Aligning Constructivist Beliefs about Teaching and Learning with Teaching Practices

By

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Abstract

Teacher education is often criticized for not sufficiently preparing teachers. As a teacher educator, I became concerned that my practice did not reflect my constructivist perspective. I was a living contradiction. As a result, I initiated this study to examine my current teaching and identify how I might align my beliefs and practice. Using a self-study approach, I analyzed my teaching practices in a high school science classroom and in a science teacher education course. The qualitative data collected included lesson plans, video recordings of teaching, student and peer interviews, a personal educational life history narrative, and a reflective journal. Brooks and Brooks' (2001) guiding principles of constructivism provided the lens for data analyses. Alignment of beliefs and practice were more prevalent in the university setting than in the high school. My understanding of constructivist practice during the high school teaching was underdeveloped, and thinking of meaningful constructivist-oriented activities was a struggle. In the subsequent university class, I developed a deeper understanding of constructivist pedagogies. The nature of the course content and increased student motivation also made planning easier. My findings suggest a need for my continued development in planning and delivering constructivist-oriented activities. One insight drawn from the research is that graduate programs in teacher education should consider preparing doctoral students to teach undergraduate students. Another insight is that the success of constructivist-oriented activities is dependent on the teaching context.

Preface

This thesis is an original work by Timothy Buttler. The research project, of which this dissertation is a part, received research ethics approval from the University of Alberta Research Ethics Board, under the Project Name "Scientific Modeling in High School Environmental Science." Pro00055236, 5/11/2015.

Dedication

My dissertation is dedicated to my family. I spent countless hours away from home while creating this document. It is time to make up for that absence.

Acknowledgments

The completion of my thesis has been personally challenging, enriching, and transformative. I would not have completed this journey without the support of my family. I am especially grateful of Colleen, my wife, who tolerated my absences during many holidays and my father, who read my work and challenged me to consider alternative interpretations.

I would also like to thank my advisory committee, Dr. Thomas, Dr. Simmt, and especially Dr. Nocente, for being patient with me as I navigated the graduate process. Thank you for volunteering to serve on my committee and supporting my emergent understandings.

And finally, I would like to thank the students, who allowed me into their classroom and my critical friends, Dr. Freed, Mrs. Ward, and Dr. Nocente, who willingly discussed my ideas and read my work. These colleagues provided invaluable constructive criticism, which significantly influenced the developed my understandings.

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Chapter 1

Introduction to My Study

> In the absence of effective professional induction and mentoring programs in most universities, it falls on teacher educators to attend to their own professional development. (Gallagher, 2011, p. 881)

Source of My Interest

Amidst the noise and the celebration of the university's winter carnival, John approached me with a determined step. Standing beside a doughnut stand I watched his face and remembered how nine months earlier he had walked across the graduation platform at the university carrying a newly minted Bachelor of Education degree under his arm. Tonight, as John approached, I noticed that his smile did not reach his eyes. We shook hands and exchanged greetings, and he began telling me the reason he no longer looked as happy as he had the previous spring.

Soon after graduation, John began teaching high school science courses in an isolated school in northwestern Canada. The number of students in this school has been increasing, partly due to the nature of the educational programs offered and the success the graduates have experienced. John explained to me that the school's administrators emphasize an approach that reflects the reforms we had discussed in my classes. For example, John had been encouraged to create a student-centred learning environment and to use strategies including inquiry learning.

My former student quickly explained that his job was causing him a great deal of stress. Initially this did not concern me, for it is not uncommon for education graduates to describe their first year of teaching as more demanding than they had anticipated. Increasingly, though, I became troubled by what John was saying. After describing the progressive approach of the school and the requirements of his teaching assignment, John finally asked me for help. "The principal wants me to use inquiry learning in my science classes," he said. "How can I teach this way? It is not how I was taught and not how you taught me." John was correct; I did not model this type of teaching approach, for I focused on helping my students develop strategies that supported efficient methods of information dissemination. That is, methods to efficiently pass on the teacher's knowledge to students. My instruction had not prepared him for his present assignment, in which he was asked to act as a facilitator or a guide as his students created an understanding of concepts. As we continued to talk that winter evening, I gave some suggestions, but I began to realize that I could not provide concrete suggestions for him. John left that evening without a satisfying answer to his questions, and I left feeling that I had failed him. I also wondered, could I teach at John's school? Would I have the skills to teach in a non-didactic manner?

From time to time in our personal and professional lives, we come across realities that simply cannot be ignored. John's dilemma highlights the reality that I am now experiencing daily as a teacher educator. In the realm of science, Kuhn (1970) suggests, growth is not an evolutionary progression, but rather a series of punctuated revolutions of thought followed by relatively peaceful interludes of acceptance of a new worldview. That winter evening marked the beginning of a revolution of my understanding of my role in teacher education. It was the first time I remember sensing what Whitehead (1993) describes as "experiencing yourself as a living contradiction" (p. 8). I recognized that although my educational beliefs had evolved, my teaching strategies and practices had not. This feeling is common among teachers who become teacher educators (Korthagen, Loughran, & Lunenberg, 2005) as well as when teacher educators return to the K-12 classroom (Ritter, 2014).

John’s dilemma highlights the questions I now ask myself daily as a teacher educator. Am I effectively preparing my students for teaching? How should I change in order to help my students better? As I interacted with John, I began to feel as though I had not helped prepare him effectively. Prior to attending my classes, he had experienced only traditional teaching, and although I included a lecture about inquiry-based learning and problem-based learning, I modelled only traditional pedagogies in the classroom. I had not provided John with the opportunity to consider any type of a constructivist approach as a viable option.

The serendipitous meeting with John occurred at the same time that I attended a graduate course that specifically examined inquiry teaching and learning in the science classroom. Although other anomalies had challenged my teaching approach in the past (see Chapter 2 for details), the confluence of the encounter with John and the graduate courses I attended allowed me to see that my beliefs and practices no longer aligned.

John’s situation reflects that of many new teachers as they experience a “reality shock” resulting in a “washing out” effect (Fazio & Volante, 2011; Harfitt & Chan, 2017; Zeichner & Tabachnick, 1981), which encourages new teachers to fall back on traditional teaching approaches. I began to ask myself if my teaching approach set up my students for a reality shock and washing out. I started to realize that I taught constructivist pedagogies through the filter of a traditional approach and finally accepted that I was not adequately preparing my students for the day-to-day practice of inquiry. I began to feel that I should change my teaching practices.

A Living Contradiction

My desire is to provide the best opportunity for my students to succeed as teachers, therefore facilitating the process by which education students develop conceptual understandings. John’s comments made it clear to me that he was not prepared for his teaching assignment in the secondary science classroom. Unfortunately, John’s difficult transition from preservice teaching to in-service teaching is common (Feiman-Nemser, 2012). In Canada, teacher turnover in the first five years of service is up to 50% (Schaefer, Long, & Clandinin, 2012). Teacher attrition research suggests that there are many reasons educators leave the profession (Vagi, Pivovarova, & Miedel Barnard, 2017). Likewise, there are many reasons why John’s first year of teaching was difficult. With regards to the current study, the preservice education I provided did not prepare him for his specific teaching assignment. I had the opportunity to encourage him to develop progressive pedagogies. Could I have equipped him better for the realities of teaching? This question has significantly influenced my desire to align my teaching practice and beliefs, thereby ensuring that my teaching provides the best opportunity for my students to succeed.

Kuhn’s (1970) description of a scientific paradigm change is analogous to the way I changed my understanding of teaching and learning. My educational experiences prior to graduate school (see Chapter 2) led me to develop an affinity to one teaching approach while discounting other methods. My personal practicum experience, 20 years ago, supported a behaviourist perspective in that my supervisor viewed all behaviour as a stimulus-response cycle. For example, he demonstrated how my body posture influenced the noise level in the classroom. At the time I respected how this worked in his classroom and worked hard to emulate it in my science classroom.

The anomalies described in the next section, and in Chapter 2, parallel Kuhn's (1970) idea of scientific paradigm change. Kuhn argues that scientific information that challenges an old paradigm normally exists long before the paradigm shift occurs. Furthermore, only when the old paradigm cannot account for numerous anomalies does the collective thought of scientists change. My encounter with John is a significant emotional anomaly that in retrospect is easily identifiable. In addition, prior to that encounter, other belief-practice or theory-practice anomalies (see Chapter 2 for details) had begun to produce tension within me.

Significant Anomalies

A paradigm shift occurs only when there are many anomalies that challenge an understanding (Kuhn, 1970). I believe that during my graduate studies I experienced a change with regards to my appreciation of effective pedagogies. Prior to that change, many events had challenged my traditionalist educational stance. One such event about a year before my meeting with John left me feeling unsettled. It occurred when I visited Stephen, one of my old education classmates. As Stephen and I reminisced about the teacher education courses we had both taken, he suggested that the theory-heavy courses did not prepare him to teach effectively, that the professors encouraged him to sit and listen passively. He argued that the professors advocating for active learning did not model that teaching practice. Consequently, he did not learn to value encouraging students to participate in the learning process. Stephen contended that education students must actively apply the theories discussed, not simply passively receive the concepts. Surely the professors should have been using the pedagogies they instructed us to use, he concluded.

It was difficult to disagree with Stephen's assessment, although at the time I felt that my preferred teaching methods were effective. I had taught high school science for 10 years, focusing on the transmission of information, and I believed that university education courses should reflect that stance as well. I rationalized my feeling of dissonance by falling back on my comfortable argument for the use of direct instruction. How could I spend the time demonstrating specific pedagogies like inquiry learning when presenting the theory was such an efficient process?

A second significant anomaly that also predated my meeting with John occurred as I drove to a hockey game with a previous graduate of my program. This successful teacher lamented, “The older teachers at my school make it difficult to teach. The students are so accustomed to sitting and listening that I barely can get them to move” (Keldon, third-year teacher). Throughout this conversation, we discussed different perspectives that teachers have about learning. Together we agreed that these “older” teachers likely viewed students as “blank slates” or *tabula rasa*, ignoring the learners’ ability to think and develop theories. Although Keldon remembered my classes fondly, I asked myself, am I one of these “older” teachers? Do I provide what my students need, or simply what I believe they need? Do I treat my education students like blank slates, waiting for knowledge to be inscribed on them?

I often reflect on those conversations with Stephen and Keldon. There was something that bothered me, yet each time I was able to convince myself that I was using the appropriate educational strategies. These experiences are also consistent with Kuhn’s (1970) description of paradigm change. He suggests that “the perception that something had gone wrong [is] only the prelude to discovery” (p. 57). The discussions with Stephen and Keldon became two of many experiences that added to my perception that something was wrong. Each time my pedagogical decisions were challenged, I became more open to the possibility of change. I began to feel that my educational perspective was not ideal, but unfortunately, I had not been exposed to a more viable option.

The final significant anomaly I will mention is the exposure to constructivist pedagogies I experienced in my graduate courses. As I discuss in Chapter 2, I did not know about constructivist learning theory until I attended the University of Alberta. Prior anomalies and the encounter with John prepared me to seriously examine constructivist teaching pedagogies as an alternative to my traditional pedagogies.

New Teacher Educator Uncertainties

Throughout my teaching career, I created an environment typically described as traditional (Hammerman, 2006). For example, expository methods dominated in a classroom where I directed all activities towards memorization of the “right” answer. However, after giving a great deal of thought to my teaching strategies, I realized that I felt uncomfortable with my teaching approach (see Chapter 2 for details). Today I question didactic teaching styles. Kuhn suggests that a paradigm shift occurs when an individual is willing to change the lens that he or she uses to view the world. Personally, this change requires me to abandon a familiar educational perspective and practice, while professionally it challenges me to profess a view that, in the school of education where I am employed, is not reflected by many of my colleagues.

My changing understanding of the role of a teacher educator has moved me into what Land, Meyer, and Flanagan (2016) describe as a liminal space, a place where an individual has abandoned established methods but has yet to replace one foundation with another. As I began this study, I had lost my foundation. I no longer felt that my practice (pedagogies) matched my teaching beliefs and I did not have a clear understanding of where I should be. While I experienced a paradigm shift in my beliefs, I stepped into a liminal space regarding my teaching practices. For example, I understood how to teach as a behaviourist, but was not prepared to employ constructivist pedagogies. As I write this document, I can say with certainty that I have accepted the tenets of constructivism (see Chapter 3), yet I have had a difficult time shifting my teaching practices to reflect my changed beliefs.

As a new teacher educator, I am not alone in my quest to improve my educational practices (Gallagher, Griffin, Parker, Kitchen, & Figg, 2011). Many teachers (Helsing, 2007) and teacher educators (Edwards, Gilroy, & Hartley, 2002) experience uncertainty about what teaching strategies to use. For example, Peter Gilroy, a teacher educator at Manchester Metropolitan University, experienced psychological pain living through a paradigm change. Gilroy, who taught in a department of teacher education, described the dissonance that resulted when he tried to resolve the academic contradictions between his teaching and writing (Edwards et al., 2002).

Today I question the quality of the teaching strategies I used for 17 years, strategies that focused on transferring information to students through the use of traditional, didactic methods. For example, I now understand that preservice teachers arrive in my classroom with unique expectations as a result of their prior educational experiences. In the past, I viewed students as empty vessels waiting for information to be poured into them. As I walk into the classroom today, I see students who already have a belief regarding how they will teach. I now ask myself two questions: how can I encourage my students to identify what they currently believe, and how can I encourage them to develop an understanding of the strategies that will best support the high school students they will teach and, inevitably, impact.

The anomalies described above (and in Chapter 2) created an environment that allowed my understanding of education to change, not by accretion, but through a revolution. In the following pages, I will describe further anomalies, the accumulation of which eventually forced a paradigm change. My experiences allowed me to perceive that the pedagogies I practiced did not match the pedagogies that I asked my students to use in their classrooms. Although my teaching approach continues to evolve, it was through a revolution that I became aware that I was a living contradiction.

Research Problem and Questions

Research Problem

Of the nearly 18,000 newly trained teachers who graduate from Canadian universities yearly, 75% report that their teacher education programs prepared them “fairly well” or “very well” for teaching (Crocker, Dibbon, & Raham, 2008). Although these statistics indicate that Canadian teacher education graduates believe their education programs prepare them for teaching, many educational scholars advocate teacher education program reform (Carroll, Featherstone, Featherstone, Feiman-Nemser, & Roosevelt, 2007; Korthagen et al., 2005; Russell, McPherson, & Martin, 2001). These scholars suggest that preservice teachers would benefit from improved teacher education programs. As mentioned earlier, Canadian teacher turnover in the first five years of service is up to 50% (Schaefer et al., 2012), whereas the province of Alberta, where I teach, has a five-year attrition rate of 40% (Clandinin et al., 2015). Although Schaefer et al. (2012) suggest that teacher education programs impact attrition rates, Borman and Maritza Dowling’s (2008) meta-analysis indicate that there are many reasons that teachers leave the profession. Borman et al. describe a significant number of personal and professional factors that are important predictors of attrition, most of which are beyond any teacher educator’s influence. Nevertheless, Korthagen et al. (2005) argue that teacher educators significantly impact the preparation of new teachers. The connection to this study is that teacher education is one factor that contributes to teacher attrition rates (Clandinin et al., 2015). This is a factor that I can influence.

Teacher education programs are often criticized for not preparing teachers sufficiently (Appleton, 2003; Loughran & Russell, 2007), yet many scholars note the lack of teacher education research and the lack of a call for a thoughtful examination of teacher education programs (Christou, 2017; Crocker et al., 2008; Korthagen, 2017; Zeichner, 2005).

These calls for inquiries into Canadian teacher education reform have not captured the attention of politicians, journalists, or even academics (Walker & von Bergmann, 2013). Nevertheless, teacher educators have looked critically at how they prepare teachers (Loughran, 2004b). During the last 10 years, the calls for reform in teacher education have become even more insistent (Bourke, Ryan, & Ould, 2018; Roose, 2016; Tatto & Pippin, 2017). This push for critical examinations of teacher education is evident in the special interest groups of the American Educational Research Association (See Chapter 3). The research reported in this document reflects the desire, described by Loughran (2004b), to examine and learn how a teacher educator may "teach in ways that are commensurate with the learning intentions that they have for their students" (p. 3).

Key participants in the reforms of teacher education are the teacher educators themselves. Within the university classroom, a teacher educator is a person who balances the tension between practice and theory (DeLuca & Pitblado, 2017) and encourages preservice teachers to develop this balance. In short, criticism of teacher education programs comes from the teacher educators themselves. Korthagen et al. (2005) point out that researchers must acknowledge that many teacher educators have not received any instruction in the methodologies they instruct preservice teachers to practice. Kitchen (2009) writes, “In light of a growing body of knowledge on effective teacher education practices and programs, more attention needs to be given to faculty development” (p. 3).

In my case, I received little education to teach preservice teachers; therefore, I was unprepared for the tensions I immediately experienced. When assigning me to become a science teacher educator, my institution seemed to assume that because I had taught science, I was qualified to teach others to teach science. When I entered teacher education, my goal was to encourage new science teachers to teach as I had taught in the high school science classroom. I modelled didactic pedagogies, reinforcing the teaching approach that many of my students had experienced.

As a teacher educator who desires that my students develop an understanding of constructivist teaching practices, I appreciate Richardson’s (2003) argument that “teacher education classes should be conducted in a constructivist manner for ethical reasons, to increase the legitimacy of the theory among the teacher education students, and to help students develop a deep understanding of the teaching process” (p. 1627). One way some teacher educators have strengthened their pedagogical competency is through self-study (see S-STEP in Chapter 3). These teacher educators often find that through self-study they experience professional development that supports pedagogical growth while contributing to scholarship (Lunenberg & Willemse, 2006). As I conduct this self-study I ask myself, am I part of the problem? Could I have better prepared John for his teaching assignment if I had modelled a constructivist-orientated pedagogy?

Purpose and Research Questions

The purpose of this research was to examine my journey as I worked to align my teacher education practices with my teaching beliefs in order to provide preservice teachers with models of constructivist practice. I used a self-study approach to examine and reflect upon my current practices to identify areas that require further development and to identify ways of moving forward with my practices. The specific research questions considered in this dissertation are:

1. What were my teaching practices?
2. How can my practice more closely align with my emergent beliefs about teaching and learning?

I answer these questions by using Brooks and Brooks' (2001) principles of constructivist classrooms as a lens to critically reflect on my teaching practices and to work on changing my pedagogy. I also use Haney and McArthur's (2002) modified Theory of Planned Behaviour to produce a condensed summary of my teaching practices, thereby summarizing how I incorporated Brooks and Brooks' principles in my teaching.

A secondary purpose of this study is connected to the self-study of teacher education practice (S-STEP) methodology. A methodological component of self-study is the commitment to taking the knowledge generated via self-study and making it available to the public. The reflection that occurs in this self-study must be communicated so that it can reach others. "[There is] an expectation that learning through self-study might also help to positively challenge and change teaching and teacher education practices" (Loughran & Berry, 2005, p. 194).

I began my inquiry into these questions by examining the education-related experiences that shaped my teaching approach prior to this study (see Chapter 2). These experiences helped me to understand what I knew when I started my dissertation, which in turn helped me better understand what I had been doing as a teacher.

The Significance of My Study

Self-study appears to focus on only one entity. Although my teaching practices are the focus of the research, the findings will impact others, placing me in a better position to help education students develop their teaching practices. As a consequence of my self-study, my students will be better prepared to enter the profession as science teachers, especially if they choose to use constructivist-orientated pedagogies.

My journey may also resonate with other teacher educators who are caught in their own liminal space. This research adds to teacher education literature by providing insight for other teacher educators who may choose to engage in self-study research in order to bridge their belief-practice gap.

Finally, my story is not unique, for it is mirrored by many who have struggled to make the transition into teacher education (Hamilton, 2018; Loughran, 2014). My research informs the recommendations made for prospective teacher educators and graduate schools.

Summary

Against a backdrop of teacher education reforms, I undertook the current self-study research with the aim to examine my educational beliefs and practice, describe the journey that I am experiencing as I alter my educational practices, and share my experience with others who recognize similar challenges. Ideally, my research will contribute to the literature regarding the professional growth of teacher educators by examining what I came to understand after experiencing a paradigm shift. This information will also inform my actions as I endeavour to create a learning environment that is consistent with my new understandings and will support the development of future education students' understandings of teaching and learning.

Overview

Within the remainder of this document the reader will find my educational life history narrative, including critical reflections on experiences that established my teaching beliefs prior to this study (Chapter 2); a literature review of constructivism, constructivism in education, teacher education, and teacher educators (Chapter 3); a description of the self-study research methodology, theoretical frameworks used in the study, and data collection and analysis procedures employed (Chapter 4); and a presentation of the data (Chapter 5) that informs the conclusions and implications (Chapter 6) resulting from the research questions.

Chapter 2

Construction of My Teaching Approaches

> What a man sees depends both upon what he looks at and also upon what his previous visual-conceptual experience has taught him to see. (Kuhn, 1970, p. 113)

Introduction

This chapter examines the foundations of my educational approach prior to the initiation of the self-study. The first section examines how I function as a researcher and the subject of the research. The second section is a narrative, My Educational Life History (within this chapter), which follows My Educational Life History Timeline (see Appendix A), tracing the development of my educational beliefs by examining significant experiences, my responses to these experiences, and the resulting understandings developed from the experiences.

Myself as the Researcher and the Researched

In this self-study, I am both a teacher and researcher, endeavouring to investigate my teaching practices. A significant influence on my growing understanding of teaching developed from my educational life experiences; therefore in the next section, I examine (describe) myself as the primary subject of this investigation, studying my own teaching (Russell, 2002). Additional participants include high school science students, university education students, and critical friends (colleagues), all of whom play critical roles in this research (described in detail in Chapter 4).

I am a faculty member in a four-year bachelor of education degree-granting program at a Western Canadian university. The university is a small-sized institution of higher education offering both elementary and secondary teacher education programs. The university's vision statement conveys the message that the institution aims to provide quality education in a Christian environment that respects individual success and the attitude of community renewal.

I am a white male raised in a middle-class community in Alberta, Canada. My interest in science began as I explored the Rocky Mountains during annual field trips conducted by my father, a biology professor. Although my father employed a traditional teaching style within the classroom, what I experienced during these field trips was a type of education that engaged students by giving them the opportunity to investigate their surroundings. During these field trips, students were challenged to make learning personal (possibly the first traditional teaching anomaly I experienced). From the age of six until well into my high school years, I attended excursions in Alberta's and British Columbia's national parks, designed to introduce university students to the complexities of biological life found within the Rocky Mountains. The field trips that produced the most significant memories were excursions for a course called *Issues in Science and Religion*. Many of the students in these classes held a literal interpretation of the creation narrative found in the Bible, including that the Earth was created by direct acts of God less than 10,000 years ago. These students, therefore, resisted all scientific theories and professors who explained theories that did not support the seven-day creation of Earth. Some of the students displayed outright hostility to these theories. The trips were significant in that they created a tension that I continue to experience with regards to science and religion. I believe the tension has to do with the students' (and some teachers') tendency to resist any new knowledge that does not fit into their current worldview. My father's students resisted the possibility that there is more than one answer to many of the questions that biologists and geologists examine. This tension exists today as I examine my teaching approach and the pedagogies I encourage my science preservice teachers to develop. I feel the desire to find the one correct teaching approach.

Each school I attended prior to the graduate program at the University of Alberta used pedagogies described by Brooks and Brooks (2001) as traditional. For example, as I describe in detail in the next section, all my science teachers taught in a didactic manner. As a student, I succeeded when these strategies were used.

I view my graduate studies at the University of Alberta as the accident that initiated my teaching evolution, for the courses I took challenged my beliefs about teaching and learning. As noted in Chapter 1, my professional life reflects Khun's (1970) description of a scientific paradigm change. An apparently arbitrary element, the choice of graduate institutions, was instrumental in leading me to change my appreciation of teacher education. What I learned in my courses strongly influenced my decision to examine how model-based teaching (MBT) encourages students to change their understandings of science conceptions. It was while implementing a research pilot that I encountered significant internal and external resistance with regards to the strategies I used. The constructivist learning theory provided the foundation for these teaching strategies. I understood little about constructivism. Loughran (1996) argues that internal conflict is natural, the "more deliberately a teacher considers his or her actions the more difficult it is to be sure that there is one right approach to teaching" (p. 3). The first time I became aware that my teaching beliefs and strategies did not match occurred during a research pilot at a local high school. I was conducting the pilot to examine new (to me) strategies which I would then incorporate into my teacher education courses. During the pilot, the high school students appeared to resist the teaching and learning strategies that deviated from the traditional pedagogies. This resistance was mirrored by the science teaching staff of the high school where the pilot research was conducted. These educators were unable to envision how the teaching strategies I used could be effectively integrated into their classrooms. I now believe that I was attempting to use a constructivist pedagogy with a behaviourist approach. During the next semester of study, I had my aforementioned encounter with John and began to rewrite my lesson plans and research proposal based on my desire to teach with a constructivist approach.

