Interview, 6/9/12). Even though she is a racialized minority female, she initially attributed her success to hard work and passion for science. She never considered that some groups are “not part of the elite science pipeline” (Ibid.). Their thoughtful responses to the Draw-a-Scientist activity depicted a greater recognition of the relationship between individuals and society. They became more aware of how the self is embedded in categories of difference that shape and are shaped by school and society. They came to understand institutional
structures, including curriculum and media, as playing powerful roles in relaying dominant and distort ing images of science and scientists, which become internalized within ourselves. Rebecca and Shiva’s understanding of systemic oppression, rather than individual acts of discrimination, moved them to fundamentally alter their views on science and science education. By the end of the academic year, they challenged traditional science instruction, and instead favored science pedagogy that makes the role of race, culture, and other social differences explicit in curriculum, teaching, and learning. During her interview, Rebecca shared how she had changed in her thinking about teaching:

One of the first things I think about before teaching is my students’ race and culture, and it’s terrifying that teachers do not consider these things when planning. I never saw race as important to teaching, but now I believe it’s all intertwined…. How can I make my lessons culturally relevant if I don’t really know my students and the cultural attributes they bring to school? (Rebecca, Interview, 6/8/12)

For Rebecca, the recognition of the relationship between individuals and society resulted in developing her own critical consciousness and understanding the complexity of teacher-student interactions in educational institutions that are stratified by power and social differences.

I always think about my social location now. What does it mean to be a White female teacher? I believe it’s so important that every single day, every single interaction you have with a student, to be aware of your location and the impact you’re having on a student. So what experiences you’ve had that shaped the way you are. What kind of privileges you’ve had, what opportunities you’ve had, or maybe haven’t had. (Rebecca, Interview, 6/8/12)

**Recognizing the Importance of Taking Action on Socioscientific Issues**

The third teaching and learning condition links socioscientific issues to the Freirean notion of praxis (Freire, 1970), the iterative process of reflection and action. Socioscientific issues are those that occur at the intersection of science, technology, society, and the environment, and require teachers and students to grapple with how marginalized communities
are unfairly straddled with environmental burdens. Explicit attention is paid to how Aboriginal, racialized minority, poor, and global South communities often bear this burden in society. Although this condition is generally linked to the dimension on sociopolitical action, it is also informed by the dimension on critical nature of science due to its explicit analysis of who benefits and loses from scientific progress. It is also connected to the dimension of critical knowledge and pedagogy due to its emphasis on the complex role that race and culture play in school and society. Ultimately, this condition stresses that awareness, understanding, and reflection are not enough. It urges teachers and students to address and act on socioscientific issues as genuine praxis for teaching science for social justice.

Both Shiva and Rebecca began the academic year believing that science is a value-neutral content and that teaching science is an objective activity. They were also resistant to the idea of what Derek Hodson (2001) calls “politicizing the science curriculum” (p. 219). However, as the year progressed, their beliefs began to change, and developing agency became a central focus for both of them. At the end of the year, they shared deep convictions about producing agents of change and becoming agents of change themselves. Shiva reflected,

As I look back through the course and my own experiences with science, I do realize that my ideas at the beginning of the year about myself as a teacher were wrong…. By not leading my students or, rather, empowering them to become agents of change, I uphold the status quo. If you told me before coming into this class that I would believe this way, I would tell you that you were totally wrong. I never saw science or teaching [as] political acts. (Shiva, Interview, 6/9/12)

Shiva’s espoused beliefs manifested in her beliefs-in-use through her actions: “In my practicum, I put on a school-wide assembly about Aboriginal treatment and worldviews. I hope it jarred my students, who were not Aboriginal, to want to make changes in their country” (Ibid.). She added, “If I were working in an Aboriginal community, I would need to be out there, front and center, making my social justice goals known to everyone…. Aboriginal students must see science as a
tool they can harness to improve their living conditions” (Ibid.). Ultimately, Shiva believed that activism is important when working with Aboriginal and other disenfranchised communities.