Prior to initiating a second pilot, I began to ask myself if my education strategies matched the needs of the education students in the university courses I taught. I entered the second pilot with the desire to research the change I was making in how I approached teaching, so I could become a better teacher educator. Although I believed that I shifted my focus to a constructivist approach, I again experienced a great deal of internal and external resistance to the pedagogies I brought to the high school classroom.

In light of the struggle that I encountered during the second pilot, I am using the current study to examine and understand my experience as a teacher educator in the process of reforming my pedagogical practice (changing my teaching approach) to match my reformed teaching beliefs. The stimulus of my shift in understanding again parallels a scientific paradigm change (Kuhn, 1970). I embarked on the current study because I could no longer ignore the repeated anomalies: a change was required. My beliefs had evolved, yet my teaching practices remained unchanged. I stepped into a liminal space (Land et al., 2016).

My Educational Life History

In the fall of 2015, I began the creation of my Educational Life History narrative. This narrative is a written reflection of significant events that I believe to have impacted the development of my educational beliefs. The process began with the creation of My Educational Life History Timeline (see Appendix A) delineating the major educational and professional events of my life. These chronological events laid the foundation for my understanding of teaching, brought me to my current professional context and, finally, generated a paradigm change and the need for pedagogical change.

In the following narrative, I examine significant events of my Educational Life History, searching for an understanding of my teaching beliefs by focusing on answering the guiding questions (Magee, 2009): (a) what occurred during each experience? (b) how did the experiences contribute to the development of my understanding of teaching? and (c) how did these experiences support my development of a traditional or a constructivist teaching approach? Similar to a change in scientific understandings, this narrative first reveals the development of what I believed was "Normal" education. Kuhn (1970) argues that when problems are identified in science, a paradigm gains credibility if it is more successful than competing paradigms for solving known problems. Similarly, my understandings of teaching and learning before the current research met my educational objectives; therefore I felt I understood how best to teach. Beyond the major anomalies described earlier, My Educational Life History narrative reveals multiple minor anomalies that created tension and ultimately helped inspire me to examine my understanding of how we learn and, consequently, how I could teach.

In the following narrative, I also search for understandings that Meyer and Land (2003; 2005) describe as threshold concepts. These concepts are conceptual gateways that "may be *transformative* (occasioning a significant shift in the perception of a subject), *irreversible* (unlikely to be forgotten, or unlearned only through considerable effort), and *integrative* (exposing the previously hidden interrelatedness of something)" (p. 374, emphasis in original). In this study, a significant shift occurred within me. The transformation relates to how I view the process of learning and therefore how I came to view the process of teaching. My acceptance of constructivism as viable is a possible threshold concept. In the next section, I explore the educational approach I brought to this study, yet once I accepted the viability of a constructivist educational approach to teaching and learning, I shifted and now “I can’t go back.” The essential characteristic of a threshold concept is that it is transformative (Land et al., 2016). The following account presents findings that examine the origins of my teaching understandings and the transformation that occurred within me.

My Educational Journey Begins (Traditional Teaching Beliefs Established)

I spent 14 years as a student in a parochial educational setting in Lacombe, Alberta. The worldview of this community informed my initial understanding of science and science education. Multiple teachers influenced the way I think about teaching science. Each teacher taught didactically, with the intention of passing on the science understandings supporting a creationist worldview, which resulted in my traditional (Brooks & Brooks, 2001) understanding of science education. As I reflect on the style of instruction found in my elementary science classes, one of my earliest memories of a “science class” is of my teacher sitting behind a desk while a miniature steam engine spewed water vapour into the air. This teacher created an atmosphere of secretive mystery and hidden answers that he would provide if we listened intently. There was no investigation: he spoke, and we listened. As a student I grew to expect teachers to teach didactically, disseminating information to students.

Upon further reflection, I believe that this elementary teacher exhibited what many preservice science teachers aspire to become. Before I began this self-study, I believed that I needed to be like this elementary science teacher. In order to become a “good” educator, I needed to be the authority, dispensing information. I brought this traditional understanding with me into teacher education. I rarely sought or valued the preservice teachers' points of view. If I discovered what they felt, it was unplanned, haphazard, and random.

The high school science education I experienced continued the tradition of didactic teaching. The general science and biology teacher, respected and promoted as a model teacher in our school, would lecture for an entire class period. She once explained that her science courses functioned as a bridge to postsecondary education courses that disseminate information through lectures.

My Journey as a Post-Secondary Student (Traditional Teaching Beliefs Reinforced)

My transition to university was seamless. The biology, chemistry, and physics courses I attended focused on lecture and memorization. Laboratory assignments verified what the instructor had previously taught, and the examinations sought to determine my ability to comprehend and reproduce the curricular knowledge. My university science instructors disseminated information, and I accepted the information as fact. Although the professors made mistakes based on faulty memory, at no time did we as students question the underlying authority of didactic teaching in the science classroom. As a result, I developed an understanding of education that ignored the students' suppositions (Taylor, Fraser, & Fisher, 1997) and assessed students outside of the context of learning through high stakes, closed response assessments (Brooks & Brooks, 2001).

Traditional authoritative teaching strategies dominated the next phase of my education as well; my experience at a Midwestern American college of chiropractic medicine continued to reinforce my teacher-centred understanding of science education. Although the professors held diverse views regarding the relationship between science and medicine, the courses relied predominantly on memorizing facts delivered through lectures and assessed via multiple-choice examinations. The view expressed by my classmates reflected my understanding that a professor's job was to provide us with the knowledge necessary to succeed as chiropractors. We expected to be recipients of the professors' knowledge. The professors spoke, we listened; the search for personal meaning was not a goal. Concerning the structure of the curriculum, the big picture (Brooks & Brooks, 2001) was often overlooked while my classmates and I examined separate, isolated, aspects of biology.

My Journey into the Field of Teaching (Constructivist Teaching Ignored)

After working as a chiropractor for three years in Illinois and Washington State, my professional trajectory changed following what seemed an insignificant choice. Upon returning to Canada and while waiting for a Canadian chiropractic license, I accepted a position as an educational assistant at an alternative school for at-risk students. I observed teachers who changed the lives of their students, and I found that I enjoyed working with students. These teachers did not instruct traditionally. They taught with their students in mind. The content was relevant, yet the students were more important than the subjects being studied. The experience made such an impact on me that I chose to leave the chiropractic profession and enroll in a local teacher education program. I saw the non-traditional teaching at this alternative school as an acceptable anomaly, for the students did not fit into the traditional teaching setting. Their previous behaviours had caused them to be expelled from mainstream K-12 schools. Nevertheless, this experience (anomaly) helped set the stage for my future paradigm change. I now question a system that discards these students. They were not bad kids, but many were unable to sit and learn from a teacher telling them things.

Professors in the School of Education where I enrolled continued to employ the traditional pedagogies that I had experienced. They modelled teacher-centred, lecture-based, multiple-choice assessed courses where the students' point of view was rarely relevant. As it was for many of my classmates, the practica was the focus of my time in the education program. During this time, two high school science teachers became my role models, inspiring me to reproduce their strategies. They reinforced my perceptions about how teachers should teach and students learn. They relied on highly structured, orderly programs that focused on providing lectures and assessing student memorization of content. I felt that if I reproduced what they demonstrated, I would be an effective teacher. As a result, I developed an understanding of teaching that is the antithesis of constructivist teaching (Brooks & Brooks, 2001). I learned from these teachers that classroom activities should be consistent and predetermined. There was no need to identify and challenge student suppositions, since supplying organized, sequential curricular information was the key to good science teaching.

My Journey as a High School Teacher (Traditional Teaching Enacted)

My traditional teaching experiences provided the foundation for my teaching practices as I began teaching high school science courses. In my classroom, I provided the information that I believed the students needed. I prepared the students for governmental multiple-choice examinations and future lecture-based university courses. I believed that if they listened to me, they would succeed. When a superintendent suggested I incorporate some teaching activities that reflected the constructivist principles described by Brooks and Brooks (2001), I rejected the suggestion as misguided. His suggestions seemed too time-consuming and focused on outcomes that I did not value. As I moved past the first years of teaching, my science students performed well above the provincial averages, thereby reinforcing my belief that my traditional classroom was an effective learning environment.

This belief was also reinforced and tacitly endorsed by experts in the field, including graduate-level instructors. While the Master of Education (M.Ed.) program I completed adopted a novel method of assessment (writing papers), the underlying pedagogy focused on disseminating information through lectures while requiring students to work in isolation from their peers. While completing my M.Ed., my stance that teacher-centred classrooms were ideal remained unchallenged.

My Journey into Teacher Education (Traditional Teaching Propagated)

I brought a traditional teaching approach to the next phase of my professional life. After completing my M.Ed., I accepted a teacher educator assignment at a western Canadian university. My assignment included teaching the science, math, and technology curriculum and instruction courses. I began with a strong connection between my teaching beliefs and practices. I modelled didactic teaching strategies that reflected my understanding of the successful teaching strategies I had experienced throughout my educational history. As with the high school students, the university students responded well, academically, to my teaching approach. They performed well on the examinations that I had inherited from past professors. As a result, I taught the students to emulate my traditional teaching strategies. I modelled a rhythm I felt they should create in their classrooms. This included didactic lectures, demonstrations, and PowerPoint presentations that I used each semester with little alteration. I guided my students to develop knowledge and comprehension, with occasional forays to activities that asked for the application of new understandings. I assessed every student product and recorded every score. Finally, I rarely allowed students to work together or in groups. I viewed this as a time killer, or entertainment, which is useful but certainly not a strong method for developing conceptual understanding.

In retrospect, it is unsurprising that John had such a difficult time adjusting to his teaching assignment. Although I taught the concepts he was required to use; I did not model or require my students to understand the theoretical underpinning of the constructivist pedagogies we discussed.

As with many science teachers, I brought my teaching approach to teacher education without reflection (Berry & Loughran, 2012; Nelson, F., 2015). There seemed to be an assumption by my employer that since I was a successful high school science teacher, I could effectively teach preservice teachers. Without training, I was viewed as an expert in my discipline and thus received little instruction about how to teach teachers. This is not uncommon for new teacher educators, as the issue of teacher educator instruction has been neglected (Korthagen et al., 2005; Korthagen, 2017). Often new teacher educators are inadequately prepared, and most are provided little professional development support focused on pedagogical improvement (Zeichner, 2005). In response to the lack of specific teacher educator education, graduate programs offer doctoral seminars that encourage teacher educators to develop scholarship and practice (Dinkelman et al., 2012; Gregory, Diacopoulos, Branyon, & Butler, 2017). Others suggest a type of graduate studies apprenticeship where candidates serve as teaching assistants and through a mentoring experience develop teacher educator pedagogical content knowledge (Demirdögen, Aydin, & Tarkin, 2015). Although there are efforts to prepare teacher educators for the classroom, Ping, Schellings, and Beijaard’s (2018) review of more than 1700 teacher education professional development articles suggests that teacher educators feel they learn on the job how to be a teacher educator.

In my case, my preparation for teacher education did not include an apprenticeship or any doctoral seminars. My preparation did include a mentor, a senior teacher educator who was assigned to help my entry into teacher education. This individual was caring, ensuring that I felt comfortable in my new position. His efforts focused on ensuring that I understood the school's procedures and had the required teaching materials, but he provided little guidance regarding pedagogy or what it is to be a teacher educator. He observed my teaching on two different occasions, encouraging me to continue to employ didactic teaching strategies. The only pedagogical advice he provided was to encourage students to express their opinions more often during discussions.

My Journey as a Graduate Student (Encountering a Constructivist Environment)

During my first year as a teacher educator, I began my graduate work in the Faculty of Education at the University of Alberta. The courses I took modelled a teaching approach that shifted the focus away from the teacher and towards the student. Moving from a traditional parochial educational system to a constructivist pluralistic system was disconcerting. The understandings that the professors shared were not what I expected; I was not required to memorize and reproduce the knowledge that the professors shared. After telling some of my colleagues at the small western Canadian university where I worked full time that my teachers were using a constructivist method, I was warned to be careful. My colleagues believed that this view of learning was incompatible with a Christian worldview. Everything I read about constructivist teachings made me wary. For example, some of the rhetoric used by Zwaagstra (2013) suggested that constructivism was dangerous. But in the classrooms where I experienced a constructivist approach, the teaching was excellent. Another contradiction between the rhetoric and reality was that the coursework at the University of Alberta did not provide the absolute truths that I had come to expect during my previous studies. For example, the first course I enrolled in, Teaching Science/Elementary & Secondary, presented a process of scientific inquiry that promoted aspects of asking questions, collecting data, and interpreting data to formulate explanations. My previous science experience had focused on confirming scientific understandings whereas this course encouraged me to view the nature of science as a search for understanding. The professor used elements of a constructivist teaching approach (Brooks & Brooks, 2001) and introduced examples from Brooks and Brooks' work (possibly influencing my choice of a constructivist lens for this study). I vividly remember that the professor structured learning around "big ideas" and once fostered a discussion about using a pendulum to pose problems of emerging relevance. Additionally, the professor suggested that teachers should allow students to ask some of the key questions that they would then examine. This pedagogy did not conform to my previous education. It was not teacher-centred, and it made me uncomfortable.

Subsequent University of Alberta graduate courses continued to produce what I believed to be cognitive dissonance. I used this term as I described my educational experience in a paper for a curriculum inquiry course. At that point, it was evident that I was losing confidence in the precepts of what I considered traditional education. Each graduate course I attended at the University of Alberta included elements of a constructivist learning environment, thereby facilitating my shift in beliefs and moving me into a pedagogical liminal space (Land et al., 2016). My dissonance reached a peak during the Robotics and Learning course, for this course modelled only constructivist lessons. The design challenged my perceptions of effective education settings. The majority of this course was devoted to creating, testing and modifying various products or ideas.

As my graduate coursework concluded, my understanding and beliefs shifted, but I could not conceive how to apply this change to my classroom practices. This model of education worked in graduate courses but would it work in teacher education?

My Journey into Research (Acknowledging My Living Contradiction)

My changing beliefs regarding teaching influenced my choice of research topics. In the spring of 2014, I conducted a pilot research project at a local high school in preparation for the current study. This preliminary work included the creation of model-based teaching (MBT) lesson plans I anticipated using in later research. My goal was to encourage students to create personal models of environmental science content, therefore encouraging knowledge construction or conceptual change. During the pilot classes, the students created individual concept maps, yet their products were often identical to my own. Upon reflection, I realized that these students produced artifacts that bore none of their own individuality. My deep-set traditional educational approach encouraged the students to learn in a very traditional way instead of learning to question and think independently.

During the following summer, I began to sense that I was a living contradiction. As a result, when I began to plan my graduate research project, I realized that I could no longer use the traditional lesson plans that I had developed. I rewrote the lesson plans, intending to add more constructivist strategies. For example, I specifically added the Predict-Observe-Explain (POE) strategy to multiple activities. In the spring of 2015, I conducted a second research pilot at a local high school science classroom.

While enacting the developing MBT lessons, I felt a constant tension between my teaching intent and my actual pedagogies, that is, my desire to create a constructivist environment and my actual traditional actions. Although I attempted to implement the MBT strategies described by Clement (Clement, 2008b; Rea-Ramirez, Clement, & Núñez-Oviedo, 2008), I created a traditional teacher-centred environment. Although I intended to teach from a student-centred approach, my deep-seated educational attitude influenced my teaching practice. Clement's (2008b) Model-Based-Teaching strategies provide for a balance between didactic and discovery strategies, yet I struggled to achieve this balance. I directed the students via a systematic strategy that exemplified a traditional environment, but there was a disconnection between the MBT theory and my teaching practice. The lessons that I directed were highly didactic and ignored the student-centred, or constructivist-oriented, practices that Clement (2008a) advocated.

During the second pilot, I did not achieve Clement's (2008a) MBT goal for the "middle road" between teacher-centred and student-centred pedagogy. Consequently, when I began designing the high school activities for this study, I took a step back and reflected upon how I could enact the MBT pedagogy more effectively. I read Brooks and Brooks (2001), *In search of understanding* and Taylor, Dawson, and Fraser (1995), *A constructivist perspective on monitoring classroom learning environments under transformation*. Both resonated with me yet challenged me to identify what I believed effective teaching entailed. At the time I realized that I had implemented a pedagogy that reflected what I believed others (administrators, colleagues, and students) desired, yet I was certain that I no longer agreed with that traditional teaching approach. Although I had personally succeeded in an educational system that encouraged passive learning, memorization of inert factoids, and multiple-choice examinations, I recognized that it was important to me that my students develop deeper understandings than what I had achieved as a student. The world we live in is ever-changing, and I realized that I believe that students must construct and reconstruct their knowledge, not merely reflect what others tell them. As I began to plan for the high school lessons, I examined the teaching approach that I had implemented during the second pilot and attempted to reconcile it with my growing desire to teach in accordance with a constructivist perspective. That is, "learners actively construct their own understandings rather than passively absorb or copy the understandings of others" (Simon & Schifter, 1991). I found that taking a stand with regards to changing my teaching approach became problematic. I moved into a state of *liminality* (Land et al., 2016; Meyer & Land, 2005). *Limen,* Latin for "threshold," suggests a transitional space or time. As noted earlier, I experienced a paradigm change in my understanding of learning: I accepted the general tenets of constructivism, how we learn, but I could not envision how to put that understanding into practice. My liminal space developed because I had no foundation to apply constructivist teaching strategies. Concerning teaching practices, I rejected the traditional teacher-centred classroom but did not have a clear understanding of an acceptable constructivist alternative. Meyer and Land quote Goethe (2003) as he describes the experience of those in a liminal state: one "must strip away, or have stripped from them, the old identity. The period in which the individual is naked of self—neither fully in one category or another—is the liminal state" (p. 376). Meyer and Land (2003) also describe how a person in a liminal state will mimic an understanding. I began the current self-study by mimicking what I believed were "good" constructivist pedagogies. During this process of mimicking, I slowly changed my practices and truly began to infuse a new understanding of teaching and learning in the classroom.

During the entire self-study, I continued to teach preservice teachers. As a teacher educator, I still modelled a traditional teacher-centred environment and encouraged education students to develop similar strategies. My acceptance of how my teaching approach impacted both pilot results and the repeated anomalies—for example, John's story, discussion with peers, and the University of Alberta graduate courses—pushed me to re-examine my teaching approach. As with many teacher educators, self-study became my tool to seek a better understanding of my teaching beliefs and practices (Kosnik, Beck, Freese, & Samaras, 2006). It was at this point that I began to believe that I was not preparing education students appropriately and accepted that I was a living contradiction (Whitehead, 1993).

Summary

My educational life history highlights the key experiences that influenced the development of my educational perspective and eventually led me to acknowledge that I must change my pedagogies. My personal education consisted of classrooms where expository methods dominated, laboratory activities used cookbook-like instructions, and teachers focused on having students produce the "right" answer. When I accepted the high school science teaching assignment, my teaching approach mirrored my personal educational experiences, reflecting Brooks and Brooks' (2001) description of traditional teaching. I focused on the individual details of the curriculum, ignoring the big picture and making no attempt to connect the curriculum to the students' out-of-school lives. I taught didactically with little alteration or regards to the uniqueness of the particular group of students. I assessed every student product and permanently recorded scores. I used assessments to prove that the students had learned. Finally, I rarely allowed students to work together in groups. I viewed learning as a process that occurred within each student, separate from those around them.

The graduate courses at the University of Alberta widened my views on teaching and learning, while the experience of implementing two research pilots forced me to accept that my understanding of teaching had changed. The growing number of anomalies and experiences during the pilots pressed me to re-examine my teaching approach.

Chapter 3

Literature Review

> Teaching and learning are seen as being linked in powerful and important ways such that the intention implicit in the use of the terms is that teaching purposefully influences learning and vice versa. Therefore, pedagogy is not merely the act of teaching (which itself can easily be misinterpreted as the transmission of information), more so, it is about the relationship between teaching and learning and how together they lead to growth in knowledge and understanding through meaningful practice. (Loughran, 2006, p. 2)

Introduction

In this chapter, I review three areas of literature: constructivism, teacher education, and the connection between belief and action. As I came to understand constructivist-based pedagogy better, I accepted the need to remodel my role as a teacher educator. In the first section, I will briefly examine the constructivist learning theory, present a constructivist continuum, and describe my current understanding of constructivism. Since my changing beliefs and pedagogies have impacted and will continue to impact the teacher education program where I am employed, the second section of this chapter examines the teacher education context, the ongoing process of teacher education reform, teacher educators themselves, and science teacher educators. In the final section, I briefly review the literature that examines the connection between belief and action.

For the literature review, I accessed multiple databases, predominantly ERIC, the ProQuest Education Database, and Google Scholar, and others (e.g., ProQuest Dissertations and

Theses Global) as necessary. The initial search terms for the literature review included teacher education perceptions, science teacher education, Canadian teacher education, self-study of teacher educator practices, and teacher beliefs and practices. After this initial search, I conducted subsequent searches for constructivist learning theory, constructivist teaching, constructivist pedagogies, and constructivist teaching beliefs. Finally, after identifying the relevant literature, I used the works cited by the authors to deepen my search.

Constructivism and the Constructivist Approach Used in this Study

"Constructivism is an epistemology, a learning or meaning-making theory that offers an explanation of the nature of knowledge and how human beings learn" (Ültanır, 2012, p. 195). The research questions considered in this study stem from the personal education experiences that shaped my understandings of teaching and learning and the pedagogical crisis I experienced as my epistemological view shifted and I began to incorporate constructivist-oriented strategies into my teaching approach. What follows is a brief examination of constructivism, how this learning theory has influenced education and, finally, teacher education reform, which is the professional context of this study. In Chapter 4, I examine the specific theoretical framework of constructivism used. Through this examination, I endeavour to provide a clear picture of the threshold concept (constructivism) of my educational paradigm change. The following statement by Smith (1997) exemplifies the teaching approach with which I entered teacher education:

> For thousands of years, the following assumptions have dominated educational philosophy: The teacher knows the information, tells it to the students, and supervises their study to make sure they learn. The students are supposed to be good listeners, do the assignments, and study enough to pass a test. Within a few weeks or months, they may not be able to recall or use the information, but that has

been considered an inevitable downside to education because it was assumed that students' intelligence levels could not be changed. (Smith, 1997, p. 34)

In contrast to the assumptions described above regarding teaching and learning, constructivist learning theory suggests that learners actively assemble meaning and understanding for themselves (Smith, 1997). This is not a new theory: Von Glasersfeld (1989) attributes the first writing about constructivism to Giambattista Vico who, in the 18th century, suggested that for humans "'to know' means to know how to make" (p. 123). That is, for humans to understand they must create understanding.

Vico's statement still echoes within our current understandings of constructivism. Although contemporary understandings grew out of Jean Piaget and Lev Vygotsky's work describing cognitive development, constructivist ideas can also be traced back to Dewey (1929) and Bruner (1966). For example, Dewey (1929) believed that "all education proceeds by the participation of the individual in the social consciousness of the race" (p. 291).

Although their reasons for believing in constructivism differ, both Piaget and Vygotsky agree with Dewey (1929) that the learner is actively involved in the learning process. Piaget believed that the mind is shaped by biology (Messerly, 2009) and that, as Rummel (2008) explains, cognitive development is "a product of the individual mind, achieved through interaction and experimentation, whereas Vygotsky viewed learning as a social process, achieved through interaction with more knowledgeable members of the culture" (p. 80). In other words, Vygotsky focused more on the social environment of the learner, whereas Piaget focused on the individual's ability to utilize the knowledge acquired through biological processes (Rummel, 2008).

Piaget also proposed that children pass through specific cognitive stages as they age, allowing educators to "predict what children can and cannot understand at different ages" (Rummel, 2008, p. 80). This view of human development is an underpinning for cognitive constructivist approaches to teaching and learning (Weegar & Pacis, 2012). Piaget's framework suggests that the teacher's role is to provide age-appropriate experiences to encourage the learner to build on prior knowledge.