During the interview, Rebecca noticed the overlap between Assignment #2 (Environmental Justice Strategy) and Assignment #3 (Culturally Relevant Lesson Plan) in her focus on addressing community-based concerns and developing activists. She said, “I really enjoyed the [culturally relevant] lesson plan and the [environmental justice] strategy assignments because they were so connected for me. For both of them I focused on the critical consciousness aspect of social justice which had a strong activist orientation to them” (Rebecca, Interview, 6/8/12). Rebecca focused on the Northern Enbridge Gateway Pipeline and its impact on local communities for Assignment #3 (described in Chapter 6) and the case of Africville in Nova Scotia for Assignment #2 (described in Chapter 5). By the end of the academic year, Rebecca welcomed the importance of challenging unequal power structures and encouraging students to take action on socioscientific issues. However, she understood that teaching for social justice can be complicated, and defies traditional visions of teaching and learning. Rebecca stressed, “We really have to be careful, right? I mean, teaching controversial issues as a new teacher may not be safe in some communities…. We will need to work up to it, earn respect in the community and then hopefully have their support” (Ibid.). While aware of potential limits and dangers, Rebecca’s conviction was clear when she stated, “As a future urban school teacher, if I don’t advocate and teach my students to advocate, then nothing in their lives and communities will ever change. By doing nothing, I have failed not only them, but also myself” (Ibid.).

In my development of a new theory of belief change about teaching science for social justice, my study contributes to particular scholarly areas, to which I will turn in the next section.
Scholarly Contributions

This study contributes specifically to the three scholarly areas of qualitative research methodology, theories of belief change, and science education content.

Methodological: Use of Constructivist Grounded Theory

My review of the scholarly literature reveals that studies on beliefs are overwhelmingly quantitative in nature and situated in the disciplinary framework of psychology (e.g., Pajares, 1992; Rokeach, 1972). However, studies on belief change also draw from qualitative research methods, which foreground the problems, processes, and patterns of shifts in beliefs (e.g., Rodriguez, 1998). I contribute to the empirical works on beliefs and belief changes by pursuing a qualitative study that utilizes Kathy Charmaz’s (2006) constructivist grounded theory. Based on my review of the scholarly literature, I have not come across a published study on beliefs or belief changes that uses grounded theory or constructivist grounded theory. Therefore, my work may be one of the few to examine beliefs and belief changes from the methodological approach of constructivist grounded theory.

I employed constructivist grounded theory (CGT) for my methodology since I was interested in developing a new theory of belief change. CGT, like the original version of grounded theory (Glaser & Strauss, 1967; Strauss & Corbin, 1998), is useful for generating a middle-range theory that describes specific situations that are limited to the context and scope of the study. Yet CGT refutes the positivist underpinnings of the original version, which suggest that an external reality can be uncovered by an objective researcher. On the contrary, Charmaz (2006) contends that there are multiple realities that are continually created as individuals interact with the world around them, and that both data and theories are co-constructed during
the interplay between the researcher and the researched. I follow Charmaz’s directive in my qualitative study to produce an interpretive portrayal of the studied phenomenon and to make explicit the sociocultural contexts that shape the lives, experiences, and perspectives of research participants.

**Theoretical: New Theory of Belief Change**

According to my review of the literature, discussions in teacher education on the process of belief change are dominated by two schools of thought. One school of thought, led by George Posner (Posner et al., 1982), takes a psychological approach that sets up four conditions for conceptual change, including dissatisfaction, intelligibility, plausibility, and fruitfulness. The other school of thought, led by Alberto Rodriguez (1998, 2005), takes a constructivist approach that offers a broad set of strategies for ideological change, including reflexivity and dialogicality. While Posner’s theory of conceptual change is useful in understanding belief change from a psychological perspective, it is limited when I consider the sociocultural aspects of learning in my science methods course. Rodriguez’s theory addresses this limitation with his notion of sociotransformative constructivism. His strategies of reflexivity and dialogic conversation have been utilized in numerous content areas (Aguirre, 2005; Rodriguez, 2010). I build on Rodriguez’s constructivist approach to belief change in order to generate a new theory that is centrally focused on the content area of science education and that delineates specific examples of effective pedagogies to teach science for social justice.

My new theory of belief change about teaching science for social justice posits three teaching and learning conditions that facilitate belief change: preservice teachers need to recognize (1) the relationship between science and society, (2) the relationship between
individuals and society, and (3) the importance of taking action on socioscientific issues. This theory is derived from my analysis of the interview, questionnaire, assignment, and reflection data from 11 preservice teachers in my science methods course. It is also situated within the context of my course, which is based on my review and synthesis of the scholarly literature on science education, teacher education, and social justice (see Table 7.1 in this chapter). Hence, my new theory of belief change – as shaped by constructivist grounded theory – focused on the empirical data from my qualitative research, without completely disregarding previous studies that informed it.

Content: Teaching Science for Social Justice

My study lies at the intersection of two areas of research: science for social justice; and teacher education for social justice (see Figure 1.1 in Chapter 1). On the one hand, research on the teaching of science for social justice has primarily emphasized practicing teachers and school-university partnerships (Lee & Buxton, 2010). On the other hand, research on preparing preservice teachers for social justice is well established (Ball & Tyson, 2011), yet few studies pertain to the preparation of teachers in specific content areas, especially in science education. Only a handful of published studies address the preparation of teachers in an elementary science methods course with a social justice emphasis. Let me highlight two key studies. Julie Bianchini and her colleagues (Bianchini et al., 2003) investigated how preservice teachers’ views shifted concerning their conceptions of science during a science methods course. The course emphasized how science is practiced and how science is situated in social, cultural, and political contexts, using feminist, anti-racist, and multicultural perspectives. Felicia Moore (2009) implemented a book club in her science methods course to challenge preservice teachers’ cultural biases,
assumptions, and stereotypes about racialized minority students. She found that three types of learning – individual, collaborative, and collective – were integral for fostering critical reflective inquiry and ideological change concerning diversity in urban science education.

My scholarly and practical aim is to bring together science education, teacher education, and social justice in a comprehensive curricular and pedagogical framework. For the 2011-12 academic year, I re-designed an existing science methods course, “Science and Technology Education for Elementary School Teaching” (EDU 1450), at OISE, University of Toronto, which served as the site of my research study. The re-designed course was grounded in my review of the scholarly literature, which enabled me to develop a critical – cultural theoretical framework to teaching science for social justice. My curricular and pedagogical framework includes three dimensions – critical nature of science, critical knowledge and pedagogy, and sociopolitical action – which inform the course readings and assignments (see Figure 7.1 in this chapter). When examining existing studies through my overarching framework and three dimensions, the work by Julie Bianchini and her colleagues is focused on the dimension of critical nature of science, and the work by Felicia Moore is centered on the dimension of critical knowledge and pedagogy. Neither study addresses the dimension of sociopolitical action. Therefore, I contribute to this line of scholarly inquiry and professional practice by offering a more comprehensive science education framework that addresses the three dimensions in an interconnected way. All three dimensions need to be addressed in order to fully engage and enact teaching science for social justice.
Future Directions for Research and Teaching

In this section, I will delineate potential future directions for research and teaching as subsequent steps that are informed by this study.

Unpacking Resistance to Social Justice in Science Education

The first direction for future research and teaching is to understand and work through the resistance of preservice teachers to meaningfully and genuinely integrate social justice in science education.

In this study, I focused on beliefs due to the scholarly consensus that beliefs are precursors to actions and that changing beliefs is crucial to changing practices. For widespread and sustainable science education reform to occur, I align myself with critical scholars who indicate that many preservice teachers enter teacher education programs with beliefs that are antithetical to teaching for equity, diversity, and multiculturalism (Hollins & Guzman, 2005). In my study, some participants held beliefs that I construed as impeding teaching science for social justice. They were preservice teachers with initial liberal beliefs and showed minimal change by the end of the year. They expressed that all students should be treated the same and that students’ race, ethnicity, and culture have no role in teaching and learning. They were adamantly opposed to what they deemed as indoctrinating students and to having students take action on social issues. These types of beliefs, in my view, uphold the status quo, and perpetuate inequities in school and society for many marginalized students. Subsequently, failing to account for equity, diversity, and multiculturalism may lead to students’ academic disengagement and failure in science.
My combined research and teaching objective was to create an inquiry space in my elementary science methods course that was conducive to investigating science teaching and learning through a critical lens and that could potentially challenge and shift preservice teachers’ beliefs about teaching science for social justice. In this process, I paid close attention to pedagogical practices that, according to my participants, promoted changes in their beliefs (see Table 7.1 in this chapter). In my study, two participants demonstrated substantial changes, and five others showed refined changes in their beliefs. However, out of the eleven participants, four experienced minimal changes in their beliefs. My comparative analysis of the qualitative data pointed to resistance from these four preservice teachers. In the three dimensions of teaching science for social justice, these participants exhibited only a slight change in the dimension of critical nature of science and no change at all in the other two dimensions. They firmly adhered to the infallibility of positivism, the irrelevance of race and culture in teaching and learning, and the apolitical nature of teaching. Their initial beliefs created a formidable wall of resistance to the curriculum and pedagogy in my elementary science methods course. They de-criticalized course activities and assignments, so that they remained consistent with their initial beliefs. They ignored or dismissed the lessons’ or assignments’ critical possibilities and social justice implications. Although I was able to generate a theory of belief change, my findings resonate with Goldstein (in press) and Kumashiro (2000) who contend that, even though anti-oppressive teacher education is necessary, belief change is an unpredictable endeavor.
Using the Framework of Teaching Science for Social Justice in Other Contexts