Piaget also proposed that the learner has a role in constructing knowledge. He argued that learning is an active process by which knowledge is incrementally created through assimilation and accommodation, in order to create equilibrium. Assimilation is when new experiences are incorporated into past mental structures, without changing those structures, accommodation is when new mental structures are fundamentally restructured or created to interpret a new experience, and equilibrium occurs when environmental stimuli and mental structures are balanced (Reinking, Labbo, & McKenna, 2000). Archer (1998) argues that a "basic implication of this view is that knowledge cannot be "given," that learners are constantly acting on data they receive, assimilating from and accommodating to their environment, creating new knowledge structures" (p. 88).

Vygotsky's form of constructivism examines the development of knowledge as a social process. Knowledge, Vygotsky argues, is the result of social interaction and is a collective rather than an individual experience (Doolittle & Camp, 1999). Teachers with a social constructivist perspective create learning activities that are "characterized by active engagement, inquiry, problem-solving, and collaboration with others. Rather than a dispenser of knowledge, the teacher is a guide, facilitator, and co-explorer who encourage learners to question, challenge, and formulate their own ideas, opinions, and conclusions" (Weegar & Pacis, 2012, p. 7).

Based on his understanding of how an individual's knowledge is shaped by the social interactions with those they encounter, Vygotsky (1978) proposed the concept of *the zone of proximal development*. He defined this concept as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem-solving under adult guidance, or in collaboration with more capable peers" (p. 86). Vygotsky's focus included the social environment and the individuals around the learner that influence learning.

A Constructivist Continuum

Constructivism, which is often described as a continuum, embraces a variety of associated ideas (Archer, 1998). For example, O'Connor (1998) differentiates between social constructivism (knowledge created by the collective), individual constructivism (knowledge created within the individual), and socio-cultural constructivism (knowledge created through interactions between the collective and the individual). Phillips (1995) suggests that a second dimension, or continuum, exists between whether knowledge is made or discovered.

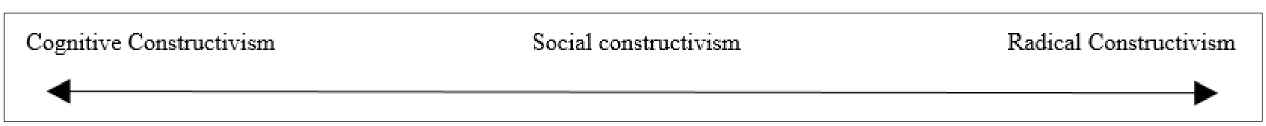

Figure 1. A Constructivist Continuum. This figure is an adaptation of Doolittle's (2014) constructivist continuum. The poles of this continuum illustrate a spectrum between the knowledge transmission of knowable reality (left side) and the interpretation of personally viable reality (right side).

The process of creating this chapter became the first significant step I took as I began to develop an understanding of constructivism. I began my search by seeking to identify the constructivist perspective that best aligned with my beliefs. At this time I was drawn to the cognitive constructivist's view of learning. In my search, I found it useful to examine Doolittle and Camp's (1999) review of forms of constructivism and Doolittle's (2014) illustration of a constructivist continuum. As illustrated in Figure 1, Doolittle identifies three broad categories that include many forms of constructivism.

Cognitive constructivism.

Cognitive constructivism represents one end of the continuum and is associated with information processing and component processes of cognition. Doolittle (2014) defined these forms of constructivism as those that emphasize the external nature of knowledge. He used the term *Trivial Constructivism* to describe this area of the continuum.

Cognitive constructivism originates from Piaget's work focusing on how the individual constructs knowledge (Powell & Kalina, 2009). Powell and Kalina (2009) contend that Piaget believed that learners cannot be given information but must instead construct their own knowledge. Knowledge, from this point of view, "is the result of the accurate internalization and (re)construction of external reality. The results of this internalization process are cognitive processes and structures that accurately correspond to processes and structures that exist in the real world" (Doolittle & Camp, 1999, p. 6). This view presumes that reality is knowable, which is significantly different from what is espoused in social and radical constructivism.

Cognitive constructivism relies heavily on cognitive research, which "shows that learning is an active process occurring within and influenced by the learner. Hence, learning results from an interaction between the information that is encountered and how the student processes that information based on perceived notions and extant personal knowledge" (Bybee et al., 2006).

In summary, Hartle, Baviskar, and Smith (2012) suggest that the learner arrives "with pre-existing 'constructs,' and in order to learn, must modify these existing structures by removing, replacing, adding, or shifting information in them" (p. 31). In other words, cognitive constructivism is a theory that characterizes learning as fitting new concepts or experiences into an organization that includes the individual's prior knowledge.

Social constructivism.

Social constructivism lies somewhere between the two extremes; it explains the acquisition of knowledge as social or interactional in nature (Doolittle, 2014). "[T]he belief that knowledge is the result of social interaction and language usage, and, thus, is a shared, rather than an individual, experience…. In addition, this social interaction always occurs within a socio-cultural context, resulting in knowledge that is bound to a specific time and place" (Doolittle & Camp, 1999, p. 8). Additionally, "knowledge does not exist independently, nor does it in any sense pre-exist knowers. Rather, the collective itself constructs knowledge" (Archer, 1998, p. 87).

Although reality exists, human knowledge of reality is contingent on agreed-upon understandings of facts and how these facts are connected and construed. This results in objectivity that is a shared agreement among individuals regarding acceptable constructions (O'Connor, 1998). Advocates of social constructivism propose that even science is not exempt from this process of social construction, as facts are constructed via discovery and presentation and are dependent on arrangements between people who agree upon how to interpret and how to report knowledge (Archer, 1998).

Vygotsky, a key proponent of this view, also argued that an individual's knowledge is shaped by social interactions with people whom he/she encounters. The *zone of proximal development* is a common application of Vygotsky's theory in education. As discussed earlier, the learner and the significant others in his/her environment are both parts of the learning process.

In summary, social constructivists view learning as a “process of building internal models or representations of external structures as filtered through and influenced by one’s beliefs, culture, prior experiences, and language, based on interactions with others” (Doolittle, 2014, p. 487).

Radical constructivism.

Radical constructivism represents the opposite end of the continuum. Knowledge acquisition, from a radical constructivist point of view, “is not an accurate representation of external reality, but rather is an internally coherent and coordinated collection of processes and structures that provide for adaptive behaviours” (Doolittle, 2014, p. 487). The defining principle of this form of constructivism is the internal nature of knowledge, that although there may be an external reality, it is unknowable to the individual.

Von Glasersfeld (1998) argues that developments in the philosophy of science call into question the existence of objective knowledge and the possibility of communicating it. His view of knowledge is radically different than cognitive constructivism, for his view “deliberately discards the notion that knowledge could or should be a representation of an observer-independent world-in-itself and replaces it with the demand that the conceptual constructs we call knowledge [need] to be *viable* in the experiential world of the knowing subject” (Von Glasersfeld, 1998, p. 12, emphasis in original). That is, the process of constructing knowledge relies on the individual’s interpretation of his/her experience; therefore knowledge is a subjective reality.

In summary, radical constructivists contend that knowledge is constructed from the interaction between external experiences and previous mental structures. At the same time, they emphasize that the nature of knowledge is internal and subjective.

Summary

Although cognitive, social, and radical constructivists view reality differently and therefore link theory to practice in a manner that is significantly different, there are common theoretical and practical factors that are essential when applied to constructivist-oriented pedagogy (Archer, 1998; Doolittle & Camp, 1999; Nelson, A., 2017). Brooks and Brooks (2001) summarize these elements in their description of five essential factors of constructivist classrooms. These are discussed in Chapter 4.

Constructivism in Education

Constructivism represents one of the big ideas in education (Bada, 2015). It has influenced education for more than three decades (Tobias & Duffy, 2009a) although the constructivist practice of teaching is a recent consideration (Richardson, 2003). Constructivism, argues Richardson (2003), "is not a theory of learning but a model of knowing… [that] may be used to build a theory of learning" (p. 1624). The meaning of constructivism differs based on one's perspective and position (Ültanır, 2012, p. 196) and is not limited to one particular pedagogy, as advocates suggest a number of different teaching practices (Bada, 2015).

When the term constructivism is used in the context of education, a binary is often constructed between teacher-centred and student-centred teaching strategies that places traditional teaching behaviour in opposition to constructivist teaching behaviour (Hammerman, 2006), as well as between opposing extremes of guided instruction (Herman & Gomez, 2009; Kirschner, Sweller, & Clark, 2006). Additionally, constructivist strategies are frequently interpreted as a relativist model of teaching (Gordon, 2009) and are "often set in opposition to behaviourist methods, where external reinforcements regulate learning as well as direct instruction, where students are told or shown what to do" (Schwartz, Lindgren, & Lewis, 2009).

Contemporary views on teaching and learning have shifted away from a behaviourist view and towards a constructivist view of learning (Luckay & Laugksch, 2015). The behaviourist perspective, which is primarily focused on environmental stimuli (Ertmer & Newby, 2013), has shifted towards a social constructivist view (Luckay & Laugksch, 2015) and a perspective that emphasizes the learner's construction of knowledge through personal experience (Weegar and Pacis, 2012). Today those who view learning from a behaviourist position continue to focus on the content to be learned and the effect that external stimuli has upon that learning, whereas educators who view learning from a constructivist perspective are more concerned with knowing how the learner endeavours to construct meaning (Bush, 2006).

When comparing behaviourist and constructivist-oriented perspectives, Kauchak and Eggen (2012) describe a behaviourist teacher as one who controls stimuli, shaping student behaviours through reinforcements in order to cause the passive learner to exhibit the correct responses. In contrast, a constructivist-oriented teacher aims to partner with the learner in an active meaning-making process as the student develops strategies to organize and retrieve information (Kauchak & Eggen, 2012).

Constructivist education research was reignited in the 90s when Brown et al. (1989) argued that knowledge is situated in the activity of the learner and is a creation of that activity in the context of the learning. This suggests that "learning takes place outside the individual's head and in the participatory activity itself" (Archer, 1998, p. 89). This conception of learning is in direct contrast with that of objectivists, who believe that knowledge is outside the human mind and that the learner's representation is either correct or incorrect (Jonassen, 1991). For the objectivist, the context of learning or the goals of the learner in knowledge creation are not seen as important when conceiving of knowledge acquisition (Tobias & Duffy, 2009a).

Schwartz et al. (2009) add to this discussion by considering the goals of the learning context, arguing that any given style of instruction is not appropriate for all outcomes. For example, teaching strategies that support memorizing an unchanging domain may not be appropriate for learning within a developing or shifting domain. Schwartz et al. (2009) argue that this is "particularly true for highly stable domains where it is possible to cover nearly every possible combination of skills and performance conditions" (p. 37). For example, these authors claim that inquiry-based teaching strategies would not be appropriate for learning unchanging subjects (e.g., typing), whereas constructivist teaching strategies that aim at the big picture or the development of evolving concepts (Clement, 2008b) may be appropriate for domains that are flexible or support more than one answer. Schwartz et al. (2009) point out that "two clusters have been consistently called out and pitted against each other: constructivist-type learning verses direct-instruction type learning. It did not have to be this way" (p. 51).

How does a constructivist-oriented teacher impact the learning of students differently than a traditional teacher using a transmission model of teaching? Richardson (2003) explains that "a constructivist classroom provides students with opportunities to develop deep understandings of the material, internalize it, understand the nature of knowledge development, and develop complex cognitive maps that connect together bodies of knowledge and understandings" (p. 1628).

Although Schwartz et al. (2009) suggest that traditional and constructivist-oriented classrooms do not have to be viewed in opposition, I began this study with the belief that I should completely shift from traditional to constructivist-oriented practices. Therefore, I sought to contrast these perspectives. In this study when a traditional classroom is discussed, the behaviourist and objectivist perspectives are assumed. In Table 1, the traditional and constructivist classrooms are contrasted.

Table 1

Traditional Classrooms Compared with Constructivist Classrooms

Traditional Classroom	Constructivist Classroom
The curriculum emphasizes basic skills with a focus on parts that create a whole.	The curriculum emphasizes big concepts, beginning with the whole and expanding to include the parts.
Strict adherence to a fixed curriculum is highly valued.	Student questions and interests are valued in curriculum choices.
Materials are primarily textbooks and workbooks.	Materials could include primary sources and manipulatives.
Learning is based on repetition. Students are "blank slates."	Learning is interactive, building on what the student already knows.
Teachers disseminate information to students (didactic manner); students are recipients of knowledge.	Teachers have a dialogue (interactive manner) with students, helping students construct their own knowledge.
Teacher's role is directive, rooted in authority.	Teacher's role is interactive, rooted in negotiation.
Assessment is through testing, searching for correct answers to validate student learning.	Assessment includes student work, observations, and points of view, as well as tests. The process is as important as the product.
Knowledge is seen as inert.	Knowledge is seen as dynamic, ever-changing with our experiences.
Students work primarily alone.	Students can work in groups.

Note: Table 1 is an amalgamation of Tam's (2000) and Brooks and Brooks' (2001) work.

There is a great deal of variability in the constructivist concept; likewise, depending on the point of view of the individual teacher, the constructivist-oriented pedagogies used in a classroom vary significantly. For example, when planning for learning, Hartle et al. (2012) argue that only cognitive constructivism can help teachers understand how students learn, while Powell and Kalina (2009) argue that social and cognitive constructivism have “situational advantages… they both have their place in the classroom and occur interactively in an eclectic learning atmosphere” (p. 249). In conclusion, although Tam (2000) does not argue for a specific flavour of constructivism, she argues that “[i]nformation may be imposed, but understanding cannot be, for it must come from within” (p. 51).

A Constructivist-Oriented Science Teacher

What is expected from a science teacher? Today science teachers are tasked with more than simply transferring information to students; they are asked to balance a unique curriculum and teaching approaches (Lederman & Lederman, 2017) of Science, Technology, and Society (STS), Science, Technology, Society, and Environment (STSE), and Science, Technology, Engineering, and Mathematics (STEM) education. The form of education known as STS, which emerged in the 1970s (Montgomery, Kingori, Sariola, & Engel, 2017), moves beyond simply engaging in domain-specific knowledge; it shifts to “teaching and learning in the context of human experience” (Yager & Blunck, 1992) where students endeavour to understand their everyday experiences. Additionally, Yager and Blunck contend that STS education should utilize a constructivist teaching approach. The teaching authority that oversees the high school where this study took place include STS as one of the foundations of its science program. Alberta Learning (2016) specifically requires science teachers to provide an experience that allows students to “develop an understanding of the nature of science and technology, the relationships between science and technology, and the social and environmental contexts of science and technology" (p. 3).

Lederman and Lederman (2017) add to this discussion by pointing out that STS "has evolved over the years into Science Technology Society and Environment (STSE). Most recently the STS and STSE movements have given way to the use of socioscientific issues as a platform for teaching science subject matter, science practices, argumentation, and the nature of science" (p. 219). One may argue that the current science curriculum reflects a flexible curriculum as well as a fixed curriculum (Schwartz et al., 2009), therefore requiring a mixture of traditional and constructivist teaching approaches.

A science teacher is also expected to incorporate STEM education in his/her classroom (Breiner, Harkness, Johnson, & Koehler, 2012). The STEM emphasis is a reaction to stakeholders who "look to the nation's teaching force as a source of shortcomings in student mathematics and science achievement" (Gonzalez & Kuenzi, 2012). Yet, defining what STEM looks like uncovers multiple perspectives:

> From an educational perspective, the introduction to STEM can be a variety of activities, but generally speaking, it usually includes the replacement of traditional lecture-based teaching strategies with more inquiry and project-based approaches. To some, it only becomes STEM when integrating science, technology, engineering, and math curricula that more closely parallels [sic] the work of a real-life scientist or engineer. To others, STEM is the push for graduating more students in the science, technology, engineering, and mathematics fields so the United States can maintain its competitiveness and not fall behind emerging countries. (Breiner et al., 2012, p. 3)

As a consequence of the current curricular requirements, some education scholars suggest that science teachers should teach via inquiry-teaching methods (Sotiriou, Bybee, & Bogner, 2017). Constructivism is the basis of inquiry-teaching methods (Hartle et al., 2012) and, consequently, it is the primary learning theory underlying the American Association for the Advancement of Science's "Vision and Change in Undergraduate Biology Education: A Call to Action" (Woodin, Carter, & Fletcher, 2010). Sotiriou et al. (2017) point out that although there are many definitions, inquiry learning is regarded as a type of teaching where the learner is an "active individual learning with authentic research-like activities intended to explore, master and expand an existing knowledge-base" (p. 9).

Other education scholars suggest that science teachers should engage students in problem-solving. Nelson (2017) argues that science teachers who look for ways to engage students in their science classroom should embrace constructivist instruction. This instruction, Nelson argues, promotes "authentic opportunities to engage in meaningful and active learning" and "models the type of real-life problems solved by scientists and may enable students to be the future scientists and problem solvers of unknown challenges that they will face in their generation" (p. 4).

As described in Chapter 3, my K-16 educational experience exclusively included traditional pedagogies. Also, when I taught high school science, I employed this form of instruction. As I reflect on how I developed my understanding of science I recall factual acquisition developed from classroom experiences, yet the authentic learning provided outside of the classroom made the most impact on me: for example, the field trips to the Rocky Mountains with my father's biology classes. I am no longer a science teacher, yet I recognize that I influence future science teachers in my education courses. Consequently, it is important that I provide future science teachers with the opportunity to develop teaching approaches that navigate the tensions described in this section. Berry and Van Driel (2013) argue that science teacher educators must highlight the value of learning from experience and model the approaches that science teachers are encouraged to use in practice.

Constructivism and this Researcher

The anomalies discussed earlier are what encouraged me to study constructivism. Although I did not define myself by the continuum described above, after the pilot research, I gravitated toward a cognitive constructivist perspective. I envisioned knowledge as an objective reality that, as a teacher, I would transmit to the student. The learner would then construct a representation of the original knowledge. Piaget's concepts of assimilation, accommodation, and cognitive equilibrium seemed compatible with my behaviourist teaching style. As a result, when I initially accepted constructivism as a viable perspective, I sought to create experiences that encouraged active cognitive engagement. I thought that asking students to create concept maps would enable them to actively internalize the information I presented.

During the high school and university teaching experiences, I began to find the social constructivist perspective a useful concept. Although learning occurs in the individual, I now contend that learning often occurs through social interaction. In a classroom setting, the learner's knowledge construction is influenced by peers as well as instructors. I now appreciate the view that learning is influenced by the social context. That is, "individual learning and development is [sic] dependent on the institutions, settings, and cultural artifacts in one's social milieu" (Bonk & King, 2012, p. 35).

Finally, the radical constructivist perspective did not inform my pedagogies during this study. I did not feel that it was helpful to view knowledge as a human construction that rejects objective knowledge. Today, as I continue to examine constructivist literature, I see that there is some value in the arguments made by radical constructivists. In science education, radical constructivism plays a role in consideration of the nature of science. Observations are theory-laden, and groups of scientists can examine the same data, generating diverse conclusions (details regarding teacher educators and the nature of science are discussed below).

In conclusion, after the research pilots (described in Chapter 4), my emerging teaching beliefs were influenced by a cognitive constructivist perspective. As I began to implement constructivist practices in this study, I began to value the arguments of social constructivists and, finally, today, I have come to value some of the arguments of radical constructivists. The change in my belief system, my paradigm change, from a behaviourist view to a constructivist view pushed me into a liminal state. The focus of this state hinged on my inability to translate the constructivist learning theory into my teaching practices. I had strong models of instruction based on traditional behavioural theories, yet as I entered the high school classroom, I did not have confidence in my ability to teach in a manner that supported a constructivist environment.

Reforming Teacher Education

The context of this study is my personal journey into teacher education. In this setting, I confronted issues that encouraged me to change my teaching practices. My personal desire to change is similar to the continued international commitment to reform teacher education (Christou & Bullock, 2014; Organisation for Economic Co-operation and development, 2005; Smith, Virginia, 1997). Yet in spite of decades of educational reforms, there is an argument that more reform is required (Korthagen, Loughran, & Russell, 2006). In response to this perceived necessity for reform, there has been a recent push for improvement in teacher education programs (Christou & Bullock, 2014). This push influences both this study and my desire to fulfill my role as a teacher educator.

Becoming a teacher is consistently reported as difficult and strenuous (Akkerman & Meijer, 2011; Beijaard, Meijer, & Verloop, 2004), but there is little literature focused on teacher educators and the influence that teacher educators have on this process (Berry & Van Driel, 2013). Carroll et al. (2007) assert that “As a field, we know very little about the struggle to create and sustain decent settings for learning to teach and the structures of support and thought such settings require” (p. 9).

Some criticism of teacher education programs is questionable because teacher educators are being criticized for things that are beyond their control and originate from stakeholders who expect new teachers to perform as well as veteran teachers (Calderhead, 1989). Other criticism, for example, the slow pace of change, falls squarely on the shoulders of teacher educators (Tom, 1997). It should be noted that resistance to change stems from unique sources in teacher education. Tom (1997) points out that “the snail’s pace of change in teacher education is due in part to the numerous stakeholders involved in the formal and informal governance of teacher education… In many ways, everyone is in charge of teacher education, yet nobody is” (p. 7).

Teacher education is also a field where those who aim to improve the quality of the educational experience encounter a great deal of resistance (Carroll et al., 2007; Christou & Bullock, 2014). Korthagen et al. (2006) are not afraid to face that resistance head-on. They present three reasons they believe that teacher education is in need of change. First, traditional teacher education programs are based on lecturing, a “form of teaching about teaching; this theory-into-practice view of teacher education is increasingly being challenged for its many limitations and inadequacies” (p. 1021). The emphasis on theory and the limited transference of that theory into practice inadequately prepare first-year teachers. Russell, McPherson, and Martin (2001) stress the same points:

> The inability of traditional programs to prepare beginning teachers with more than an imitative understanding of their role emerges, in large part, from the lack of explicit connections between the actions of teachers and the pedagogical theories that inform practice. (p. 42)

The second reason Korthagen et al. (2006), and others (Fazio & Volante, 2011; Harfitt & Chan, 2017; Zeichner & Tabachnick, 1981) argue that teacher education needs to change has to do with the "washing out" of progressive practices. As new teachers experience the "reality shock" of teaching obstacles (Fazio & Volante, 2011; Harfitt & Chan, 2017; Zeichner & Tabachnick, 1981), they often fall back on traditional teaching practices. As noted previously, early in their careers, new teachers often shift their attitudes towards more traditional ways of teaching. The third reason that Korthagen et al. (2006) believe that education programs need to change has to do with newly developed concepts of teaching and learning. These include new understandings of knowledge creation (e.g., constructivism (Schwartz et al., 2009)), and knowledge and thinking (e.g., situated cognition (Brown et al., 1989)). The key point that Korthagen et al. (2006) make is that these contemporary "views contrast starkly with traditional practices in teacher education, the very same practices that were supposed to prepare teachers for new approaches to learning and teaching" (p. 1021).

The argument posited by Korthagen et al. (2006) resonates with me, as it describes the crisis that I am experiencing with my practice. Discussions with recent education graduates, including John, have reinforced my understanding of the level to which graduates from my courses are unprepared for the day-to-day practice of teaching using contemporary approaches.

Additionally, many recent graduates from my courses have described how they transformed their understanding of teaching, altering their pedagogies, to match traditional strategies. The resulting pedagogies they described often ignore the constructivist understandings of knowledge creation that I now value.

The Scope of Teacher Education and Teacher Education Research

The scope of teacher education is potentially wide-ranging. One helpful way to conceptualize teacher education is to view the field as a continuum from preservice teacher education in formal settings to continuing teacher education in professional settings (Beck & Kosnik, 2017; Clandinin & Husu, 2017a). In this paper, I write about my interactions with preservice teachers, yet personally, the learning that I am involved in would be located on the opposite end of the continuum, on the professional development or in-service side. Nevertheless, my shifting pedagogies have influenced my teaching of preservice teachers.