The second direction for future research and teaching is to examine how fellow teacher educators can utilize, modify, and/or build upon my framework on teaching science for social justice and use it in other contexts.

For teacher educators, this study might serve as a conceptual, curricular, and pedagogical framework for creating a course on teaching science for social justice (see Figure 2.2 in Chapter 2, Figure 3.1 in Chapter 3, and Table 7.1 in this chapter). I provided specific scholarly and professional readings, in-class activities and discussions, assignments, and reflection exercises. Based on this study, some of these pedagogical activities have shown promise in enabling belief change. I am also keen to learn how these pedagogies might work (or not) in different contexts and how other contexts might need different pedagogies to address their particular preservice teachers and the students, families, and communities they will be working with. While my framework has shown some success at OISE, University of Toronto, I am mindful that each institution is unique and that there are barriers that might impede this type of teaching. For example, OISE has a stated commitment to the inclusion Aboriginal knowledges and the Initial Teacher Education program mission statement details an explicit focus on equity and social justice. However, other faculties of education may not share this vision.

This research study has implications for my future research and teaching, as the course instructor, and for other elementary science teacher educators. As I stated in Chapter 1, my personal background and my professional experiences as an urban elementary school educator have had a significant impact on my beliefs and practices concerning science education and social justice. These experiences and convictions, alongside my extensive review and synthesis of the scholarly literature, guided the development of my elementary science methods course.
Due to the unfulfilled promise of the science for all agenda, I was interested in teaching a course that would put at the center the science academic engagement and achievement of Aboriginal and racialized minority students. Therefore, I constructed a curricular model that forwarded a critical – cultural framework with three dimensions of social justice as its foundational pillars.

Knowing and understanding the three teaching and learning conditions that may facilitate belief change in preservice teachers has enormous implications for future directions of research and teaching in elementary science education. If we would like to have more elementary science teachers with a social justice orientation, we can begin with the end in mind and work backwards. Hence, we need to pursue more research projects analyzing the pedagogical possibilities that can allow preservice teachers to recognize the relationship between science and society, the relationship between individuals and society, and the importance of taking action on socioscientific issues. If these conditions are the goals for an elementary science methods course, then our task as teacher educators is to engage students in readings, activities, assignments, and reflections that can enable these conditions.

**Pursuing Research on Hegemony of Positivism and on Belief to Action**

The third direction for future research and teaching is to continue pursuing empirical studies in the field of science education that pertain to elementary preservice preparation and to teaching science for social justice, especially in relation to the hegemony of positivism and the manifestation of beliefs in actions.

As Stanley and Brickhouse (1994) lament, science education has been “immune to the multiculturalist critique” (p. 388). I argue that this insulation is largely due to the hegemonic stranglehold of positivism which declares that science, as a body of knowledge, is not reflected
in or affected by social identity or human diversity. Due to positivism’s ideological power in school and society, elementary science teacher educators must persistently labor to help preservice teachers unlearn positivism because it is not conducive to teaching science for social justice. How to unlearn positivism remains a vital part of the research and teaching agenda for those of us interested in science education.

Finally, to come back in full circle to my research interests on beliefs and belief changes, I am mindful that the correlation between one’s espoused beliefs and one’s actions is not always clear or direct. Therefore, for a future research project, I would like to see how beliefs manifest in action, which will require research in practicum schools for preservice teachers or in actual classrooms for practicing teachers. How those with liberal or critical beliefs manifest in their science teaching will form the central focus of such a study. Determining the conditions that promote and constrain teaching for social justice in the schools is also an important and related inquiry to pursue.