Although DeLuca and Pitblado (2017) argue that Canadian educational thought has always contained elements of continuity and change, an examination of recent teacher education research literature leaves little doubt that the nature of education has transformed significantly during the past few decades (Guerriero et al., 2015) and that teacher education continues to change today (Christou & Bullock, 2014). For example, Canadian university teacher preparation programs continue to initiate change in response to the increasing demands that teachers experience in contemporary classrooms (Crocker et al., 2008). Refining and adjusting teacher education is a common policy in many Canadian jurisdictions (Guerriero et al., 2015). An example of this refining process is evident in the smallest province, Prince Edward Island, where new areas of improvement in teachers' learning were defined in 2013, to Canada's most populated province, Ontario, where the number of days required in classroom placements doubled from 40 to 80 (Guerriero et al., 2015).

Despite the growing research and changes made in teacher education programs, there is still criticism about the limited relationship between the theories taught in educational programs and the impact on the future practice of education students (Korthagen et al., 2006). Disrupting the theory-practice gap is one of the key purposes expressed by the more than 120 contributors to *The SAGE Handbook of Research on Teacher Education* (Clandinin & Husu, 2017b). Other scholars are critical that new teachers lack experience with new types of teaching. Christou and Bullock (2014) suggest that the "burden of education reform, then, seems to fall squarely on the shoulders of teacher educators" (p. 80). These authors argue that teacher educators must facilitate teaching experiences.

As indicated above, teacher education has changed. Pepper, Hartman, Blackwell, and Monroe (2012) suggest that the focus has switched from memorizing facts to teaching for understanding and lifelong learning. The result, Pepper et al. (2012) argue, is that key features are now reflection and inquiry. As a teacher educator, I reflect this change in focus as I shifted my teaching beliefs and now strive to shift my pedagogies. Furthermore, as teacher education continues to change (Christou & Bullock, 2014), my understandings must continue to evolve.

Teacher Educators

Beginning teacher educators face a wide range of challenges (Williams, Ritter, & Bullock, 2012) including the developing of their own identity (Dinkelman, 2011) as well as their own knowledge, skills, and competencies. Although this is my eighth year in teacher education, until recently I felt that I was a novice teacher educator. My tension-filled experience of becoming a teacher educator is common (Loughran & Menter, 2019) and is reflected in the growing field of study focusing on teacher educators (Blömeke & Kaiser, 2017). However, until recently, teacher education induction was a marginal research subject (Swennen, Shagrir, & Cooper, 2009).

It is problematic that many people assume that an effective teacher will make a good teacher educator (Korthagen et al., 2005; Williams et al., 2012) or, conversely, that an effective teacher educator will make a good teacher (Ritter, 2014). These views suggest that teacher educators are neither particularly specialized nor highly valued (Korthagen et al., 2005). As noted earlier, these assumptions are inconsistent with the growing body of research describing the expertise required for teacher educators (Korthagen et al., 2005; Koster, Brekelmans, Korthagen, & Wubbels, 2005; Loughran & Russell, 2007; Murray & Male, 2005), research that also suggests that competencies are not fixed traits, but can be learnt and improved on (Toom, 2017). Additionally, when viewed through a constructivist lens, the importance of the teacher educator is heightened when one acknowledges that the teacher educator facilitates the students' development of knowledge and skills (Korthagen et al., 2005).

Shulman (1986) also highlights the importance of the teacher educator. Instructors in schools of education may be viewed as pedagogical specialists. Shulman argues that subject knowledge is necessary, but it is not the only knowledge required of a teacher. He theorizes that teachers have specialized knowledge, pedagogical content knowledge (PCK), which distinguishes them from content specialists. Shulman (1986) argues that PCK is "that special amalgam of content and pedagogy that is uniquely the province of teachers, their special form of professional understanding" (p. 8).

Teacher educators influence preservice teachers' PCK. In fact, it is the teacher educators' responsibility to provide opportunities for preservice teachers to develop this specialized knowledge (Fraser, 2017). For example, for a science education student, a teacher educator must ensure that the preservice teacher acquires science knowledge and the "knowledge about science learners, curriculum, instructional strategies, and assessment through which they transform their science knowledge into effective teaching and learning" (Abell, 2009, p. 79).

In a parallel fashion to K-12 teachers, teacher educators have specific PCK (Abell, Rogers, Hanuscin, Lee, & Gagnon, 2009). As with K-12 teachers, teacher educators teach subject matter, yet they also teach how to teach subject matter to K-12 students, influencing the beliefs and understandings that will provide the foundation preservice teachers' future practices (Ritter, 2014; Zeichner, 2005). Additionally, it is imperative for teacher educators to stay in contact with the changing K-12 students and school environments. Maintaining an understanding of changes in school climates and continuing to learn about changing subject matter will enable these teacher educators to teach based on the most current understandings possible (Ritter, 2014).

In light of the influence that teacher educators have on preservice teachers (Ping et al., 2018), it is important to examine a teacher educator's responsibilities and expertise. Korthagen et al. (2005) propose that there are two ways to consider aspects of teacher educators' expertise: first, by examining the "big picture" of the tasks and expertise and, second, by examining specific expertise in "real world" situations. Koster et al. (2005) describe the "big picture" qualities that teacher educators believe are part of their profession, arguing that increasing the teacher educators' knowledge of tasks and competencies strengthens the profession and increases the possibilities for professional development. After a literature review, interviews, and two rounds of questionnaires completed by teacher educators, Koster et al. (2005) created a professional profile of a teacher educator that includes five task areas (six for university-based teacher educators) and four areas of competence. Teaching competencies necessary for all teacher educators include:

- Content competencies, for example, being able to discuss one's professional field with others and being perfectly at home with the content of one's field.
- Communicative and reflective competencies. For example, being able to evaluate one's own teaching and make changes accordingly and being able to reflect on the ways one operates and to develop alternatives.
- Organizational competencies. For example, being able to work in a team and being able to interact with school supervisors.
- Pedagogical competencies. For example, being able to help students to work on their own learning needs and being able to make one's own pedagogical approach accessible to student teachers.

The second method of examination is to investigate expertise in "real world" situations (Koster et al., 2005). As the pedagogical competencies of a teacher educator are the focus of this study, Chapter 5 specifically examines "real world" situations of my teaching.

Loughran and Berry (2005) provide an example of a real-world study of a pedagogical strategy. These self-study researchers described a longitudinal study examining their practice of explicitly modelling aspects of teaching. The pedagogical intent of explicit modelling is to provide preservice teachers with an opportunity to experience a teaching session and a subsequent opportunity to "unpack it" (p. 195). These authors describe the first step as an initiation of the teaching experience, in this case, a POE demonstration. The instructor held two sheets of paper, one in each hand, and asked the class to predict what would happen when air was blown between the two sheets. The instructor encouraged all of the students to make a prediction before conducting the experiment. The predictions were then tested. An open-ended discussion followed, including a specific discussion focused on the success of the predictions. The second step of the activity was the key to this research. The professors encouraged the students to deconstruct the POE activity. Loughran and Berry (2005) explain:

> Explicit modelling through "talking aloud" and "debriefing teaching," creates new ways of encouraging student teachers to grasp the possibilities for learning about teaching that is embedded in their experiences and to see these possibilities as opportunities, not instructions or recipes, for practice. In so doing, we also learn about teaching as we attempt to enact those aspects of practice we are trying to make transparent for our student teachers" (p. 196).

This example of a teacher educator pedagogical competency is consistent with constructivist-oriented strategies. For example, the instructors first probed for students' understanding regarding the POE strategy and then allowed the students to lead the discussion. This allowed for student-generated questions, including student-to-student dialogue, and encouraged students to develop answers to their own questions. The education students asked genuine questions and examined their personal feelings about the POE strategy. In this way, the authors argue, multiple teaching strategies may be modelled by teacher educators and examined by students. Explicit modelling lays bare "one's own pedagogical thoughts and actions for critique and by doing so to help student-teachers 'see into practice'— all practice, not just the 'good things we do'" (Loughran & Berry, 2005, p. 200).

In addition to the identification of teacher educator PCK and a teacher educator's specific pedagogical expertise in a real-world situation, a science teacher educator has unique competencies that must be examined. In the next section, I examine some of the unique expertise required of science teacher educators.

Science Teacher Educators

Science Teacher Educators are a specific group of teacher educators who are crucial to the integrity of the instruction that occurs in K-12 classrooms (Lederman & Lederman, 2013; Lederman & Lederman, 2016). A salient question for science teacher educators is, what PCK should they possess? Abell et al. (2009) provides a useful definition: "A science teacher educator's PCK includes his/her knowledge about curriculum, instruction, and assessment for teaching science methods courses and supervising field experiences, as well as his/her knowledge about preservice teachers and orientations to teaching science teachers" (p. 79).

Science teacher educators negotiate unique curriculum requirements (Abell et al., 2009), providing preservice teachers the opportunity to learn about concepts including the nature of science, scientific literacy (Fletcher & Bullock, 2012), scientific inquiry (Campbell, Der, Wolf, Packenham, & Abd-Hamid, 2012), conceptual development and change (Berry & Van Driel, 2013), STSE education (Pedretti & Nazir, 2011) and the larger picture of STEM education (Lederman & Lederman, 2013; Schneider, 2007). As a science teacher educator who is striving to change my teaching practice, I can attest that the concepts listed above are problematic when one shifts from a behaviourist to a constructive perspective. My priorities have changed.

The nature of science (NoS) is a unique curricular issue that science teacher educators must navigate. Lakin and Wellington (1994) suggest that the NoS appears to be contrary to "expectations held of science and science teaching in schools, not only by teachers and pupils but also those perceived as being held by parents and society" (p. 186). Several conceptions exist for the NoS (Backhus & Thompson, 2006), yet Clough (2018) contends that little has changed since

1994 and that science teacher educators devote little time in their courses to deep and robust examinations of the NoS. With this in mind, in my science education course, I should intentionally engage students in research into the NoS, including how a constructivist perspective may impact the subject.

In regards to the NoS, Taylor et al. (1997) argue that a constructivist-oriented science teacher must be aware of the “popular myth that Western science is a universal, mono-cultural (or acultural) endeavour that provides accurate and certain knowledge of objective reality. The objectivist *myth of certainty* implies that scientific knowledge exists independently of collective human experience and that it has a privileged status” (p. 5, emphasis in original). Taylor et al. (1997) state that constructivist teachers must create experiences that allow students an opportunity to develop an understanding of the limitations of scientific knowledge.

Science teacher educators must also be aware of the apprenticeship by observation that science education students have experienced throughout their lives (Abell et al., 2009; Campbell et al., 2012). During their time as K-12 students, preservice teachers developed tacit understandings and beliefs regarding “good” science teaching practices and “good” classroom situations. Often the K-12 experiences that preservice teachers bring to the teacher education classroom reflect traditional understandings of teaching. This may continue to be reinforced during their teacher education experience when the student teachers observe seasoned K-12 teachers moving from one activity to another, focusing more on “activities that work” than on teaching for scientific understanding (Appleton, 2003). This focus, Appleton argues, has a predictable outcome. Activities are “treated like isolated experiments rather than part of ongoing investigations,” (p. 17) reinforcing the view that scientific knowledge is convergent in nature. Traditional science teaching supports an understanding that scientific knowledge is predetermined and that scientific experimentation can answer every problem in nature. This view is not congruent with Ackermann's (2004) view of constructivism, for she contends that "the world is not just sitting out there waiting to be uncovered, but gets progressively shaped and formed through people's interactions/transactions" (p. 16).

In an examination of how best to prepare future science teachers, Lederman and Lederman (2013) ask the provocative question, "Do we [science teacher educators] all have the background and abilities to help prepare current and future science teachers" (p. 930)? This question is important: science teacher educators often endorse pedagogies in harmony with scientific literacy, yet the enactment of this vision is highly idiosyncratic (Berry & Van Driel, 2013; Fletcher & Bullock, 2012).

With regards to this self-study, my PCK is influenced by my struggle to transform my teaching practice. For example, although a constructivist perspective helps explain how knowledge is produced, how students learn, and how one can support preservice teachers through teacher education (Harfitt & Chan, 2017), I struggle to implement the congruent pedagogies. As I pointed out in Chapter 1, identifying this challenge has allowed me to see that I am a living contradiction (Whitehead, 1993) and this recognition has influenced my changing understanding of my role as a teacher educator. I believe that as a science teacher educator I should employ strategies that are consistent with constructivism. This is highlighted by Richardson's (2003) suggestion that all science teacher educators should model a constructivist-learning environment for their students.

Summary

This chapter examined the current state of research that informs the inquiry of this study. The first part of this chapter examined the constructivist learning theory, a constructivist continuum, and three common views of constructivism. This was followed by an examination of how constructivism impacts education. The second part of this chapter examined the context of reforms occurring in teacher education, the competencies of teacher educators, and the competencies of science teacher educators.

An overarching purpose of this chapter is to provide the context to examine the alignment of my teaching practice and teaching beliefs as I strive to improve my teaching methods.

Chapter 4

Self-Study Research Methodology

The answers you get depend on the questions you ask (Kuhn & Hacking, 2012).

Introduction

The purpose of this study is to examine how I might develop my teaching practice by aligning my teaching beliefs and practices in order to provide preservice teachers with models of constructivist pedagogies. The self-study research methodology, the theoretical framework used in this study, and a detailed description of data collection and analysis procedures are examined in this chapter.

Opening the Door to Self-Study Research

A major shift in teacher education research occurred between 1980 and 2000, opening the field of education to new types of research. That shift included an increased awareness of the self in teacher education and the importance of the role of context when examining what teachers understand (Russell, 2004). Many educational scholars (Berry & Loughran, 2002; Christou & Bullock, 2014; Loughran, 2005) point to Schön's (1983) work as the turning point in the education research landscape. Responding to what he termed a crisis of confidence in occupations claiming profession status, Schön (1983) suggested that researchers must first focus on the understandings that professionals possess in order to uncover the tacit knowledge and understandings that are unique to specific professions. Schön believed that to appreciate a profession one must recognize the importance of the individual practitioner's thoughts and actions (practice) in relation to knowledge developed through research (theory).

Schön's (1983) work provided an opening for the growing number of teachers and teacher educators who recognized the need for research focused on the teaching practitioner. Kitchen and Russell (2012) contend that prior to the 1990s, understandings developed through practitioner research were discounted by some academic researchers. However, throughout the 1990s, there was a growing appreciation of critical examinations of teacher practices. This new field of research presented a unique situation rarely confronted by researchers, that is, teacher researchers conducting research in their own classrooms, balancing their "understanding [of] educational practices with changing their educational practices and their understanding of themselves as teachers" (Kitchen & Russell, 2012, p. 1).

Throughout the 1980s and 1990s the rise in the legitimacy of qualitative methods in educational research (Denzin, 2012; Russell, 2004) and the acceptance of teacher education academic research provided the opportunity for teacher educators to choose the growing methodology of Self-Study of Teacher Education Practices (S-STEP) as a way to examine their own practices using an organized and rigorous approach (Christou & Bullock, 2014; Loughran, 2004a). This methodology, described in detail in the following sections, focuses on the personal analysis of educational practice with an emphasis on improving the learning of preservice teachers and practicing teacher educators (Bullough & Pinnegar, 2001). Korthagen et al. (2006) contend that this type of scrutiny has provided an accepted avenue for improvements in teacher education and, as Russell (2004) argues, was an inevitable result of the changes in educational research.

I chose self-study as my research methodology to answer my research questions. In the next section, I will examine the origins of self-study and the suggestions that leading educators have in regards to best practices of self-study within teacher education programs.

Self-Study Overview and Roots

During the last decade of the 20th century, S-STEP emerged as a recognizable body of work that brought together the worlds of research and practice (Loughran, 2004b). Self-study developed out of a synthesis of action research, reflective practice, and teacher research (Berry & Loughran, 2012). S-STEP is an amalgamation of self-study concepts that can be traced to the 1960s when the term self-study was used to describe a method of learning that students used to teach themselves via diagnostic testing (Loughran, 2004a). In the 1970s, the term was used as a descriptor for psychological studies in which an individual explored the concept of self. Later, in the 1980s, the term self-study was used when studying the "self" of an institution (Loughran, 2004a).

The thread that runs through these historical usages for the term self-study is the expectation that beliefs and practices should be closely aligned and that the self bears significant responsibility for establishing this alignment (Loughran, 2007). Samaras (2011) suggests that today, self-study continues to focus on the knowledge generated by the individual, yet self-study in teacher education research "builds on the necessity of a relationship between individual and collective cognition in teacher professional development" (p. 5).

Pinnegar and Hamilton (2009) examined the history of scholarly education research and identified how a space developed for the self-study of teaching practice. The discipline of psychology dominated educational research before the 1970s. This research centred on effective teaching (e.g., the Madeline Hunter model). Educational research shifted with the movement toward research on student and teacher cognition. This shift paved the way for Schön's (1983) *Reflective Practitioner* (Pinnegar & Hamilton, 2009). Schön identified a crisis of confidence of professionalism, providing a window to examine the value and tacit knowledge of professional practice. Schön (1983) argued that reflection in action allows practitioners to generate new understandings and allows changes when needed. Pinnegar and Hamilton (2009) suggest that Schön's work motivated teachers to begin studying teaching and teacher development. However, Korthagen (1995) found that teacher educators were slow to accept the need to do themselves what they asked teachers to do, i.e., study their own practice. Fortunately, by the early 1990s, the introduction of qualitative research methods into education and the redefinition of the validity of research paved the way for those interested in self-study (Bullough & Pinnegar, 2001). Korthagen et al. (2005) summarize the shift in research:

> It is interesting to note the trend in research in teaching over the past few decades, especially so when one focuses on the shift from research *on* teachers to research *with* and *by* teachers. One of the issues that has emerged through this change in research focus and concurrent action is the concentration on, and acknowledgement of, the expertise of teachers and the way this expertise can be used as a foundation on which to further build. (p. 110)

Self-study is an effective method for teacher educators who seek to improve their expertise (Korthagen et al., 2005; Zeichner, 2005) and professional competencies (Loughran & Berry, 2005). There is an S-STEP special interest group in the American Educational Research Association (AERA). This group is an organization of teacher educators who have identified a need to conduct research about their teaching about teaching and their students' learning about teaching. Russell (2002) describes the formation of S-STEP in 1993 as a coalescence of teacher educators interested in "studying their own teaching, going beyond the standard image of telling others how teaching should be done without necessarily following their own advice" (p. 3). Since the inception of the S-STEP special interest group, those interested in self-study of teacher education practices have worked to articulate the scope and range of self-study with the purpose of making the research more accessible to teacher educators (Loughran, 2004a).

A number of teacher educators have found that S-STEP is an excellent method to examine and learn about their practice with the embedded “desire to teach in ways that are commensurate with the learning intentions that they have for their students” (Loughran, 2004b, p. 3). Loughran (2004a) explains, in his examination of the history and context of self-study, that teacher educators who have a desire to better learn how to align their teaching intentions with their teaching actions use S-STEP research to investigate how they may change. The choice of the acronym S-STEP, rather than an abbreviation for self-study, reflects an understanding that the self and the teacher education practices must always be viewed together (Kitchen & Russell, 2012).

In summary, self-study of teacher education practices grew out of multiple research fields including “reflection, action research, teacher research, participation research and practitioner research” (Loughran, 2007, p. 9). Teacher organizations, including AERA’s S-STEP special interest group and the Canadian Association for Teacher Education in Canada, continue to support discussions about teacher education, research, and collaboration. Finally, many teacher educators feel that S-STEP is a “moral imperative” (Fletcher & Bullock, 2012) as self-studies provide an excellent method for stimulating positive change in teacher education.

The Purpose of Self-Study

“Self-study is many things to many people, but it is not an end in itself… As teacher educators seek to understand their personal roles more fully, there is always consideration of the long-range goal of improving teacher education” (Russell & Loughran, 2005). Pinnegar and Hamilton (2009) agree that those interested in self-study in teacher education fundamentally care about understanding and improving teacher education practice. These researchers report that they consistently find that self-study authors make a point of focusing on the purpose of conducting a self-study. This search for understanding is also reflected in the work of Bullough and Pinnegar (2001), who write that the "aim of self-study research is to provoke, challenge, and illuminate rather than confirm and settle" (p. 20). This aim is an important focus of my self-study as I seek to develop an understanding of my teaching beliefs and practices.

While recognizing that being "a living contradiction" (Whitehead, 1993) may stimulate a teacher educator to initiate a study, the personal element of the research is important. Loughran (Loughran & Berry, 2005; Loughran, 2007) argues that the greater purpose is to reach beyond the individual and contribute to the discourse of teacher education in general. The public theory and personal practice may appear at opposite ends of a research continuum, but "only when a theory can be seen to have efficacy in a practical area will that theory have life" (Bullough & Pinnegar, 2001, p 15).

In conclusion, LaBoskey (2004) argues that self-study research is effective when describing what is problematic and what has caused a shift in thinking and practice. The understanding that I am a living contradiction occurred somewhat like a revolution (paradigm change) producing a turning point (crisis) with regards to my teaching practices. Over the last several years, as that realization advanced, I recognized that my teaching practices had to change. After identifying my belief-practice contradiction and entering into a liminal state, it would be hypocritical if I were not motivated to change. Self-study is an ideal choice of research methodology for those who for those who desire to determine whether their teaching actions are at odds with their beliefs and values. It is also ideal for those examining their steps towards change.

Self-Study Methodology

Teacher professional development is often trusted as a strategy to improve teaching practice. The results of this strategy are frequently disappointing (Opfer & Pedder, 2011) as they are conceptualizations of teacher professional learning that ignores how the professional lives of a teacher impact his/her learning (Timperley & Alton-Lee, 2008). Through this self-study, I sought to examine how my past and current professional life impacts my teaching practices. A critical piece of the current study is the narrative titled, "My Educational Life History" (See Chapter 2). Williams et al. (2012) contend that careful examination through a personal biography is a common practice for many teacher educators, as "becoming a teacher educator involves examining beliefs and values grounded in personal biography" (p. 256). I chose to explore the origins of my paradigm change in this way after reading the work of three researchers who examined their teaching experiences through self-study narratives. In her doctoral dissertation, Magee (2009) used narrative to describe how she struggled to teach in a school climate that did not support an inquiry-based science-teaching approach. The second and third self-study narratives that motivated my choice are found in the work of Loughran and Northfield (Loughran & Northfield, 1998) and Russell (1995). These teacher educators all returned to K-12 classrooms in an effort to maintain "recent, relevant, and successful" (Russell, 1995, p. 95) teaching experiences.

Russell (1995) returned to the classroom, teaching two semesters of Grade 12 physics in Ontario, Canada. The questions he asked apply to my research: "Can I practice what I preach?" and "Can I do in my own teaching what I ask of those entering the teaching profession?" (p. 98). Russell sought to better understand what his preservice physics students were learning via their practicum experiences and discover the realities of teaching physics at that time. Northfield

(Loughran & Northfield, 1998; Northfield, 1996), also a teacher educator, conducted a year-long examination of teaching mathematics and science to Year 7 students. Northfield used self-study to better understand the strategies he urged his preservice students to use and, therefore, more fully understand his role as a teacher educator.

The work of Magee, Russell, and Northfield reflects aspects of my current self-study, including the need to articulate the purpose of educational practice for oneself and ensure that preservice teachers are supported effectively. In my case, by aligning my beliefs and practices, I believe that I will better support the growth of science preservice teachers and, more importantly, impact their future students.

The choice of a narrative approach for this self-study also finds support in Harris's (2007) self-study. She highlights the need for "interactivity between the personal details of biography and the broader picture" (p. 137), thereby providing insights that may go beyond the individual. My Educational Life History reflects this desire, for it is not simply a list of experiences, it includes reflections about how my education has affected my understandings of teaching and how it provided an opening for a paradigm change. Those that have had similar experiences may find my study useful. In addition, Day and Leitch (2001) assert that there is "no doubt that raising experience to the level of conscious reflection and dialogue, whether through speaking aloud or writing, enables new forms of critical interrogation" (p. 406).

Narrative works are common in self-study literature. However, the diversity of narrative methods poses a concern for the researchers who want their work to move outside of the self to impact others. With this in mind, it is important to note Bullough and Pinnegar's (2001) assertion that, "It is our view that biography and history must be joined not only in social science but also in self-study research. When biography and history are joined, when the issue confronted by self is shown to have a relationship to and bearing on the context and ethos of a time, then self-study moves to research" (p.15).