**Conclusion**

During my ten years in urban public elementary schools, hundreds of students passed through my classrooms as a teacher and my schools as an administrator. However, only a few students, like Tyrell, have had an immensely profound impact on me personally and professionally. Although Tyrell’s and my paths may never cross again, his fleeting words – captured at the beginning of the thesis – were a powerful catalyst for this research project. As a teacher educator, I am uniquely positioned to prepare preservice teachers to re-imagine science and science teaching in a way that may better meet the needs of racially and culturally diverse students, many of whom have been and continue to be systemically marginalized in school and
society. To do this, I argue that we must be concerned with preservice teachers’ beliefs and belief changes. This area of scholarly inquiry is particularly important because many preservice teachers possess beliefs that impede teaching science for social justice. It is my hope that my new theory of belief change about teaching science for social justice will substantively contribute to this endeavor.

According to Alberto Rodriguez (1998) self-reflection can “give us the tools to better understand ourselves and our actions and inactions” (p. 601). In this spirit, I would describe this research project has been both invigorating and challenging. I enjoyed the process of designing and carrying out the study. In particular, I learned tremendously from the data analysis process. My goal was to enter the worlds of my participants as nearly as possible and to convey their beliefs, shifts, and perspectives through my interpretation of the data. Constructivist grounded theory provided useful tools that guided my research process from data collection to analysis. However, one of my biggest challenges was juggling working full time and pursuing doctoral studies and thesis research full time, which often left me overwhelmed. When I was not working, I was sifting and sorting through rich qualitative data, and was writing and revising my chapters. Even when I was not coding or writing, I found that I could seldom get away from my research since I was thinking about it all the time.

Finally, as a teacher educator, I continue to reflect on my teaching. During the time frame when I carried out this research study, I scrutinized my own goals and practices as I sought to provide a challenging and engaging science methods course to preservice teachers. There were numerous times when I felt that I could have done a better job at teaching science for social justice. For example, engaging Aboriginal epistemologies is new to me, and I view myself as a beginning learner in this area. There were also moments when I felt that I was making a
significant impact, and preservice teachers like Shiva and Rebecca give me hope. As I enact the Freireian concept of praxis, I see my scholarly and professional need to continue building on my socioscientific knowledge and my pedagogical content knowledge, so that I can persistently challenge and push my work to effectively bring together science education, teacher education, and social justice.
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Appendix A

Course Outline

Science & Technology Education for Elementary School Teaching

Teaching Science for Social Justice

EDU 1450

2011-2012

Instructor: James C. Eslinger
Office: Room 10-150 (office hours by appointment)
Email: james.eslinger@utoronto.ca

Course Overview

This course is intended to help beginning teachers develop their understanding of science and technology and explore a variety of teaching approaches to help students learn effectively. Science and Technology is part of the Curriculum and Instruction Course. With a focus on inquiry learning and cross-curricular integration, the course components will enable teachers to work toward the five “Standards of Practice for the Teaching Profession” of the College of Teachers: commitment to students and students learning, professional knowledge, professional practice, leadership in learning communities, ongoing professional learning.

Course Content

Teacher candidates will work together to develop knowledge and competency in
- utilizing the Ontario Curriculum Grades 1-8: Science and Technology (2007) to organize and plan science lesson and unites and understand science/technology concepts and skills
- planning inquiry and design-based lessons
- developing meaningful ways of connecting science to students’ experiences (such as children’s literature, real life experiences, and cross-curricular connections)
- implementing a variety of teaching/learning strategies that will engage all students
- integrate the use of instructional technologies
- select and apply a range of appropriate strategies and tools for assessing and evaluating student achievement in relation to the Science and Technology Curriculum

Reference Texts and Resource Books

Ontario Curriculum Grades 1-8: Science and Technology (2007) must be brought to each class.

Course Assignments / Due Dates / Weighting

<table>
<thead>
<tr>
<th>Assignment</th>
<th>Due Date</th>
<th>% of Total Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-class Assignments / Participation / Professionalism</td>
<td>Each Session</td>
<td>20</td>
</tr>
<tr>
<td>Science Is Questionnaire</td>
<td>First Session</td>
<td>10</td>
</tr>
<tr>
<td>#1 Western &amp; Aboriginal Worldviews of Science</td>
<td>Third Session</td>
<td>25</td>
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</tbody>
</table>
Program-related Responsibilities
Teaching candidates should demonstrate a professional attitude, time management skills and reliability.

Attendance and Punctuality
Regular attendance and punctuality are expected as this course revolves around peer interaction and hands-on activities. If you are absent, you will be given an article to summarize for participation points for that day.