Although Bullough and Pinnegar (2001) state that there is no one methodology for self-study, they found that narrative is often the preferred choice in self-study literature. To this point, Feldman (2003) stresses that "if we want others to value our work, we need to demonstrate that it is well founded, just and can be trusted" (p. 28). Loughran (2004a) expressed a similar concern and sought to build trustworthiness in a field of research where there is no specified method. One of his first steps was to summarize features frequently found in self-study research. For example, Loughran and Northfield (1998) developed 10 statements with the intention of prompting those interested in self-study research to connect their personal experience with the emerging tradition of self-study research.

Ten statements intended to prompt self-study researchers.

As a research tradition, self-study continues to mature. In 1998, Loughran and Northfield provided an in-depth examination of Northfield's one-year teaching assignment in a secondary school mathematics and science classroom. The resulting work reflects their belief that teacher-generated knowledge must be shared. These scholars also believe that self-study "proponents have a responsibility to critically analyze the nature of the process and the features of the knowledge it yields.… This requires addressing the issues of quality, reliability, and validity if self-study is to continue to make a contribution to knowledge and understanding" (p. 19). The result of Loughran and Northfield's work was the production of 10 statements intended to stimulate discussion about the emerging tradition of self-study and later was reflected in the organization of the *International Handbook of Self-Study of Teaching and Teacher Education Practices* (2007).

1. Self-study defines the focus of the study (i.e., context and nature of a person's activity), not the way the study is carried out.
2. Even though the term "self-study" suggests an individual approach, we believe that effective self-study requires a commitment to checking data and interpretations with others.
3. It is very difficult for individuals to change their interpretations (frames of reference) when their own experience is being examined.
4. Colleagues are likely to frame experiences in ways not thought of by the person carrying out the self-study.
5. Valuable learning occurs when self-study is a shared task.
6. Self-confidence is important.
7. Self-study outcomes demand immediate action, and thus the focus of the study is constantly changing.
8. There are differences between self-study and reflection on practice.
9. Dilemmas, tensions, and disappointments tend to dominate data-gathering in self-study.
10. The audience is critical in shaping self-study reports.

Following the creation of these 10 statements, Loughran and Northfield (1998) emphasized that four of the 10 focus on the importance of collaboration. These four statements (see points 2, 3, 4, and 5 above) help differentiate self-study from reflection on practice. Loughran and Northfield argue that collaboration is "essential for checking that focus, data collection and interpretations do not become self-justifications and rationalizations of experience" (p. 18). To summarize, self-study is not done in isolation; during the study, critical friends provide an important sounding board. Once the research is concluded, peer evaluation of published results provides additional checks.

Methodological five foci of this self-study.

As self-study continues to mature, multiple methodological perspectives have developed (LaBoskey, 2004; Samaras, 2011). Noting the multiple perspectives, LaBoskey (2004) argued that educational researchers "need to be explicit about our theoretical stance and take time to ensure that our methodologies are consistent with those theories" (p. 817). With this in mind, the methodology chosen for this study reflects Samaras's (2011) work which has been "gleaned, refined, and extended from almost two decades of work by self-study scholars" (p. 70). The work referenced by Samara, and discussed elsewhere in this paper, includes that of LaBoskey (2004), Loughran and Northfield (1998), Samaras and Freese (2006), and Bullough and Pinnegar (2001). The following, known as Samaras's Five Foci Methodological Components of Self-Study, are regularly cited in self-study research:

1. Personal situated inquiry
2. Critical collaborative inquiry
3. Improved learning
4. A transparent and systematic research process
5. Knowledge generation and presentation

Although these components are presented in sequence, Samaras notes that self-study research is fluid and recursive. Since the process is not linear, a researcher may begin an inquiry and later shift the research question as a result of a change in focus. Although Samaras (2011) is deeply committed to being systematic in the research process, she does not suggest that there is a specific procedure. "I understand how much a recipe is helpful, but ultimately, you are working to understand, uncover, and reframe your understanding of practice. That requires an openness to discovery and change during the research process" (p. 71).

In the following sections, each of Samaras' five methodological components is examined, first by listing the focus, followed by providing Samaras' definition of the methodological component, providing and examining literature that exemplifies the component, and finally by how this study attended to each component.

Personal situated inquiry.

"Self-study teachers initiate and study their own inquiry in their classroom and utilize a self-study method aligned with that inquiry" (Samaras, 2011, p. 73). This type of study, Samaras and Freese (2006) explain, originates from the teacher-researcher's questions that are situated in the particular context of that teacher.

Loughran and Northfield (1998) contend that the reader must understand the study's context so that he/she may better relate to the study's conclusions. Elsewhere, Loughran (2004a) further developed this concept by unambiguously stating, "Understanding the context of a given self-study is then important in shaping the perceived relevance—or extent of application—of others' work to one's own" (p. 18).

An example of this self-study component is provided by Magee (2009). Magee describes in detail how she examined the alignment of her teaching approach and teaching practices within the context of a multicultural English-language learners (ELL) science classroom. The description of the self-study's context, including the role played by the ELL students, allowed readers to determine if they could apply what Magee learned to their own situations.

I attend to the personal situated inquiry foci by clearly examining the context of my teaching crisis (see Chapters 1 & 2). I describe the teaching setting and the struggle I experienced as I worked to align my beliefs and practices as a science teacher educator in a parochial university.

Before continuing to the next methodological component, the reader must keep in mind a unique challenge, or ethical demand, that self-study requires of the researcher. LaBoskey (2004) points out that “the practice setting must also be framed and reframed in sequences of reflective instances that are responded to with action” (p. 825). In other words, when a teacher develops a new understanding, a response by the educator in response to the new knowledge is required. This change creates an opportunity to continue to practice and develop a deeper and more robust understanding with regard to the specific context. If a new understanding is uncovered, it must be acted upon and with (LaBoskey, 2004; Loughran, 2004a).

Critical collaborative inquiry.

“Self-study teachers work in an intellectually safe and supportive community to improve practice by making it explicit to themselves and to others through critical collaborative inquiries” (Samaras, 2011, p. 74). Regardless of the appearance of individualism that the term self-study initially presents, it is difficult to develop an understanding of how one thinks and acts independently of others (Loughran & Berry, 2005). Many researchers suggest that it is crucial for an effective study to include others, critical friends or colleagues, to check data, interpretations, situations, and or conclusions (Harris, 2007; Loughran & Northfield, 1998; Loughran & Berry, 2005).

Samaras (2011) uses the term *critical friend* to refer to a trusted person who, understanding the context of the study, is able to provide specific feedback, ask provocative questions and offer a critique with the intention of improving the researcher’s self-reflection and supporting his or her explicit thinking. Research colleagues or peers may fill the role of a critical friend. Colleagues may frame experiences in ways that the individual self-study researcher has not considered, thereby acting as a stimulus for new perspectives, questions, and actions (Loughran & Northfield, 1998). For example, Loughran and Berry (Loughran & Berry, 2005) examined how they explicitly model for their students the theory and practices of pedagogical approaches.

Although the above description of a critical friend may suggest an individual external to the study, both Loughran and Northfield were impacted by Northfield's one-year return to high school teaching. Northfield's purpose for the study was different from Loughran's; nevertheless, had they not worked together they would have neither refined their views regarding nor contributed to the growing understanding of self-study. "[I]t was the collaborative nature of the analysis of the event that stimulated [the] development of our emerging view on self-study" (p. 13).

Within this study, I included three critical friends to provide a collaborative nature in my study. Their specific link to me and education is examined later in this document (see Data Collection Methods).

Improved learning.

"Self-study teachers question the status quo of their teaching and the politics of schooling in order to improve and impact learning for themselves" (Samaras, 2011, p. 78). The first two methodological components describe the context and the individuals involved in self-studies, whereas the third component describes the stimulus for the studies. Pinnegar and Hamilton (2009) point out that researchers arrive at self-study of teacher practices from a number of different places, but "the fundamental reason is that they care about understanding and improving practice" (p. 7).

As explained earlier, the word self in self-study focuses the learning towards the self, but this is a purposeful improvement (LaBoskey, 2004). Samaras (2011), speaking directly to the reader, suggests that a self-study researcher questions personal practices “for the goal of improving your own teaching in order to impact your students’ learning.” Samaras continues by specifying that improved learning “involves your own understanding of what works and what does not work in your teaching” (p. 78).

Senese’s (2000) self-study is a good example of an examination of the self to improve one’s teaching practices. After eight years as a school administrator (staff developer), Senese returned to the classroom. In his self-study, he sought to understand how he had changed during his time as a teacher educator and how that change impacted the way he taught high school English. Specifically, Senese had been influenced by the constructivist learning theory during his time as an administrator. He applied that understanding when returning to teaching. Senese identified three axioms (statements he regarded as self-evident truth) from his self-study as a staff developer. These axioms, which significantly influenced his experience as an English teacher, included, “go slow to go fast,” “be tight to be loose,” and “relinquish control in order to gain influence.”

I began my self-study with the intention of using it to change my teaching practices. Therefore, my focus on improved learning in this study is significant. Chapter 5 reveals the first steps of this process. Improving one’s practice through reflection is an end for some types of research, yet, as discussed below, S-STEP researchers do not view personal improvement as the last step in the research process.

A transparent and systematic research process.

"Self-study requires a transparent research process that clearly and accurately documents the research process through dialogue and critique" (Samaras, 2011, p. 80). Feldman (2003) argues that to build validity and quality in self-study, the research outcomes "ought to be more than believable—we must have good reasons to trust them to be true" (p. 26).

Including a critical friend in a self-study helps to facilitate transparency. In fact, Loughran (1998) suggests that a critical friend(s) provides the researcher with alternative points of view and is an element that is crucial to self-studies.

Additionally, being systematic, having a plan and schedule, keeping an accurate audit of data collection, and sharing the analysis and evidence with others builds the credibility of a self-study (Samaras, 2011). In essence, all aspects of a self-study must be public in order for the audience to trust the interpretations and conclusions. I sought to reflect all of these qualities of a transparent and systematic research process in my study. Within this document, I intend to communicate exactly how I moved through my research process (e.g., data collection and analysis), thereby allowing the reader to accept or reject my findings based on a clear understanding of what occurred.

Knowledge generation and presentation.

"Self-study research generates knowledge that is made public through presentation and publication" (Samaras, 2011, p. 81). As noted earlier, what makes self-study different from reflection on practice is that self-study is meant to generate information about learning that can be shared so that others can scrutinize and then incorporate it into their practice (Loughran, 2004a). "Reflection is a thoughtful process, but it is something that largely resides in the individual… self-study demands that knowledge and understanding derived be communicated…

so that it might be challenged, extended, transformed and translated by others" (Loughran, 2004a, p. 25-26).

There is a commitment within self-study to make one's work public because the reader is important in influencing one's work. There must be an intention of making it useful to others (LaBoskey, 2004; Loughran & Northfield, 1998; Loughran, 2010; Samaras, 2011). Harris's (2007) efforts to develop an integrated play-based pedagogy for her preservice teacher education program is an example of intentional dissemination of new knowledge. When describing the phases of her self-study, Harris's goal was to make the insights from her study useful and informative for other teacher educators. Responding to the growing contradiction between teaching preservice teachers about play pedagogies and didactic pedagogies, Harris describes a study that encourages other teacher educators to explore the tension between student expectations, needs, and preferences.

Within this study, I responded to this research foci as I created and disseminated this document. Additionally, I have presented my tentative findings locally and at an educational conference. Therefore, I contend that the current self-study adheres to all of the methodological components described by Samaras (2011) while also reflecting S-STEP's aims to improve teacher educator's practice by meeting the call for serious research (Loughran & Berry, 2005).

Theoretical Framework of Constructivism Used in this Study

The research questions considered in this study stem from my growing understanding of constructivism and the crisis (time of intense difficulty) I experienced as I sought to incorporate constructivism into my teaching approach. The models of instruction that I examine in this self-study are based on the framework that I describe in the following paragraphs.

"Constructivism is not a theory about teaching. It is a theory about knowledge and learning… The theory defines knowledge as temporary, developmental, socially and culturally mediated, and thus, non-objective" (Brooks & Brooks, 1993, p. vii). Translating a theory about knowledge construction into a theory of teaching has resulted in many models of instruction (Tobias & Duffy, 2009a).

In response to the sentiment noted by Tobias and Duffy (2009a), I sought a general framework within which to base my investigation, allowing for focused analysis and reflection. I examined the constructivist framework that provides the backbone of the Constructivist Learning Environment Survey (Taylor, Fraser, & White, 1994), which was used in the modified Theory of Planned Behavior (TPB) (Haney & McArthur, 2002). After studying constructivist teaching examples provided by Brooks and Brooks (1993) in my graduate courses at the University of Alberta and struggling to incorporate the examples into my teaching philosophy, I sought the latest edition of their work. Because their framework is so widely recognized and continues to resonate with education researchers, I chose Brooks and Brooks (2001) as the seminal framework for this study. As a result, eight editions of their book, *In Search of Understanding: The Case for Constructivist Classrooms*, are referenced in more than five thousand publications (Altun & Yücel-Toy, 2015; Bybee et al., 2006; Kesal & Aksu, 2006; Ültanır, 2012).

Brooks and Brooks (2001) suggest that constructivist teaching is elusive, because "Deep understanding, not imitative behavior, is the goal… In the constructivist approach, we look not for what students can repeat, but for what they can generate, demonstrate, and exhibit" (p. 16). These authors suggest that constructivist teachers ignite students' interest while traditional teaching stifles that interest.

Brooks and Brooks (2001) suggest that constructivist-oriented teachers are people who keep five basic principles in mind when fashioning constructivist-learning environments. Therefore, after selecting this theoretical framework as the lens with which I intended to examine my study through (see research timeline below), I referred to the following principles as I created lessons, wrote in my reflective journal, interacted with the participants, and finally analyzed the study's findings. Through this entire process, my understanding of constructivism deepened, resulting in shifting applications of constructivist-oriented pedagogies.

Principle One: Posing Problems of Emerging Relevance (Questions that Awaken)

"Posing problems of emerging relevance is a guiding principle of constructivist pedagogy" (Brooks and Brooks, 2001, p. 35). Brooks and Brooks (2001) argue that although prior student knowledge is important and student interests must be acknowledged, few students arrive in the classroom with the desire to learn all the concepts being taught. Brooks and Brooks argue that teachers need to structure their lessons so as to awaken students' interests and help them develop an understanding of the importance of the topics. Savery and Duffy (2001) describe this as creating puzzlement. Brooks (2015) argues that "When students struggle to answer questions that are important to them or spend time solving real-life problems that emerge as relevant, they predictably work hard and want to share their findings" (p. 2).

Tobias and Duffy (2009b) suggest that a learner's goals are a central component of developing understanding. Lessons should be relevant to a student's personal motivations or touch on problems or contexts applicable to a student's life (Taylor et al., 1997).

The key to helping students see the relevance of a topic is to start with a good problem. Based on problem-solving research and Brooks and Brooks' (2001) own additions, five conditions are set with regards to good problems. First, the problem should involve students making and testing predictions; second, the problem should be solvable with inexpensive equipment; third, the problem should be genuinely complex; fourth, the problem should support a group effort, and fifth, the problem must be seen as relevant and interesting. For example, I created Predict-Observe-Explain (POE) activities for the high school science lessons (see Chapter 5 for an analysis of a POE teaching episode).

The teacher can make a difference in whether or not students find relevance in a topic. “The structuring of the lesson around questions that challenge students’ original hypotheses presents students with the initial sparks that kindle their interest” (p. 37). The teacher must balance the initial objective of the lesson and the developing interests of the students, often by asking questions students may not normally consider. Although this is not unusual in classrooms, constructivists ask questions that take considerable time to answer. Students are viewed as thinkers with emerging theories instead of as “blank slates” onto which teachers inscribe answers to numerous, specific questions.

The key point, with regards to asking good questions, is to keep in mind how the questions will affect the students. Good questions significantly impact “the depth to which the students search for answers. Posing problems of emerging relevance and searching for windows into students’ thinking… cannot be included in a teacher’s repertoire as an add-on. It must be a basic element of that repertoire” (p. 44).

Principle Two: Structure Learning Around Primary Concepts and “Big” Ideas

Brooks and Brooks’ (2001) second principle stresses that a vital element of constructivist pedagogy is the organizing of curriculum around primary concepts. Traditional classrooms present a curriculum from part-to-whole, emphasizing basic skills, whereas constructivist classrooms present a curriculum from a whole-to-part, focusing on big ideas. Brooks and Brooks

(2001) argue that "students are most engaged when problems and ideas are presented holistically rather than in separate, isolated parts" (p. 46). These authors also argue that when concepts are presented as wholes, students break them down into parts that make sense to them, while when parts of the "whole" are presented, students often do not develop an understanding of the big picture.

Anchoring learning activities within larger tasks or problems provides the student with an opportunity to realize the purpose of the activity, beyond completing a task because "it is assigned." Anchoring provides an opening for the learner to see that there is a greater purpose beyond the isolated task (Savery & Duffy, 2001).

Organizing information in conceptual clusters is one way to present a curriculum from whole-to-part. For example, in the Science 10 curriculum, Alberta Learning (2016) created a program of studies built on four foundations: developing an understanding of science, technology and society; constructing knowledge; developing skills; and encouraging the development of a scientific attitude. These foundations represent the essence of this science program, the big ideas. Although the specific outcomes may be viewed as prescriptive, the program rationale and teaching approach provide a big picture through which a teacher can build a course. The Program of Studies provided by Alberta Education (2016) models a method of organizing content in conceptual clusters that teachers can follow.

Brooks and Brooks' (2001) final argument is that designing curriculum via conceptual clusters, problems, questions, or discrepant situations alone will not automatically engage the students. "The teacher's ability to foster collegial interaction among students, mediate the emergence of relevance, and match curricular questions to the student's present suppositions encourages the student's search for understanding" (p. 58).

Principle Three: Seeking and Valuing Students' Point of View

This principle highlights the need to provide opportunities for the students to utilize their prior understandings and express their opinions. Brooks and Brooks (2001) argue that seeking to "understand students' points of view is essential to constructivist education…. Each student's point of view is an instructional entry point that sits at the gateway of personalized education" (p. 60). When comparing traditional classrooms with classrooms that reflect more constructivist pedagogies, Boaler (2003) found that, "Whereas the teachers in the traditional classes gave students a lot of information, the teachers of the reform approach chose to *draw* information out of students, by presenting problems and asking students questions" (p. 4, emphasis in original). Ackermann (2004) also contends that identifying prior knowledge impacts the teacher and learner significantly; as he explains, students do not simply absorb what is taught. Instead, they interpret, or translate, the learning experience in light of their knowledge and experiences.

In science education, knowing how to teach science means understanding what the students have already learned as well as their possible misconceptions (Appleton, 2003). A constructivist teacher must understand the student's scientific knowledge in order to facilitate growth (Brooks & Brooks, 2001).

Brooks and Brooks (2001) find value in Vygotsky's (1978) focus on social interactions, for he believed that a learner's prior knowledge in a learning situation is important. As noted in Chapter 3, Vygotsky proposed that an individual's knowledge is shaped by social interactions. By paying attention to the zone of proximal development, a constructivist teacher can recognize the understandings that the student brings to the classroom and may therefore be able to provide the guidance to encourage growth beyond what the student could accomplish independently.

Principle Four: Adapting the Curriculum to Challenge Students' Suppositions

"All students, irrespective of age, enter their classrooms with life experiences that have led them to presume certain truths about how their worlds work. Meaningful classroom experiences either support or contravene students' suppositions by either validating or transforming these truths" (Brooks & Brooks, 2001, p. ix). Regardless of how charming the teacher is, many students will find little meaning in lessons if their suppositions are not addressed. Altun and Yücel-Toy (2015) point out that it is the teacher's role as a facilitator to guide learners as they "pass from an initial stage of drawing on their own experiences through active learning to another in which they create their own concepts of the subject knowledge" (p. 249). Therefore, a teacher must seek out and respond to the student's understandings as the student grows.

Although this principle is based on Piaget's theories of developmental stages of children's thinking, Brooks and Brooks (2001) warn against labelling students for the purpose of providing tasks that match students and the cognitive demands required of a given task. They believe that this will limit the student, for "at any one point in time, people use several cognitive structures" (p. 71). Therefore, while constructivist teachers should understand the cognitive demands of a given task, they should provide openings for students to reveal their ideas, and then adapt the lessons to match students' suppositions.

"When, how, and upon which content a teacher asks students to engage in such activities is a dynamic decision made by the teacher, and informed by an understanding of the student's suppositions. Each answer a student offers to a teacher's questions reveals suppositions the student is making about the issue at hand. Knowing the student's suppositions enables the teacher to adapt the curriculum to address them" (Brooks & Brooks, 2001, p .74).

Principle Five: Evaluating Students' Learning in the Context of Teaching

Constructivist teachers, Brooks and Brooks (2001) argue, should be cognitively linked with their students such that an assessment provides an understanding of what students are thinking during lessons, allowing the teacher to guide student growth. In a traditional classroom, the assessment occurs after a task has been completed. The typical intent is to measure how well a student is able to reproduce the correct answer. Black and Wiliam (2009) suggest a framework for formative assessment that reflects, in part, the constructivist ideals mentioned above. These authors contend that through dialogue student learning follows "Vygotsky's principle that ideas appear first in the external "social" plane, then become internalized by the individual" (p. 19). Classroom communications should allow for continuous formative assessment.

"Constructivist teachers don't view [the] assessment of student learning as separate and distinct from the classroom's normal activities but, rather, embed assessment directly into these recurrent activities" (Brooks & Brooks, 2001, p. x). One way to do this is through discussions. Black and Wiliam (2009) suggest that through dialogue, a teacher may use cognitive conflict to stimulate learning. In contrast to providing answers to students, the give-and-take of formative assessment encourages knowledge creation in a constructivist manner. In other words, constructivist teaching and assessment include socially relevant interactions (Cowie, 2015).

Savery and Duffy (2001) advise teachers to resist providing their opinions. Instead, they suggest that teachers should merely affirm student responses. This provides an opportunity for the students to understand that the teacher values their current knowledge and is willing to support their growth. "'Rightness' and 'wrongness,' then, relate as much to the filtering system used by adults to sort through students' responses as to the students' conceptions of the issues and questions to which they respond. To teachers, inaccurate responses are 'wrong.' To students, inaccurate responses often represent the state of their current thinking about topics" (Brooks & Brooks, 2001, p. 87).

Theoretical Framework Usage

Beginning this study in a liminal state, I sought a foundation. I used Brooks and Brooks' (2001) principles as a theoretical foundation throughout the study, creating the lessons, reflecting on my teaching, and analyzing the findings.

Teaching Beliefs and the Alignment of Teaching Practices

A teacher's beliefs matter. There is a correlation between what teachers believe and their actions in the classroom (Haney, Lumpe, Czerniak, & Egan, 2002; Pajares, 1992). Also, according to Bandura (1986), the beliefs people hold are the best indicators of the decisions they make through their lives. A teacher's beliefs are important indicators of a process of change (Bybee, 1993; Tam, A., 2015; Turner, Warzon, & Christensen, 2011) and strongly affect the way a teacher interprets education reforms (Philipp, 2007). Examining the connection between my beliefs and practice is important to this self-study. The topics in the literature about the relationship between teacher beliefs and practice relate to constructivism, curriculum, science education, inquiry, the nature of science, reform strands, science, technology, society, and teaching and learning (Savasci-Acikalin, 2009). This study focuses on my teaching beliefs that relate to constructivism and the relationship that those beliefs have with classroom practices.

My goal is to align my beliefs and practices; however, there is literature that suggests that beliefs may not lead to practices (Chen, 2008; Philipp, 2007; Raymond, 1997) and that changing a teacher's belief may not result in a change of practice (Shirrell, Hopkins, & Spillane, 2018). Nevertheless, evidence suggests that encouraging teachers to adjust their beliefs and practices

(Shirrell et al., 2018), for example, on-the-job exposure to colleagues' teaching practices, is effective.

Theory of Planned Behaviour: Description and Critique

Ajzen (2005) asserts that humans typically behave in a sensible manner by considering the implications of their actions based on the information available to them. Founded on that assumption, Fishbein and Ajzen (1975) created the theory of planned behaviour (TPB). With this theory, Fishbein and Ajzen endeavoured to disentangle people's beliefs from their practices. Key to the TPB is the behavioural intent of the individual. Intentions, Ajzen (1991) argues, are formed by two social cognitive variables: attitudes toward the behaviour and a subjective norm. These are influenced by one's perception of how much control one has over a situation. In other words, the intent is influenced by two factors: the prospect that the behaviour will have an expected outcome, and a risk-benefit analysis of that outcome. Ajzen (2005) later described intentions, and the resulting behaviours, as "a function of three basic determinants, one personal in nature, one reflecting social influence, and a third dealing with issues of control" (p. 117).

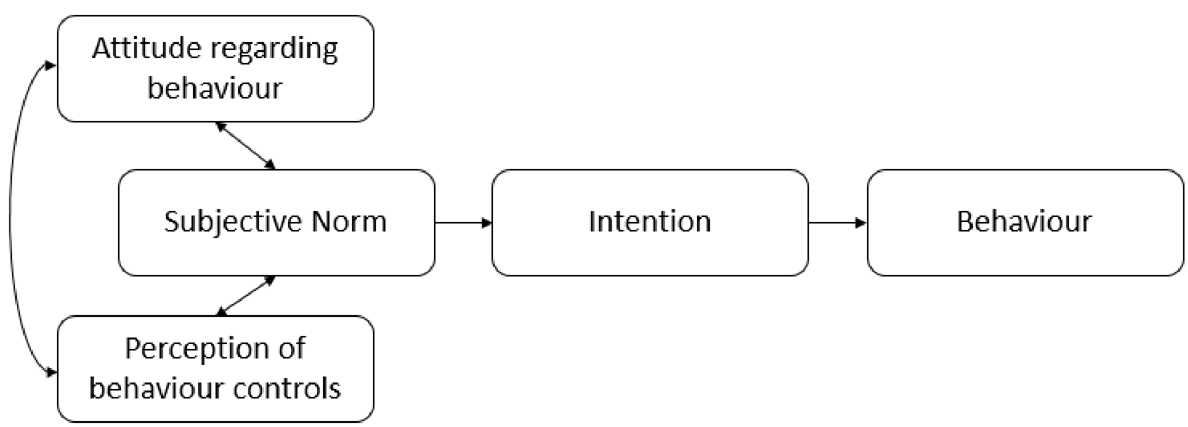

Figure 2. A Simplified Schematic Representation of the Theory of Planned Behavior. This figure shows that a behavioural intention is an amalgamation of the attitude toward the behaviour, a subjective norm, and a perception of behavioural control. The intention is the immediate precursor of behaviour. Adapted from Theory of Planned Behavior in *The Theory of Planned Behavior*, by Ajzen, 1991, Organizational behavior and human decision processes, 50(2), 182 and Theory of Planned Behavior Diagram, by Ajzen, 2006, accessed from https://people.umass.edu/~aizen/tpb.diag.html.

The TPB reflects a linear cause-and-effect behaviourist approach (Haney & McArthur, 2002) that does not account for moral obligations (Alleyne & Phillips, 2011) or a teacher's beliefs with regards to constructivist principles (Connell, 2007). When examining a change in teacher's beliefs and practices, Calderhead and Shorrock (2003) found that change happens when conditions are present that encourage teachers to reflect on, question, and explore their beliefs. Additionally, the three components of the TPB do not influence teachers' intentions equally. For example, when teachers make teaching decisions, Lee, Cerreto, and Lee (2010) found that the attitude towards the behaviour has twice the influence of the subjective norm and three times the influence of the perceived behavioural control. Others question the simplicity, validity, and utility of the TPB (Sniehotta, Presseau, & Araújo-Soares, 2014). Ajzen (2015) responded to criticism from Sniehotta et al., by defending his position by suggesting "Some of their arguments are misguided, resting on a poor understanding of the TPB and of the nature of psychological research, while others are illogical or patently wrong" (p. 1). Nevertheless, the questions raised regarding the limited predictive validity of the TPB should be kept in mind when examining this theory.

Haney et al. (2002) sought to find a connection between teachers' beliefs about teaching science and their ability to implement that science instruction. They found that teacher reflectivity significantly impacts the relationship between teachers' beliefs and practices. In fact, belief is not the key indicator of change; reflection is (Haney et al., 2002). In their study, belief without reflection did not result in the intended teaching behaviour. Based on these results Haney and McArthur (2002) argue that Ajzen's TPB must include a feedback mechanism. Therefore they modified the TPB by specifically accounting for reflection and a constructivist approach.

Haney et al. (2002) propose that there is a feedback system where belief and action influence one another. In other words, beliefs lead to actions, and the beliefs are subsequently affirmed or repudiated following mediation in a belief-action-belief process (see Figure 3). Therefore, all teacher professional development, including this self-study, should include a process of identifying, discussing, and reflecting on the belief-action-belief relationship (Haney et al., 2002).

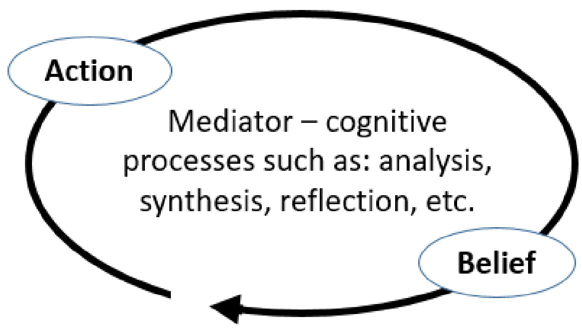

Figure 3. Belief-Action-Belief Feedback System. Haney's (2002) feedback system that illustrates how beliefs lead to actions, and how those actions lead to the "creation of new, reconstructed, or reaffirmed beliefs" (p. 12). Adapted from belief to action to belief feedback system in "From Beliefs to Actions: The Beliefs and Actions of Teachers Implementing Change," by Haney et al., 2002, *Journal of Science Teacher Education, 13*(3) p. 12.

The current research reflects this commitment to reflection. As discussed in detail in Chapter 4, I identify my teaching beliefs through narrative, reflection on my teaching practices and discussions with critical friends and, finally, I reflect (through journaling and thoughtful analyses) on the connection between my beliefs and actions.

Modified Theory of Planned Behaviour

Haney and McArthur's (2002) modified TPB allows researchers to examine a hierarchy of beliefs. The extent of the congruence between a teacher's beliefs and teaching practices is determined on two different levels: core beliefs and peripheral beliefs. An examination of the congruency within and between levels of beliefs and practices can be used to guide future practice.

The modified TPB reflect clusters of beliefs. Haney and McArthur built on the concept proposed by Rokeach's (1968), who "compared the belief structure to an atom and explained that some beliefs form the nucleus in a central-peripheral system" (p. 786). In the modified TPB, the central beliefs, or core beliefs, are the most important and hold the peripheral beliefs together to create a belief structure. A teaching constructivist belief structure is similar to a nucleus, as seen in Figure 4.

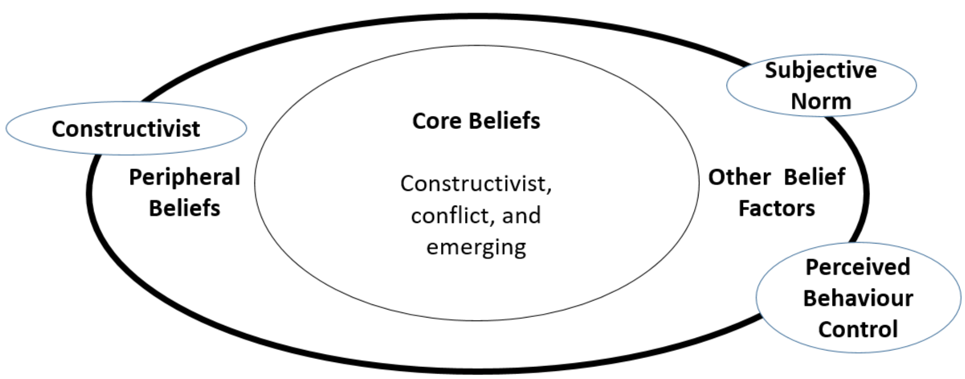

Figure 4. Constructivist Belief Structure of the Modified Theory of Planned Behavior

Core beliefs are constructivist beliefs that are both stated and enacted. This is an indication of intracongruency. In accordance with the modified TPB, core beliefs are further separated into three groups: constructivist core beliefs, emerging core beliefs, and conflicting core beliefs. Constructivist core beliefs are enacted beliefs that are congruent with constructivist teaching principles. Emerging core beliefs are enacted beliefs that are congruent with general teaching principles, yet are not congruent with constructivist practice. Conflicting core beliefs are enacted beliefs that are incongruent with constructivist teaching principles.

Peripheral beliefs are constructivist beliefs that are stated, but not enacted. Teachers may or may not be aware of the lack of congruence between constructivist beliefs and practice. Identifying these beliefs makes it possible to put them into action. Haney and McArthur (2002) place the subjective norm (socially influenced beliefs regarding people interested in the behaviour) and the perceived behaviour control in the peripheral belief of the modified TPB, for these beliefs have less impact on behaviour. For example, in the high school setting I was impacted by curricular restrictions (perceived behaviour control) and, as a teacher educator, I am impacted by my relationships with my education colleagues (subjective norm).

The present study differs from Haney and McArthur's (2002) research in two ways. First, the modified TPB analyzed enacted beliefs associated with Taylor, Fraser, and White's (1994) constructivist model. My study applies Brooks and Brooks' (2001) constructivist model as a lens to organize and analyze my enacted beliefs (see Data Collection and Data Analysis sections below). I selected Brooks and Brooks as the established set of constructivist principles instead of Taylor et al. (1994) because I did not want to confine myself to a social constructivist model. The second difference between my study and Haney and McArthur's is the method of data collection and analysis. Haney and McArthur's work involves an external observer analyzing the teachers' reflective journals, lesson plans, portfolios, and interviews. I apply their theory within this self-study.

My alternative use of the modified TPB parallels Connell's (2007) usage, in that she also applied the theory within a self-study and chose an alternate constructivist framework. Connell used Hammerman's (2006) principles of inquiry-based instruction to investigate her belief-practice congruency, whereas I investigated my belief-practice congruency based on Brooks and Brooks' (2001) principles of constructivist teaching. In conclusion, Haney's modified TPB (Haney et al., 2002; Haney & McArthur, 2002) is a plausible framework for the analysis of my teaching practices.

Research Timeline

Pilot 1	Pilot 2	Lesson plan rewrite	High school teaching	Teacher education teaching
Spring 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016

Figure 5. Research Timeline

This current self-study of teacher education practices included at least four significant periods of research prior to consolidating the research in this document. Figure 5 illustrates these periods of time.

Research Pilots

During the spring 2014 and 2015 semesters, I conducted research pilots to begin my fieldwork. The purpose of the pilots was to create activities and lesson plans for subsequent research. I taught the environmental unit in the Science 10 course at a local high school. During the first pilot, I began to create lessons based on Clement's (Clement, 2008b; Rea-Ramirez et al., 2008) Model-Based Teaching (MBT) strategies. I developed lessons that employed concept maps (Novak & Cañas, 2008) as a key teaching tool. As described in Chapter 2, I experienced significant internal and external residence to MBT. These lessons did not become part of my self-study, yet I used the first pilot lesson plans as a foundation for the second pilot.

The intention of the second pilot was to create lesson plans and teaching resources that I would subsequently use in my dissertation (see Appendix B for an example of a lesson plan). As described earlier, the pilots resulted in lesson plans that supported traditional teaching. My teaching practices did not match Clement's (Clement, 2008b) intentions. Again, the internal and external resistance to my teaching strategies significantly contributed to my desire to shift my teaching practices (see Chapter 2).

Lesson Plans Rewrite

The second pilot's lesson plans became the starting point for the creation of high school lesson plans in which I sought to embed constructivist-oriented pedagogies. The course content did not change between the pilot and the rewrite of the lessons, but the teaching perspective did. The MBT lessons were written in a direct instruction or traditional form (Berg & Clough, 1990). I sought to edit the lessons using Brooks and Brooks (2001) suggestions about constructivist teaching. This change was difficult for me; although I altered the lessons, intending them to allow me to use constructivist-oriented strategies, the structure of the lesson plan remained the same. As I note on the second page of my Reflective Journal, "Every time I examine the Science 10 lesson plans, I see ways in which I plan to teach in a didactic manner even though I intend to use an interactive, student-centred style."

The overall purpose at the time of the rewrite was, "to increase the student interaction with content and in the process reduc[e] the passive learning the students may be accustomed to" (Reflective Journal, p. 3).

High School Teaching Experience

In the spring of 2016, the edited lessons plans formed the basis of the high school science teaching experience (see Appendix C for an example lesson plan). I intended to incorporate constructivist pedagogies, thereby producing lessons that aligned my teaching beliefs and practices. For example, I planned activities that allowed the students to be part of the process, not passive recipients (e.g., Appendix C, activity 2), including opportunities for students to question their personal understanding through one-on-one and small group interactions with their classmates (e.g., Appendix C, activities 3 & 4).

Prior to teaching any lessons, I had begun to visit the science classroom to build familiarity between the students and myself. Although I was familiar with the teaching and administrators at the high school, the students did not know who I was. These visits also allowed me to identify any unique procedures or aspects of the school culture that may impact my time in the classroom there. For example, the cooperating teacher conducts a worship activity at the beginning of the school day, usually she read a one-page inspirational story.

One significant change that occurred between the pilot and the self-study research had to do with the participating high school switching from a two-semester-based class schedule to a four-quarter-based teaching schedule. The impact on the classroom was that lessons that were planned to occur on subsequent days occurred on the same day, both in the morning. The science lessons were taught in the first and third blocks of the student's schedule. Thus, I taught their first class, they attended another class for 80 minutes, and then returned for their third class. Friday's classes were 60 minutes long. Over the 18 class periods I taught, 67 teaching activities occurred. The teaching episodes examined in Chapter 5 are drawn from these activities as well as from my interactions with the students between class periods.

The schedule change may have impacted the students' perception of my lessons. First, the students expressed to me a general discontent regarding the quarter-based schedule and second, although I taught the same number of classes during the pilot, the period of time (calendar days) that I taught was reduced and there was a concurrent reduction in opportunities (evenings) for the students to study or work on assignments.

Teacher Education Teaching Experience

During the fall semester of the 2016/2017 academic year, following two months of reflection, I began to integrate constructivist-oriented pedagogies into a science teacher education methods course. I began by rewriting the course syllabus. The first paragraph describing the teaching/learning models planned for the course reflects my constructivist-oriented intent:

> The application of inquiry-based and constructivist approaches has been encouraged in the reform of the science curriculum in many countries including Canada. Although traditional teaching methods will be examined, this course will emphasize student-centered, inquiry-based, and constructivist approaches. The activities and strategies implemented by the instructor will model these approaches. (EDCI 468 – Course syllabus, p. 2)

I then began to alter the lessons to reflect a constructivist-oriented environment (see Appendix D for a lesson plan example). That is, I sought to plan lessons that might engage the students in the learning process. Keeping in mind to plan for opportunities that encouraged the students to make sense of new experiences based on prior knowledge, I used Brooks and Brooks' (2001) principles and their suggestions for "Becoming a Constructivist Teacher" (pp. 101- 118) as a guide during the lesson planning process. I identified my content outcomes and then created activities that included constructivist-oriented teaching practices. The lesson plan (Appendix D) includes an example of this. During the activity, Becoming an Effective Science Teacher (Appendix D), instead of telling the students about the research regarding effective science teachers, I planned to encourage my students to examine and share their experience of effective science teachers.

Five students enrolled in the Fall 2016 Curriculum and Instruction teacher education course. Each of these university students chose to participate in this study by providing data. The students gave permission for me to collect data from notes I made following classroom discussions and notes I made following a post-course interview. Only two students participated in a post-course interview.

Research Setting and Participants

The setting for this self-study was a local high school science classroom (Grade 10) and a teacher education course (EDCI 468 - Curriculum and Instruction (C&I) in Secondary Science) at the university where I am employed. The 19 participants in the high school science course were drawn from a school in the teaching district where I am employed. I taught one unit of study for 18 class periods. The university participants, who came from the teacher education program, enrolled in a science C&I course I taught. Five preservice teachers volunteered to provide data (dialogue within the classroom), and two participated in post-course interviews (transcribed) focused on the C&I course and the effect that the course had on their first practicum experience.

Ethical Considerations

All participants and the parents/guardians of the high school students were informed about the purpose and study methods of the research. They were also informed that their participation was completely voluntary (and where required needed parental consent) and that they could quit and have their data withdrawn at any time during the study. Measures were taken to ensure the protection and privacy of the participants. Data remained with the researcher and was kept confidential. All names were removed and replaced with pseudonyms. This research received approval from the University of Alberta Research Ethics Board (see Appendixes E, F and G for more details).

Data Collection Methods

This section outlines the data collection methods employed to answer the research questions. The questions ask for a deep examination of my current teaching practices and how I changed my teaching approach to better align my beliefs and practices. To answer these questions, I began by examining my education-related experiences prior to the current study. Through a narrative process, I examined events that shaped my teaching approach and established my current educational beliefs. After collecting data to identify my beliefs, I collected data about my teaching practices over the research period.

Table 2

Data Sources and Date of Data Collection

Data	Date of collection
High school lesson plans	Spring 2014 – Spring 2016
My Educational Life History	Spring 2015 – Spring 2017
Researcher's Reflective Journal	Fall 2015 – Fall 2018
Critical friend interviews	Fall 2015 – Fall 2018
Video recordings: High school lessons	Spring 2016
High school student interviews	Spring 2016
C&I instructor's documents	Fall 2016
Education student interviews	Fall 2016

Table 2 lists the data and date of collection. The data includes My Educational Life History (see Chapter 2), video recordings of the high school lessons, my reflective journal, student interviews, and my reflections after I conducted the critical friend interviews. The next section describes the data sources and how I collected them. The methods that I used to analyze the data are described in the following section. My Educational Life History

My Educational Life History (see Chapter 2) describes the influences that shaped my teaching approach and stimulated my paradigm change. Through the narrative process modelled by Magee (2009) (see Chapter 1 for description), I examined how I came to view myself as a living contradiction, and I identified aspects of the teaching practices I brought to teacher education. I began writing this narrative immediately after identifying the self-study methodology (Spring 2015) as appropriate for my research. First I created my Educational Life History Timeline (see Appendix A for details). Based on this timeline I began writing the narrative, guided by three questions: first, what occurred during the experience; second, what were my responses to this experience; and third, how did the experience contribute to my understanding of teaching. Throughout the study, I continually revisited and expanded upon the narrative.

Researcher's Reflective Journal

My reflective journal became the most significant source of data. The journal is not a complete record of events, but a description of the significant activities, student responses, and possible implications concerning my changing teaching practices. As this journal was a major source of insight into my paradigm change, it was not simply a written record of events; it contained positive and negative incidents that affected my perception of good teaching. For example, when I identified an activity that did not meet my constructivist-oriented goals (i.e., Brooks and Brooks' principle-based goal), I reflected on alternative strategies that I could implement in the future to meet those goals. I also reflected on why I did or did not use a constructivist strategy. For example, I reflected upon possible subjective norms or perceived behavioural controls that influenced my actions.

The first set of reflections I created described my experience as I revised the direct instruction lesson plans. The first set of daily reflections began during the high school teaching experience. Additionally, I made daily reflections as I became more comfortable incorporating constructivist-based strategies into my teacher education courses. For example, I explicitly modelled (Loughran & Berry, 2005) a 5E lesson (Engage, Explore, Explain, Elaborate, and Evaluate). Prior to and following each class in the teacher education course, I made journal entries. My final set of reflections focused on the two preservice teachers who consented to interviews.

Student Interviews

Two preservice teachers who completed my university education course volunteered to participate in an open-ended interview. The remaining students declined to be interviewed. Although I did not read the questions to the preservice teachers, three general questions guided the interview process: 1) How was the university course you took from me different from other education courses? 2) Do you feel that this style of teaching would work in science courses? 3) Were you able to use this style of teaching in your practicum? Following these opening questions, I used the principles in Brooks and Brooks (2001) to probe for further understanding of how the constructivist concepts exemplified during my course impacted my participants' practicum experiences.

Critical Friend Discussions

Three critical friends were involved in this study: 1) the principal (CF1) of the high school where I collected data for this study, 2) the Dean of the School of Education (CF2) where I am employed, and 3) my graduate supervisor (CF3) at the University of Alberta. I had discussions with these critical friends after they either viewed my classroom instruction, read parts of my dissertation, or after I verbally described a teaching incident or dilemma. My goal in these discussions was to look for alternative perspectives.

The focus of the discussions was the change in my teaching strategies and the ramifications of that change. I took notes during all discussions. Immediately after the meetings, I recorded these notes and descriptions of the discussions in my reflective journal. Later during the same week, I reviewed the journal entries and added further reflections. I did not record these discussions.

Video Recordings of My High School Instruction

During the high school science course, 17 video recordings of my instruction were created. The video camera was focused on me, the instructor, which provided rich data with which to check for congruence between my constructivist beliefs and actual teaching practice.

Following the teaching experience, I added significantly to my reflective journal after examining the video recording multiple times. I watched all of the recorded lessons and viewed them again, paying particular attention to how I incorporated the constructivist approach advocated by Brooks and Brooks (2001). An analysis of these recordings is discussed below.

Lesson Plans and Supporting Documents

All the documents that I used to plan and administer the courses became sources of data. I also created a set of reflections that focused on the differences between the pilot and the lesson plans that I used to teach the high school lessons.

Teaching Episodes Timelines

The findings are presented according to Brooks and Brooks' (2001) principles. As a result, they are not presented chronologically. As change is temporal, it may be helpful to the reader to develop an understanding of when I conducted the teaching episodes examined in Chapter 5. Figure 6 (high school teaching experience, Spring 2016) and Figure 7 (university teaching experience, Fall 2016) illustrate the timelines when data was collected for each of the teaching episodes examined.

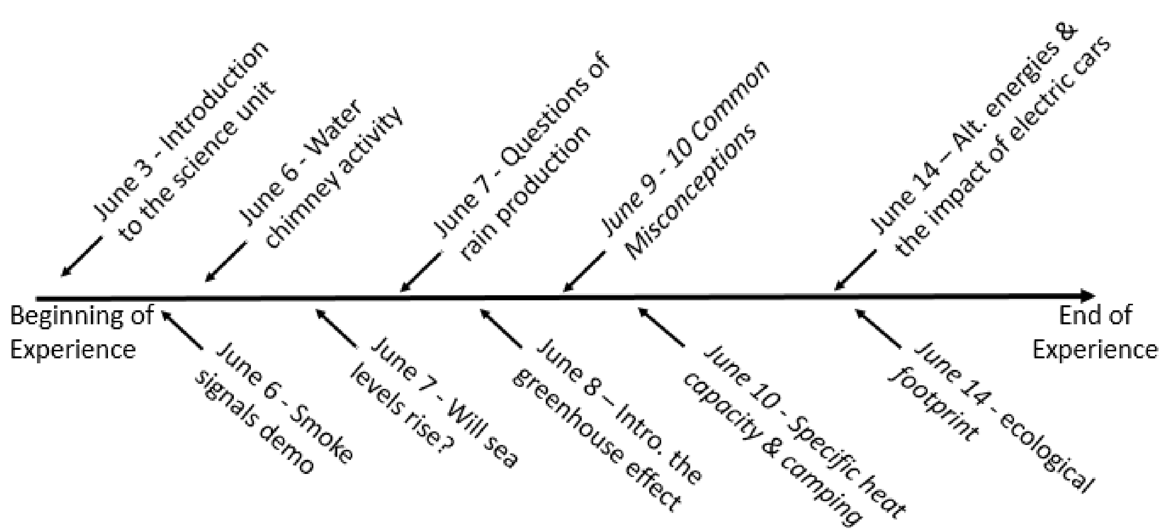

Figure 6. High school teaching episodes timeline. There were 67 teaching activities. Ten were selected for analysis. See the Data Analysis sections for details.