Completion of Assignments
Please adhere to the assigned due dates. If you expect to have difficulty with a particular date, please speak to me in advance. Late assignments will not be graded if you have not spoken to me prior.

Consideration of Others
Make every effort to arrive on time to maximize your contribution and minimize disruption. Punctuality is an essential characteristic of a responsible teacher. Turn off cell phones, pagers and anything that beeps before class. Use of any such device should be during break time only.

Grading
Grades range from A+ to F based on the Grading Practices Policy in the OISE/UT Initial Teacher Education Calendar 2010-2011, pp. 54-55.

Use of Blackboard (http://portal.utoronto.ca)
It is expected that you will utilize Blackboard to access all readings and resources for this course. You will need your UTORid and your password to do this.

Academic Integrity
The Code of Behaviour on Academic Matters, University of Toronto, clearly states that it is an offence for a student "To knowingly represent as one’s own any idea or expression of an idea or work of another in any academic examination or term test or in connection with any other form of academic work.” ie: to commit plagiarism.” Whether quoting original work or adapting it, always cite the source. For reference, see handouts 'How Not to Plagiarize' and 'Standard Documentation Formats' at www.utoronto.ca/writing/plagsep.html and www.utoronto.ca/writing/document.html respectively.

Student Accessibility and Disability
Immediately inform me and/or the UT Accessibility Services Office about specific disability or health considerations that may require appropriate accommodations. For more information: <www.studentlife.utoronto.ca/accessibility.aspx>.
SUMMARY OF ASSIGNMENTS

Assignment #1: Visual Representation of Aboriginal and Western Worldviews of Science

You will compare and contrast Aboriginal and Western worldviews using a visual representation, and will consider how these two worldviews of science shape our notions of truth, evidence, and validity. My hope is that you will reconsider the Eurocentric approach to science by exploring Aboriginal ways of knowing. This assignment will have two components. First, on an 11x17 size paper you will depict (perhaps metaphorically) the tensions and similarities between Aboriginal and Western worldviews. Second, you will submit a written reflection that: (1) describes and explains your visual representation; (2) takes a position as to why knowing that different cultural groups may have different worldviews is (or is not) important; and (3) how you might incorporate Aboriginal worldviews in your science teaching. I have uploaded selected readings for this assignment, and you will be expected to draw from these readings for this assignment.

The written portion of this assignment should be approximately 1,000 words and will be uploaded to Blackboard. Mark this as “private” so only I will have access to your work. A photo of your visual representation will also need to be uploaded as well in the same note and you will bring your visual representation to class to hand in during our third session.

I am interested in your views about this assignment. On the same ‘note’ that you upload the assignment please briefly answer the following: 1) How did you feel about doing this assignment? Did you have any reservations, issues, or concerns? 2) Do you view Aboriginal ‘science’ as ‘real science’? Why or why not?

Assignment #2: Environmental Justice Strategy

There is a strong connection between social justice and environmental issues. For this assignment, you will identify an environmental issue that affects vulnerable or marginalized communities, and will explain how you will engage elementary students in learning about the issue and developing a strategy for taking action on the issue. I urge you to consider the needs of your practicum schools or the communities they are located in. Your assignment will need to include the following: (1) identify and explain the environmental issue and its impact on society; (2) elaborate on how you would teach this issue and make it relevant to your students (e.g., provide specific teaching and learning activities); (3) describe how you will engage students as advocates; and (4) explain how you might address the pertinent stakeholders for this environmental issue and strategy.

This assignment will be uploaded to Blackboard by our fifth session. Mark it as “private” so only I will have access to your work.

I am interested in your views about this assignment. On the same ‘note’ that you upload the assignment please briefly answer the following: 1) How did you feel about doing this
Assignment? Did you have any reservations, issues, or concerns? 2) How did you select a “vulnerable or marginalized community” – what were the criteria? 3) Do you believe teachers should politicize the science curriculum? Why or why not?

Assignment #3: Culturally Relevant Science Lesson Plan

Effective teachers of diverse students develop lessons that are culturally relevant to their students, and use their lived experiences as scaffolds and bridges to learning. For this assignment, you will draw on frameworks provided in readings and discussions (Ladson-Billings, 1995; Villegas & Lucas, 2007) to craft a science lesson plan that this is aligned to the Ontario Science Curriculum and that utilizes your students’ funds of knowledge. I strongly encourage you to consider the student demographics in your practicum classrooms for this assignment.