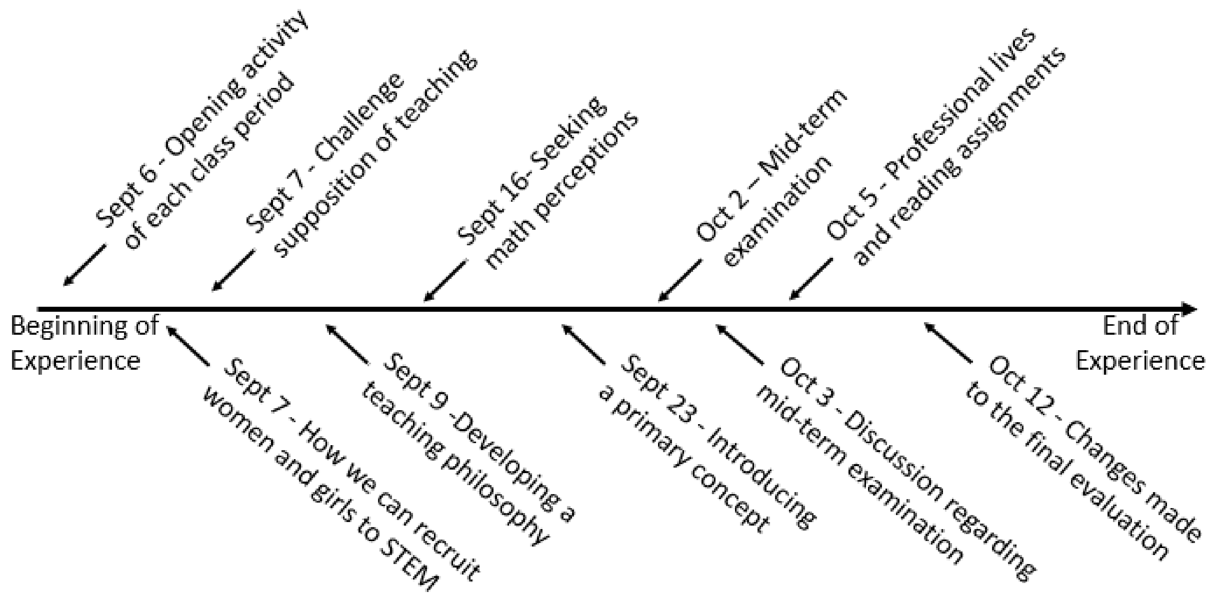

Figure 7. University Episodes Timeline. This timeline illustrates the dates and order of the university teaching episodes that are examined in Chapter 5.

Data Analysis

The data analysis provided information that I used to answer the research questions: first, what were my teaching practices, and second, how could my practice more closely align with my emergent beliefs about teaching and learning? Answering these questions informed my overall purpose, which was to improve my teacher education practices.

The bulk of the analysis (see Chapter 5) involved using Brooks and Brooks' (2001) principles of constructivist teaching as an analytic lens. Chapter 5 looks at my congruent and incongruent teaching practices and compares what occurred in the classroom (behaviour) with what I intended to do (plan). Finally, I used the modified Theory of Planned Behavior to summarize the analysis of my teaching practices. The final product is a figure that illustrates my core beliefs surrounded by my peripheral beliefs. That is, in the diagram, my core beliefs are represented by congruent behaviours that align teaching beliefs and practices, and my peripheral beliefs are represented by incongruent behaviours where beliefs and practices are not aligned. The illustration provides a stimulus that guides the reflection and conclusions found in Chapter 6.

Mechanics of Working with the Data

This study included multiple data sources. The large amount of data that I collected was daunting. In the following sections, I describe the process of analysis (coding) for each data source. This analysis enabled me to determine which teaching practices were congruent with my beliefs and which were incongruent with my beliefs.

Selecting teaching episodes to include in this study became the next step. For example, during the high school teaching experience I planned and implemented 67 teaching activities, but I reported on only 10 of these activities in Chapter 5. First, I chose all of the events that represented a teaching episode coded for the specific constructivist principle upon which I focused. Second, from these events, I chose the teaching episodes that made a significant impact on me. That is, I made multiple entries in my Reflective Journal and later reflected further upon these teaching episodes as I created NVivo memos (seven- to 14-page documents for each Brooks and Brooks' principle) in which I sought to identify congruent and incongruent teaching practices. In other words, I chose the examples that revealed multiple coded data, from multiple data sources. This also allowed for deeper analysis. There are many episodes that I did not include in this dissertation. I selected only the events that had enough data or data sources for that specific constructivist category.

The process of coding and categorizing the data is found in the next section of this chapter.

Researcher's Reflective Journal

I used a coding process described by Bogdan and Biklen (2007) to analyze data recorded in the reflective journal. These researchers contend that coding information is a technique consistently used in qualitative research in order to find meaning within data. I found meaning by coding the reflective journal's content according to categories, themes, and patterns that would shed light on the research questions. For example, the reflective journal became a significant source of data to examine my effort to align my teaching beliefs and teaching practices.

I began the procedure, described by Bogdan and Biklen (2007), by intentionally organizing the data and then reading the data without interruption. Prior to reading, I generated a list of preliminary coding categories (see Appendix H). The original category headings included Brooks and Brooks' (2001) principles of constructivism and their description of traditional and constructivist teacher characteristics. During the initial reading, I modified this list by adding coding categories that emerged. It is normal for topics and patterns to emerge during this initial process (Bogdan & Biklen, 2007).

The qualitative researcher should acknowledge that "[d]ifferent theoretical perspectives that researchers hold shape how they approach, consider and make sense out of the data" (Bogdan and Biklen, 2007, p. 168). The initial categories, chosen for this study, allowed for a search for a constructivist-learning environment. Applying these category headings allowed for congruency in analysis and reporting with data gathered from the critical friend interviews and student-teacher interviews. The consistent use of the categories also made it possible to coordinate the secondary data sources including video recordings of my high school instruction, my lesson plans, and supporting documents (student handouts). This facilitated data triangulation, meaning multiple sources of data informed the analysis, allowing for increased validity. During the initial reading, I added two categories: one for data about how I reacted and how students reacted to the new teaching strategies, and one that includes data about how I plan to implement these strategies in the future.

In order to maintain an organized coding system, I used a computer software package designed for qualitative data analysis. I selected NVivo based on the literature that describes how NVivo successfully facilitated the analysis of large volumes of data. All data used in the analysis and subsequent interpretations produced are contained in the NVivo files. The codes and source documents are linked, which allowed me to move smoothly between each coded section and the source documents. Brooks and Brooks (2001) provided the foundational constructivist lens and the source of the initial categories used in the data analysis. In other words, this lens establishes clarity with which to begin the analysis of the data. I chose to use this framework to create the categories of analysis and supplemented the coding with a set of open codes (see Appendix H) that developed as I examined and reexamined the data. Table 3 illustrates how I used open codes that originated outside Brooks and Brooks' (2001) principles.

Table 3

Example of Coding Categories and Analyzed Data

Name	Description	References	Example
Resistance to change (Sub-category: Researcher's resistance)	Resistance to change from traditional teaching pedagogy to a constructivist-oriented pedagogy	28	Reference 1: I still struggle with the planning that allows for student-led interactions. During the planning sessions where I plan for activities in which students discuss content in small groups, I still feel that I am planning to "kill time." Reference 2: My planned timing was thrown off immediately as a student-led discussion of the worship quote (planned for 2-3 min) grew into a 15-min discussion where we examined how teaching positive character traits should occur in a science classroom.

Note: Table 3 contains two of the 28 coded references for the sub-category researcher's resistance. The broader category, resistance to change (104 references), includes researcher's resistance, student resistance, and institutional resistance.

After coding all documents, I spent two months reading the content, which by that time was organized in specific categories. After repeatedly reading each coded category, I created a memo (Corbin & Strauss, 2008; Lempert, 2007) (see Appendix I for example) for each category (documents seven to 14 pages in length). I also added relevant literature to each memo. These provided a place where I recorded my thoughts as I read and reread the coded data, recording how my thinking evolved with regards to that specific category. I added relevant information from related literature, creating 17 memos. I spent the majority of my time examining the coded data relating to Brooks and Brooks' (2001) principles of constructivism; therefore memos related to these principles were longer. The memos then provided the primary source from which I identified examples of congruent or incongruent constructivist-oriented teaching episodes.

My Educational Life History

I used the category headings listed in Appendix H to code my Educational Life History narrative (see Chapter 2). This provided consistency of analysis as I gathered specific data from my narrative. I focused on the categories that help reveal how my experience reflected environments that were consistent with either a traditional understanding or a constructivist-oriented understanding of teaching and learning.

Preservice Teacher Interviews

The interviews with the preservice science teachers took place after they completed the teacher education course I taught, after they completed their first practicum, and after I had submitted grades for the education students. The constructivist principles in Brooks and Brooks

(2001) provided a framework for the subsequent interviews. The interviews were recorded. After a transcriber converted the audio recording of the interview into text, the data was imported into NVivo 11. As described earlier, I analyzed the text I followed using coding procedures suggested by Bogdan and Biklen (2007).

I sought to plausibly integrate the data by consistently applying the coding categories I had established earlier. These categories are described above in the researcher's reflective journal section and in Appendix H.

Critical Friend Discussions

As discussed in the methodology chapter, self-study of educational practices is more effective when data originating outside the self is included. The discussions with my critical friends ensured that my understandings were reviewed by trusted colleagues. Following the discussions, I recorded my reflections in my journal. These reflections highlight statements made by my critical friends, and my reactions to the perspectives that were different from my own. I analyzed these reflections in the same way as described earlier.

Lesson Plans and Student Handouts

I examined each document employed during the teaching experiences multiple times before creating entries in my reflective journal. The analysis developed as I read the documents and viewed the corresponding video recordings, or reread the corresponding journal entry (see Appendix J for an excerpt). During the analysis, I aimed to identify data that reflected a traditional or constructivist understanding of learning, with the purpose of providing insight into my journey as I aimed to change my teaching practices. As with the data discussed earlier, consistent coding categories were used while Brooks and Brooks (2001) provided the lens through which the information was viewed.

Limitations of the Study

I am aware that this self-study may be viewed as navel-gazing, as per the concerns of Loughran and Berry (2005; 2007), for I did use my own lens (beliefs/biases) as I collected and analyzed the data. It is important to anticipate the possibility of bias to reduce the impact of biases (Ross, 2014). I am well aware, and my readers should be as well, that any bias I brought to this study or developed during my graduate studies has impacted my interpretation of the findings.

Samaras's (2011) self-study methodology acknowledges the possibility of bias and suggests ways to create quality, reliability, and validity. The steps taken to reduce bias in this study include the three key critical friends who reviewed my research process and data interpretations. CF1 provided high school context-specific analysis, CF2 provided teacher education context-specific analysis, and CF3 provided ongoing guidance throughout the self-study process, often with regards to my growth in understanding constructivist pedagogies. These individuals significantly altered my perspective as I conducted this study.

Other possible issues with the data collection arise in relation to the student interviews, which I conducted after submitting course marks; however, the students may have provided responses that they believed I valued. Additionally, a confounding influence may have to do with the preservice teachers' view of constructivism, which is filtered by their beliefs and prior knowledge (Haney & McArthur, 2002). For example, past science learning experiences, positive or negative, would influence how the students related to the way I introduced constructivism. Some students may have been looking to change the learning environment.

Chapter 5

Results and Findings

> "[We] do not, however, imply that analysis and interpretation rise only from the data and not from the perspectives the researcher holds" (Bogdan & Biklen, 2007, p. 168).

Introduction

The purpose of this chapter is to present the findings that answer the following questions: 1) What were my teaching practices, and 2) How can my practice more closely align with my emergent beliefs about teaching and learning? The data that informs this study was collected before, during, and after the high school and university teaching episodes. These data sources include digital recordings of my high school teaching, a reflective journal, an Educational Life History narrative, student interviews, critical friend discussions, lesson plans, and student handouts. These findings form the basis for the discussion and reflection in Chapter 6.

The presentation of findings reported below is organized according to the constructivist-oriented teaching principles described by Brooks and Brooks (2001). That is, the findings are organized into five sections: posing problems of emerging relevance to students, structuring learning around primary concepts, seeking and valuing students' point of view, adapting classroom activities to challenge students' suppositions, and assessing student learning in the context of teaching. The heading for each teaching episode reflects my analysis of whether my teaching practice was congruent or incongruent with my emerging constructivist beliefs. The categorization of congruency is based on the modified Theory of Planned Behavior. That is, are my beliefs congruent with my practices? Beliefs, in this case, are my intentions to teach using Brooks and Brooks' (2001) principles.

After presenting the data from the teaching episodes (high school and university), I present a summary for each of the five sections that highlights the key findings of my journey as I sought to shift my teaching approach. The final section of this chapter presents a summary of all those findings.

Findings

This section presents qualitative findings that I collected during my high school and university teaching experiences as I endeavoured to change my teaching practices from a traditional to a more constructivist approach. I present the findings for each section by reporting on teaching episodes in the high school science class and the university education curriculum and instruction (C&I) course. The following structure is used to present the teaching episodes:

- Lead-up to the teaching episode: This includes my intentions for the lesson and my preparation.
- What happened during the teaching episode: I describe my actions, student reactions (visible or audible behaviours), and my immediate responses.
- Teaching episode reflections: These reflections were aided by reviewing the video recording (if available), my journal, and/or my discussions of the teaching episodes with my critical friends. Based on my reflections, I make suggestions for further developments specific to the activity presented.

Each of the five sections will conclude with a synthesis of the findings for the specific Brooks and Brooks (2001) principle. This informs the discussion found in Chapter 6, where the research questions are answered.

Posing Problems of Emerging Relevance to Students

Brooks and Brooks (2001) argue that not all students enter the classroom interested in learning all aspects of the curriculum. Nevertheless, “Relevance can emerge through teacher mediation” (Brooks & Brooks, 2001, p. 35- 36). This mediation creates interest, encouraging students to glimpse the relevance of the topic. Some researchers use the term p*ersonal relevance* to describe teaching practices that connect the learning in the classroom to their students’ out-of-school lives (Johnson & McClure, 2004).

Following the method described in Chapter 4, I chose two teaching episodes from the high school experience and two from the university to examine my practices about posing problems of emerging relevance.

High school teaching experience.

Incongruent finding: Specific heat capacity and camping.

Lead-up to the teaching episode. In the high school lesson from which the first example is drawn (see lesson plan in Appendix C), I planned to tap into the students’ out-of-school experience of feeling cold at night when camping to introduce the topic of specific heat. In this school, a student organization regularly conducts camping trips to the Rocky Mountains, so I thought the camping example would resonate with many of the students. In addition, I know many of the families in this area spend their weekends in the Rocky Mountains. I used this knowledge to plan a lesson about specific heat capacity and the significance of water’s impact on the climate. The eighth lesson plan I created for these high school students contained my plan to show a picture of a sleeping bag on snow-covered ground. I planned to ask the questions, “What would keep you warmer [longer] on a cold winter’s night [in a sleeping bag], one kg of iron at 100ºC, or one kg of water at 100ºC? Or would they both keep you equally warm?” (High school lesson plan #8). I believed that this would spike student interest while preparing them for the textbook questions I would later ask them to complete.

What happened during the teaching episode. The video recording of this lesson reveals that the students accepted the idea of needing a good sleeping bag for snowy conditions, yet none had used an object to heat their sleeping bags while camping. When I asked the students if iron or water would be more effective, the students were quiet (Video - Class 7, 37:10). The students stared at me, waiting for me to tell them how this mattered to them. I then pulled them into a discussion by telling a story about my friend melting his sleeping bag with a hot rock. He counted on the stored heat in the rock to keep him warm.

As I told the story about my friend, I could see that the students were entertained. A few smiled at his situation, yet the experience felt awkward. I had not planned to tell the story, but since the original question I asked elicited little response, I sought to salvage the situation. At the time it did not occur to me that the original question was the problem. I eventually made the connection between the science concept and “real life” for the students, by simply telling them why understanding the specific heat capacity of objects might help one sleep well when camping.

Teaching Episode Reflection. I noted this incident in my Reflective Journal: “The group did not voice strong convictions, either for iron or water. A number [of students] suggested reasons why the objects may not be the same, but they did not seem to care. I did most of the talking” (p. 40). However, I did not know why the students seemed disengaged.

A discussion with CF3 helped me to see that the questions I posed were inadequate. She stated that she appreciated the camping analogy, yet wondered why I chose one kg of iron as an alternative to a hot water bottle. Why not talk about a rock instead of a chunk of iron, she asked.

This suggested to me that she also felt I missed an opportunity to connect with the students. I now believe that the fundamental problem involved the relevance of one kg of iron in a camping situation. Although I had good intentions, I had devised a manufactured closed-ended question, creating a situation that did not relate to the students' camping experiences. Although I didactically led the students to the science outcome, defining specific heat, I missed an opportunity to present a lesson that incorporated a real-life situation, and I missed the opportunity to make use of the students' experiences in a meaningful context. I focused on content knowledge. In hindsight, I believe that I could have asked questions that were more relevant to real camping situations the students experienced. I tried to force a textbook-like question into a real-life scenario. For these reasons, I classified this teaching episode as incongruent with Brooks and Brooks' (2001) principle on posing relevant problems.

As I viewed the videotapes of my teaching, after my discussion with CF3, I was dissatisfied because I noted that I had used more unproductive questions in the lesson. I could have posed better questions, first by asking the students to think about their past experiences. For example, "Have you ever seen someone put a hot object into their sleeping bag [or their bed, for those who have not camped] before going to sleep?" and "Why would a person do that?" After drawing attention to the situation, possibly by using their personal experiences, I could then have asked "why" questions. This would more likely have connected to the students' lives. They did not enter the class with the desire to learn about specific heat, but by posing good questions, I could have fostered a feeling of relevance.

Congruent finding: Alternative energies and the impact of electric cars.

Lead-up to the teaching episode. As one of my science classes ended, I began to walk down the hallway with two students, Leo and Logan, who described in detail Tesla's new sports car and Model 3 edition. Upon hearing what we were talking about as we walked out of the classroom, other students joined in the discussion. Becoming aware of the students' interest inspired me to change my plans for the next class period. I decided to facilitate a class-wide discussion to uncover each student's understandings of alternative energies.

For the lesson on climate change and human influences, I wanted to plan activities that confronted typical misconceptions, for example, the misconception that the students can do nothing to prevent climate change. My intent was to create opportunities that connected what we examined in class with the students' out-of-school lives (HS lesson plan #9). After the spontaneous discussion with Leo and Logan and their classmates, I felt comfortable altering the activities. Although my intent was to pose a problem to the whole class, I specifically intended to connect the in-school-content to the out-of-school interests raised by the two students, thus producing an event that I hoped and believed would create personal relevance for all the students.

What happened during the teaching episode. I began the activity by asking the provocative question, "Should all Albertans switch to electric cars to protect our environment?" (Video: Class 16, 31:30). Leo and Logan, two students who typically did not engage in class discussions, immediately began to provide relevant information regarding Tesla's new cars. I sought to develop all the students' understanding of how our choices impact the environment around us. Thus, after Leo and Logan contributed their positive environmental arguments for electric cars, I encouraged other students to provide counter-arguments. Students did respond with logical arguments. For example, Emily argued that electric vehicles are worse for the environment than gasoline-burning vehicles, because of the chemicals in the electric car batteries. The emotional connection suggests that, overall, the questions I asked ignited student interest. The video camera captured other students showing interest (emerging relevancy) by turning in their seats to look at their peers and asking questions about the electric cars. It appeared that Leo and Logan's passion encouraged many of their classmates to pay close attention to, and comment about, electric cars.

As the students discussed the issues, I was able to step back and let them speak their minds. They did not all agree, yet by the end of the class; I felt confident that the lesson had gone well. The back and forth of this discussion was also enjoyable for me, and I felt I had begun to align my beliefs and teaching practices during this activity.

Teaching Episode Reflection. In my reflective journal, I noted that I felt that my approach to this activity positively impacted all the students, especially Leo and Logan. The level of participation in the discussion suggested that I connected to the students' out-of-school interests. I concluded, "I believe that my [new] approach may benefit some students in a way that traditional strategies do not" (p. 51). Prior to this study, I would not have responded to student interest in the manner discussed above. I may have mentioned the Tesla discussion during a lesson, but only briefly. In the past, I simply would have affirmed Leo and Logan's connection to electric cars, by smiling and possibly stating that I agreed with them. It is evident that I was becoming more cognizant of principles associated with constructivist-oriented pedagogies. Brooks and Brooks (2001) suggest that constructivist-oriented teachers must pay attention to their students' understandings and be flexible enough to respond, asking questions that are appropriate for each student. I believe that I followed Brooks and Brooks' advice during this particular session, thereby demonstrating a shift in my teaching practice. Upon analysis, I feel this teaching episode suggests that I had begun to align my beliefs and practices. By paying attention to the students' interests, I was able to intentionally use their passion to create an opportunity to make science relevant. The video recording of the class confirmed my initial impression that the class was engaged. I felt a sense of accomplishment, and that I was making progress. I was encouraged by the students' energy in the lesson and that in turn inspired me to keep up my efforts to shift my teaching approach. Up until this point, I had not been having much success with my lessons.

I also recognized the need to be more flexible in my teaching and to be prepared to respond to student interests. If I teach that course in the future, I need to understand my students' interests better. It was just by luck I that I heard my students make reference to electric cars. In the future, I should not rely on chance. I can become more familiar with the students' interests by spending some time in the popular media that is part of their world. The better I understand their interests, the better I will be able to incorporate activities and questions they may find relevant. Nevertheless, being prepared to listen to the learner is important. I need to attend to my learners so that I can better engage them.

University teaching experience.

Two months after my high school teaching experience I taught a teacher education science curriculum and instruction (C&I) course. The following teaching episodes reflect my efforts to use what I learned during the high school experience.

Congruent finding: The opening activity of each class period.

Lead-up to the teaching episode. During the planning for the C&I course, I searched for ways in which I could create opportunities that would encourage the university students to connect my lessons to their future student-teaching and in-service teaching. My intention for the reoccurring activity described below was to encourage my students to develop an understanding that high school science teachers influence the lives of their students in significant ways beyond simply passing on science knowledge. I altered the plan for each opening activity to model understandings of what could be taught in a classroom beyond science content.

Many professors in my institution begin each class with a short devotional reading. For example, many read a page-long moral lesson. Before this study, I also consistently read a short paper (devotional thought) to my students and then informed them of the moral or ethical point of the message. I decided to change my plans because I felt that the activity was not relevant to my students.

Reading a devotional lesson is a traditional activity. The purpose of this activity is to infuse Christian values into each lesson. As I planned this activity for my classes, I recognized that the pedagogy was not connecting with my students. When I observed other professors conducting this activity, the students looked bored. More than one student informed me that he or she was "killing time" waiting for the real content of the class.

Recognizing the activity lacked relevance, I planned a lesson that avoided preaching and instead connected to the students' future teaching; I planned specific questions that asked them if/how the moral/ethical point of the devotional reading would apply to their classroom (e.g., C&I Lesson plan #1). During this C&I course, I shifted the traditional, passive, opening activity to one that asked the students what they thought.

What happened during the teaching episodes. During the opening activity of the first teacher education lesson I read a short quote from one of the founding members of the Seventh-day Adventist (SDA) church, "Nothing is of greater importance than the education of our children and young people…" (White, 1968). When I read White's quote, I did not tell the education students why I had done so. Instead, I asked them if the quote applied to them as science teachers. The students immediately accepted the quote as applicable to teaching, and provided concrete reasons as to why. For example, David said that he believed that teaching could inspire permanent changes in students (Reflective Journal, p. 71). He elaborated by explaining that helping students grow intellectually is “exciting,” yet the responsibility is “scary.” He concluded by stating that teaching is a serious matter and that “I will never simply wing it” (p. 71). During this discussion, Victoria made a religious connection between the quote and her future teaching. She said she felt that it would be her job to lead students spiritually. Her spiritual interpretation differed from David’s pragmatic science-related argument. I noticed my students’ heads nodding in agreement with the various perspectives. It appeared that the entire class felt comfortable discussing these two interpretations. David focused on learning content, while Victoria focused on the importance of helping students develop moral understanding. Content for her was secondary. The class thought both aspects were important.

In a subsequent class’s opening activity, Victoria stated that she was really worried that teachers have too much power when it comes to influencing the ethics and morals of young students. (Reflective Journal, p. 100). It appeared that she had recognized the delicate balance teachers should maintain in the classroom. How do you influence your students but not indoctrinate them?

At the end of the class, I was pleased with how the lesson had progressed. I felt I had successfully connected the quote from White with the role that the students will play as teachers.