This assignment will be uploaded to Blackboard by our sixth session. Mark it as “private” so only I will have access to your work.

I am interested in your views about this assignment. On the same ‘note’ that you upload the assignment please briefly answer the following: 1) How did you feel about doing this assignment? Did you have any reservations, issues, or concerns? 2) Briefly explain how your lesson plan is “culturally relevant” and for whom is it relevant?
Appendix B

Beginning-of-the-Year Questionnaire

Assignment #1: Science Is?
I am interested in your beliefs about science teaching as you begin your teacher training here at OISE. Without the use of Google or other search engines, please answer the questions below. There are no “right or wrong” answers; your honest and individual ideas are what are important to me.

Requirements: Answer the following questions in a typed document that is approximately 700 words in length. Please upload this to Blackboard and bring a hard copy to our first class.

1. What is science?
2. How should science be taught?
3. What is social justice?
4. What does it mean to teach science for social justice or to integrate science and social justice?
Appendix C

End-of-the-Year Questionnaire

Prior to this class …

1.A] What were your beliefs about teaching science (if any)?
1.B] What were your beliefs about social justice (if any)?
1.C] What were your beliefs about teaching science for social justice (if any)?

Prior to this class …

2.A] What and/or who shaped your prior beliefs about teaching science?
2.B] What and/or who shaped your prior beliefs about social justice?
2.C] What and/or who shaped your prior beliefs about teaching science for social justice?

During your Teacher Education Program …

3.A] Did your prior beliefs about teaching science change? YES or NO
3.B] Did your prior beliefs about social justice change? YES or NO
3.C] Did your prior beliefs about teaching science for social justice change? YES or NO

If you answered YES to 3.C, please name and/or describe the specific readings, activities, and discussions in our class that helped change your prior beliefs about teaching science for social justice.

If you answered YES to 3.C, please name and/or describe the specific readings, activities, and discussions outside of our class (e.g., other classes, practicum, OISE/UT events) that helped change your prior beliefs about teaching science for social justice.

If you answered NO to 3.C, why did your prior beliefs about teaching science for social justice not change?
Appendix D

Interview Questions

1. What interested you in becoming a teacher of science?
2. In our science methods course, we made explicit connections between science and social justice. What does social justice mean to you?
3. Do you believe that teachers should engage in social justice work in schools? Why or Why not?
4. What does teaching science for social justice mean to you?
5. How was science taught when you were in the elementary grades?
6. Did your former elementary teachers integrate social justice into their teaching of science? If so, how? If not, why do you think that was the case?
7. How was science taught in high school? At university?
8. Did your former high school teachers and university instructors integrate social justice into their teaching of science? If so, how? If not, why do you think that was the case?
9. If you had a chance to teach science during either practicum, how did you teach it?
10. Were you able to integrate social justice in your science teaching during your practica? If so, how? Why do you believe social justice was important in that specific lesson? If you did not integrate social justice, why not?
11. Did your Associate Teachers infuse social justice into their teaching? How?
12. Did your practicum experiences affect your beliefs concerning teaching science for social justice?
13. Now that the science methods course is over, can you tell me about your experience in the course? Was it what you expected or did anything surprise you? Did it meet your needs?
14. Issues such as race, class, culture, and social justice were central issues in our science methods course. How do you feel about this? Should I continue this approach?
15. Can you elaborate on instances in the science methods course that supported or challenged your prior beliefs about teaching science for social justice?

Here I will give preservice teachers their pre- and post-course questionnaires. The following questions will allow them to describe and elaborate how and why their beliefs concerning teaching science for social justice have shifted (if at all).

16. Do you notice any changes in your beliefs between these two reflections? What do you think attributed to these changes?
17. Were there any specific experiences in the science methods course (readings, activities, presentations, discussions, etc.) that impacted your prior beliefs about teaching science? Why did they have this impact?
18. Were there any specific experiences in the science methods course (readings, activities, presentations, discussions, etc.) that impacted your prior beliefs about teaching science from a social justice perspective? Why did they have this impact?
19. Were there any specific experiences outside the science methods course (readings, activities, presentations, discussions, other classes, etc.) that impacted your prior beliefs about teaching science from a social justice perspective? Why did they have this impact?
20. How do you see yourself teaching science in your future classroom? Why?