Teaching Episode reflections. The student’s responses suggest that they were able to relate to the opening quotes as relevant to their professional lives. I believe the devotional reading activity was successful in engaging the students and in meeting my institution’s goals. I was able to make the spiritual lesson relevant to the students’ future teaching practice. Nevertheless, I still found it easy to fall back into a preaching mode. I noted, “As I think back on this activity, I believe that I spoke too much" (Reflective Journal, p. 71). Likely this stems from my desire to guide these young adults. While I have altered my teaching practice somewhat, something still draws me back to traditional methods. Perhaps, it is the patriarchal culture of my institution and the tendency to help young adults find the path rather than letting them create the path. Like Victoria, I am struggling to find a way to influence my students rather than indoctrinate them.

I discussed this struggle with CF2, and she acknowledged that the shift in a didactic approach in moral education to one that is more student-centred would be slow (Critical Friend Discussions, p. 8). She encouraged me to continue seeking to make connections between the moral education goals of the institution and the students' future teaching practices.

Overall, I was impressed with how the students engaged with the devotional readings throughout the term. I recorded in my reflections, "I believe I have made a step in the right direction. This feels right" (p. 69). While I feel a measure of accomplishment in addressing the principle of relevance, I recognize that I need to work on facilitating rather than leading the discussion.

Congruent finding: Professional lives and reading assignments.

Lead-up to the teaching episode. Having students read scholarly and popular media journal articles is a key component of the education program. Therefore, each education course regularly includes the examination of assigned journal readings. In my planning for these activities, I sought to shift away from my prior lesson strategy of presenting the authors as authorities my students should follow/believe. Instead, I planned to have the students reflect on how the readings did or did not resonate with them and why. I also developed questions that required the students to apply the key ideas in the readings to their future professional lives. For example, one assigned reading from a Canadian news magazine was, *Why are schools brainwashing our children?* by Cynthia Reynolds, *MacLean's Magazine* (2012). This article described how some science teachers are weaving social justice issues into the school curriculum through cross-curricular activities, events, and projects. The article questioned whether students were being taught a mixture of perspectives when examining controversial topics. I planned to use this article to encourage my students to examine their beliefs on the purpose of science education.

In the class prior to the planned discussion of the reading, we had looked at the Science, Technology, and Society (STS) component of the science curriculum. I asked the students to think about whether they would introduce a social scientific issue in their classrooms. I stated that I intended for them to think about how their beliefs about science issues may affect their future students. I wanted the next day's class to be provocative, so I purposely selected Reynold's article, subtitled "Protesting oil pipelines, celebrating polygamy: Is the new 'social justice' agenda in class pushing politics at the expense of learning?" The article begins by focusing on elementary schools that have introduced topics ranging from zero tolerance on female genital mutilation to protesting the laying of pipelines in Western Canada. The main point of the article is to question if these topics belong in schools. The author uses the word "brainwash" to describe what is happening in the schools. Science, Technology, Society, and Environment (STSE) issues are part of the Science 10 curriculum, yet this article goes beyond the question of connections between STSE and moves into questioning if presenting ideas from a strongly progressive bent, social justice, is appropriate. I planned to use the article to challenge my students' teaching beliefs. STSE impacts cannot be ignored. Can social justice issues that are connected to science be ignored? I thought that this would make the lesson relevant to my students, for these issues may be relevant to their future students.

After this introduction to the topic, I planned to ask, “Will these issues have a place in your classroom?” Specifically, I planned to engage my students in a discussion regarding how or even if they plan to incorporate social-scientific issues in their classroom. For example, what is the role of the science teacher in teaching STSE content? Is it to simply relay information, or should advocacy be part of a teacher’s role?

What happened during the teaching episode. I introduced the discussion of Reynold’s (2012) article by reminding the students about the curricular requirement to include STS outcomes in the science classroom. Then I asked the class for their thoughts, their initial reaction to the article. One vocal student stated that social justice issues should not be in schools. She said she believed that issues surrounding female genital mutilation and ending violence against sex workers should be taught at home. When I steered the discussion away from moral issues that the Seventh-day Adventist institution had stances on and towards the science issues, the discussion changed.

The vocal student still felt that a teacher could manipulate students if that teacher held biased points of view. The following class-wide discussion was lively as this sentiment was echoed by other students. Victoria worried that teachers have a great deal of power when it comes to influencing the ethics and morals of young students. When we turned to the issues ranging from protesting the oil pipelines to recycling, it appeared that my students were not worried about tackling these issues in their classrooms.

After a discussion of how tricky this territory can be to traverse, I asked my students if they would incorporate social justice issues in their classrooms. They unanimously agreed they would. David asked, “How could we ignore these issues?” My students admitted they had biases, yet they appeared unconvinced that their beliefs would change. When I asked if teachers at this university were aware of their beliefs, the group appeared uncomfortable.

As the lesson progressed, all of the students contributed to the discussion. The interaction in the class made me think the lesson was successful and that the activity deeply and personally connected with them. I also felt that my students developed a deeper understanding of how their science course may affect their future students.

Teaching episode reflection. Following this class I wrote in my reflective journal, “From the intensity of the student answers, I believe that they were personally envisioning how they planned to teach” (Reflective Journal, p. 100). Based on this, I classified this teaching episode as congruent with Brooks and Brooks’ (2001) principle related to relevance. All the students had something to say about this topic, and they wanted to explain their reasoning. The article on social justice and the prompting questions encouraged the students to reflect on their role as science teachers. I recognize, though, I could have focused the class discussion less on critiquing other science teachers’ actions and asked more questions, such as, “What would happen if you were required to teach…?” or “Can you think of a way in which you could balance the various perspectives?” The reason to ask these questions is to focus on their future teaching, therefore making the topic relevant to their development as teachers. This teaching episode and the students’ high engagement in the class boosted my confidence in my shifting approach to teaching.

Synthesis of Findings: My Practice and Brooks and Brooks’ First Principle

When I analyzed the data specific to Brooks and Brooks’ (2001) principle of posing problems of emerging relevance, I repeatedly found inconsistencies, especially at the high school level. In addition to the high school teaching episodes highlighted here, there were several other incongruent episodes that were not described. Looking over all the episodes coded for this principle, I see that congruent activities occurred later in my high school teaching experience. Likely, I became more at ease with these students as time progressed and I got to know them better. Falling back on traditional approaches of teaching seems to be the "safe" thing to do when I have not established a relationship with the students. I am probably more inclined to take risks in teaching when I have established a positive rapport with them. Building relationships with students makes me more aware of their interests. It provides opportunities to make the science concepts relevant to high school students. As mentioned earlier, I should spend some time becoming more familiar with youth culture if I want to relate concepts to my students' interests.

It is obvious from my data that I struggled with this principle at the high school level but had more success in the university level course. Overall I also had a better relationship with the university students, possibly because they were motivated—more interested in the course content. They had a practicum to look forward to and would need to apply the course concepts then. This was not the case for the high school students. The Science 10 course was a requirement and it is possible that the students were not as motivated as my university students.

As I increase my constructivist-oriented skills, I will need to work on finding or developing good examples of problems that highlight the relevance of science concepts and pedagogy. That is, although I am able to make concepts about teaching relevant to my university students because they are interested in becoming teachers, I need to model for my students how to make science concepts relevant. If I am having difficulty demonstrating this principle when teaching science, I am sure the situation must be even more arduous for my preservice teachers. After observing one of my university students teach a high school chemistry lesson, I reflected, "Although David used a traditional style, mostly lecture, what I observed was a student teacher attempting to add constructivist elements to a traditional classroom. He introduced each lesson (I observed) with a concept that connected the content to something the students cared about." (Reflective Journal, p. 105). For example, in one lesson he connected the idea of chemical adhesion to Spiderman's ability to climb up a wall. While David was attempting to provide analogies that would interest his chemistry students, he still needed to find ways to make the content relevant. If my university course provided more concrete examples of this principle, it might have influenced David's lessons even further.

Structuring Learning around Primary Concepts

Constructivist-oriented teachers are educators who "organize information around conceptual clusters of problems, questions, and discrepant situations because students are most engaged when problems and ideas are presented holistically rather than in separate, isolated parts" (Brooks & Brooks, 2001, p. 46). This curriculum trait is a critical aspect of constructivist learning environments (Johnson & McClure, 2004). Brooks and Brooks (2001) suggest that constructivist teachers should ask themselves, are the curricular concepts presented from whole-to-part, focusing on the big ideas, or are they presented from part-to-whole, focusing on the details (traditionalist)?

In this section, the findings illustrate how I organized topics during my high school and subsequent C&I course in response to Brooks and Brooks' second principle. Two teaching episodes from the high school teaching experience and two teaching episodes from the university teaching experience reveal my journey to adjust my teaching practices.

High school teaching experience.

Incongruent finding: Introduction to the science unit.

Lead-up to the teaching episode. As I planned the introductory lesson of the high school science unit, I also worked on the literature review of this study. During this time my understanding of constructivist teaching approaches was significantly limited. At the point of my study that I crafted this lesson, I was fully in a liminal state. I chose to focus on one aspect of Brooks and Brooks' second principle, that is I sought to plan a lesson that I presented from whole-to-part, focusing more on the big ideas and less on isolated facts.

I chose to use the focusing questions for this unit of study (Alberta Education, 2016) as the big ideas. For example, "Are there relationships between solar energy, global energy transfer processes, climate and biomes?" (p. 29). I planned to make the following statement during my first class: "I find that sometimes subjects taught in schools can sometimes miss the big picture by focusing on the details. So, I want to make sure I present the whole picture, focusing on big concepts, which are then supported by details. This can be a great deal of fun to examine if we approach it in the right way" (HS lesson plan #1, p. 2).

Other focusing questions found in the program of study are, "What evidence suggests our climate may be changing more rapidly than living species can adapt?" and "Is human activity causing climate change?" (Alberta Education, 2016). Personally, I intended to promote the "big idea" that climate change is occurring.

What happened during the teaching episode. During the introductory lesson of this unit, I did not follow the lesson plan. When I began to talk about the content that we were going to examine, I stated that "this unit may be more applicable to your lives in comparison to the first three science units" (Video 1, 14:18). Later in the lesson, I stated that my goal was to look at the big picture, but immediately after making that statement, I began listing details of the greenhouse effect that we would look at in later lessons.

I asked the big question, “Is there is evidence that the climate is changing?” (Video 1, 16:53). Yet, I did not present this question as a problem that would be examined during the entire science unit. I immediately focused on the details of climate change without relating them to a larger concept, ignoring the lesson plan’s directions. Nevertheless, the students engaged in the discussion and demonstrated that they understood that the issue was significant, a “big idea.” For example, one student stated that climate change might be impacting bee populations. I agreed and then told them that humans were the cause of the loss of bees. As I changed the subject to human causes for climate change, Logan, jumped into the conversation, suggesting that coal-based electricity production is one reason for climate change and that if we produced electricity using a nuclear plant, we would create less CO_2. Victor held a different perspective for he had lived near Chernobyl. He described what he knew about some of the dangers of nuclear power plants. For the next few minutes, we discussed the advantages and disadvantages of coal-based and nuclear-based electricity production.

At the end of this lesson, I felt satisfied that I had met my goal, for the students participated well. My fears that they would not accept me were alleviated. I remember leaving the class feeling that I had succeeded.

Teaching episode reflections. It was not until I viewed the video recording that I recognized that I had vacillated between teaching approaches. Not only did I almost exclusively teach didactically, but I focused on specific discussion points (facts) without connecting the discussions to the larger purpose of the unit of study (big picture). The students’ statements suggested that they viewed the concept of climate change as an important problem. Nevertheless, I treated the student examples as isolated facts in a manner that Brooks and Brooks (2001) suggest is typical of the traditional teacher, who often breaks "wholes into parts and then focuses separately on each part" (p. 46).

There was a clear disconnect between my intention and planning, and the actual class. I planned to teach with the big picture in mind, continually returning to the focusing questions as the students presented details. The text of the first lesson plan reflects an intention to examine aspects of the focusing question, is human activity causing climate change?" In practice, I did not follow my plan. When a student presented his/her suggestion regarding this question, I focused on it, and then moved on to the next student. I treated the responses as if they were unrelated, as if they were separate topics. We discussed issues that ranged from the death of bees to electricity production in Alberta. When viewing the video recording, I noted that at no time during the lesson did I tell the students that their suggestions were part of the big picture (big ideas) that we would investigate throughout the unit.

Multiple times I remember struggling to adjust the lesson plans. I would look at a lesson and feel that it was good. Why change it? Approximately halfway through that rewriting process, I wrote that I was having difficulty planning activities where I was "comfortable covering the curriculum while teaching in a constructivist manner" (Reflective Journal, p. 1). I remember planning for students to present their ideas, yet feeling that I was "planning to 'kill time'" (Reflective Journal, p. 58). I constantly wrestled with designing plans that encouraged students to make connections between the details we examined and the overall picture of climate change.

Today as I examine the lesson plans, I see that I failed to create opportunities for the students to examine the "big picture"; instead I provided directions for what I wanted to say or teach, with little or no planning for a response to students' understandings.

I am not surprised as to how hard it was to take the initial steps of my journey. I feel that this finding is consistent with a teacher who is in a liminal state. I sought to apply a new approach, yet I planned in a traditional manner, which focused on basic understandings. The realization that I did not meet my intention to structure learning from primary concepts was frustrating. I accept that changing a focus is also hard. I likely did not put in the time to understand how to pass on the understanding that supports the development of a big idea.

I recognize that in this first encounter with these students I was nervous and that when I am nervous, I abandon my plan. Looking at my plan, I realize that it does start with a big idea. It is not surprising that I used a teaching style similar to the one I had used in the past—a style I was comfortable with. If I conducted this lesson again, I would plan to intentionally connect the students' contributions to the discussion's focusing questions. I could use more questions that connected the discussions to the broader concepts examined during the unit. For example, I could ask, have you seen a change in our environment, have you seen a change in the Columbia glacier, and what other big climate-related events can you remember? Asking the right questions is something I feel that I should continue to work on.

Incongruent finding: Smoke signals demonstration.

Lead-up to the teaching episode. In the third high school lesson, I planned a smoke signals demonstration intended to provide an opportunity for the students to examine how differences in heat cause atmospheric air movements. I chose to use the demonstration as a way to connect the in-class activity with the larger concept of atmospheric air movement. I planned to extrapolate to global air movements how smoke reacts to differences in heat.

My planning for this activity reflected Brooks and Brooks' understanding of a traditional approach. I aimed to facilitate the transfer of understanding of the smoke signals to the larger picture of the Earth's atmosphere. After the students explained why temperature impacted the smoke's movement, I asked, "Do you think that this same movement of air happens on a much larger scale in our atmosphere?" (Reflective Journal, p. 21). My part-to-whole orientation was reflected in my question.

What happened during the teaching episode.

I started the demonstration by lighting a stick of incense. As the smoke rose, I asked the students to write a prediction and an explanation for what would happen to the smoke if I held the smoking stick near a heat lamp and near a bucket filled with ice. I provided a paper where the students wrote their predictions and explanations for what would happen to the smoke. I encouraged the students to talk about their predictions with a partner. After they discussed their predictions, I moved the incense over the ice bucket and near a hot heat lamp. The students recorded their observations and explanations for what they saw. They were surprised that the cold temperature slowed the rising smoke. I asked if anyone could suggest why this happened. When no one responded with the answer I desired, I told them how the density of the air changed.

I then sought to connect the students' observations and explanations to the movements of the atmosphere by asking them if anyone had experienced air moving upward very quickly. During the ensuing discussion, Felix and Alex provided examples of how air temperature affected the movement of large air masses. After Felix described how hot sand produces "solar updrafts" in a desert he had visited during the summer (Video 3: 17:02-17:58), I explained that these same air movements are seen on a larger, more global scale. As I described these atmospheric movements, multiple students nodded, showing nonverbal acceptance of my explanation.

Teaching episode reflections. Following this activity, the reflections I made in my journal indicate that I felt I had made a connection between the in-class demonstration and the larger picture of global air motion. Later, after viewing the digital recording, my perception of the lesson changed. “The description in the above [Reflective Journal] paragraph is accurate, but what is not mentioned is that at the very end of the activity I fell back into the well-worn teacher-directed strategies to which I am accustomed” (Reflective Journal, p. 22). Watching the lesson unfold, I now recognize that the students were not making a connection between the demonstration and the “big picture” of global air movement. So, I informed them of the connection, reinforcing the part-to-whole strategy of the lesson. My intent to structure this lesson around a primary concept (global air movement) reverted to a didactic presentation of isolated science content. As I watched this recording of my teaching, I felt embarrassed. I actually stopped watching the recording, left my office, and went for a walk outside. I worked to change, believed that I had changed, yet the recording showed that my teaching style had not changed in this instance.

In hindsight, I see that this activity was structured from a traditional teaching perspective. That is, I was teaching from the belief that only when students understand the individual parts will they be able to construct the whole or the big picture. The students’ role in this class was to accept, without a critical discussion, that what occurred in the demonstration applied to the entire atmosphere.

I believe that demonstration and the Predict, Observe, and Explain (POE) strategy were effective in this activity, yet I could have begun with a discussion of the overarching idea (big picture) instead of the demonstration. I also could have included the students in the process by asking if they believed we could test some of the atmospheric interactions with the equipment in the classroom.

Although I taught using the POE strategy, which I argue is a constructivist-oriented pedagogy, I did not teach from a whole-to-part position. If I had started with a discussion of the big picture, atmospheric movements, and then moved on to how we might investigate the phenomenon in the classroom, I would have been truer to this Brooks and Brooks (2001) principle. Rather than simply performing the demonstration I could have first asked the students if they believed it would be possible to test some of these ideas in the classroom. That is, starting with a discussion of the global air movement I could have then moved the investigation to air movement in the classroom.

The big idea of this lesson related to understandings of air masses. I did not effectively provide an activity that allowed the students to extrapolate the demonstration results to a global phenomenon. Examining a local demonstration of cool or warm air could support the development of the big idea regarding air mass movements. I did not provide an opportunity for the students to make this connection.

I am not sure that I understood Brooks and Brooks' (2001) big ideas during my time in the high school classroom. For example, the movement of energy is a pillar of the entire Science 10 program, including climate change, yet I did not discuss this concept except to focus on very specific details of energy transfer. As I read Brooks and Brooks (2001) today, I see that I should continue to develop my understanding of how to teach from whole-to-part. When I discussed this difficulty with my Critical Friend (CF3), she suggested that I examine the National Science Teachers Association (NSTA) website. The NSTA suggests standards that act like the big ideas that support whole programs. The NSTA provides resources suggesting how to use the standards.

This site may help me develop my understandings of big ideas that run through entire series concepts.

University teaching experience.

The following teaching episodes reflect my efforts to use what I learned during the high school experience to design a teacher education course that reflected a curriculum that emphasized the big concepts. Below is an example of one lesson.

Congruent finding: Introducing a primary concept.

Lead-up to the teaching episode. In a previous discussion with my C&I class, some of the students stated that they could not envision how one could teach from a whole-to-part position. In response, I planned to model how a high school teacher might teach from that perspective, focusing on a primary concept (gravity), which in turn leads to the examination of specific science details (force diagram and freefall). I planned this teaching episode using a 5E Lesson plan (Engage, Explore, Explain, Elaborate, and Evaluate). The choice of the lesson plan format was intended to support previous discussions regarding constructivist-orientated lesson plan styles. After this lesson I intended for my students to be able to identify how the modelled lesson met the curricular outcome, creating a force diagram, as I taught holistically about gravity.

I planned to engage the students in the examination of gravity by showing a video clip of a young skydiver's jump. "As we watch this video clip, keep in mind the question, how can we explain a skydiver's fall?" The video clip was a springboard for the rest of the lesson. After the video clip, the planned initial exploration of the overarching idea of gravity included a class-wide discussion and the initial brainstorm based on the question, "What are the factors that would impact the skydiver's fall?" If the students did not list wind resistance I intended to ask, "If they did not use a parachute, will the diver continue to speed up during their entire dive?"

To handle the “explore” portion of the lesson, I planned to stand on a desk and drop a pen and a sheet of paper. I would then ask the questions, “What do you think will happen when I drop these two objects?”, “What happened and why?”, moreover, “What forces are involved?” At this point, I planned to link the demo and the big idea of gravity by asking, “What information do we need to collect so that we can examine the force of gravity?”

I would then explain a force diagram, a square from which arrows extend, illustrating the magnitude and direction of the forces examined. Each student would construct a force diagram, and then as a group, we would draw one together.

To elaborate, I planned for the students to test their ideas using a digital freefall simulation. The simulation focuses on very specific details of gravity by recreating Galileo’s freefall tower experiment. The students control various digital objects (table tennis balls, golf balls, soccer balls or watermelons) that are dropped off a simulated Tower of Pisa. The student-experimenter also controls whether the objects are dropped within a vacuum or within an atmosphere and with or without a parachute. The resulting speeds are shown on a speedometer and a graph.

Students evaluated their understanding of gravity and force diagrams using prompts such as “Was your model complete (force diagram)?”, “Does it explain all the falling objects tested?”, and “Could your model be used to explain gravity in general?”

What happened during the teaching episode. I modelled the mini-lesson following the 5E plan. For example, after watching the video clip, I asked the class to explain what caused the skydiver to fall, and whether her speed would continue to increase if her parachute did not open. My students provided well thought-out predictions and explanations. They also created complete force diagrams and effectively described how their work could explain how other objects fall. During the lesson, I sought to model without explaining my teaching strategies.

Following the mini-lesson, I asked my students to critique the teaching approach I modelled. During this discussion I did not provide my perspective as to how the lesson met or did not meet my intended outcomes; however, I continually asked various students to present their understanding. I began by asking general questions, “Was the lesson effective?”, “Did they believe that it would encourage understanding regarding big picture outcome (gravity)?”, and “How would they describe the detailed outcome of a force diagram for freefall?” The students explained that they felt that this type of lesson would be effective (and they enjoyed it). Yet, they worried that if they focused on the big overarching concepts, like gravity, their students might miss small details that are likely to be included on government-administered standardized multiple-choice examinations—details including manipulation of formulas and calculations of forces. As a group, the class described misgivings regarding the efficiency of teaching with a focus on big ideas. One vocal student remarked that we spent a great deal of time to learn a small amount of information.

Multiple students presented non-verbal support (arms crossed, heads nodding) when a classmate expressed misgivings about teaching from a whole-to-part perspective. Specifically, the classmates who spoke said that they worried that their future students might focus on details not specified by the Science Program of Study (Alberta Learning, 2016). One student pointed out that the simulation and work on a force diagram were useful, yet the whole lesson was not efficient.

The discussion then shifted to a critique of the 5E lesson and did not return to the whole-to-part approach to pedagogy. The students agreed that the video clip was useful, although they questioned the value of brainstorming ideas afterwards. One student said that a teacher could explain more and sooner without the brainstorming activity. At one point the conversation shifted towards how a 5E lesson could be used in upcoming practicums. One student worried that the modelled teaching strategy was not reflective of what he saw in his practicum classroom. His practicum teacher taught with only a whiteboard and workbook assignments that focused on one specific concept at a time (Reflective Journal, p. 95). The class ended without returning to the whole-to-part approach to teaching.

Teaching episode reflections. Prior to teacher education, when I taught high school students about gravity and freefall, I began with an explanation of a force diagram. Only when the students understood how to create a force diagram did I move on to how it applied in the real world. I intended to present a different strategy in my teacher education class. I consider this episode somewhat congruent because I modelled Brooks and Brooks' (2001) principle of teaching from whole-to-part, but I neglected to adequately debrief the activity with my students. I had combined modelling whole-to-part and the 5E lesson approach, and this distracted my students. They were uncomfortable with the 5E lesson. Once the critique of my modelling began, I allowed the discussion to shift to the 5E model. While I believe this was necessary, I did not achieve my intended outcome. During the debriefing, I encouraged the discussion about lesson planning because it is an area I am more confident addressing.

When I modelled this holistic lesson, I remember a lack of confidence as I moved between the parts of the lesson. It is also possible that my delivery, i.e., my hesitancy moving between the 5E sections of the lesson, impacted my students' understandings; they might have felt less confident about the whole-to-part principle. In short, my presentation led to a fuzzy conclusion. Likely I caused my students to conflate Brooks and Brooks' (2001) principle of structuring learning around primary concepts and the 5E lesson planning.

As I analyze this teaching episode, it is frustrating to realize that although my students appreciated my presentation, they doubted that it would meet their future classroom outcomes. I thought that the 5E lesson example was effective, including the debriefing, but the debriefing of my teaching (based on a primary concept) was not explicit.

In the future, I plan to guide a debriefing that specifically looks at these two issues separately. For example, first, encourage the students to critique the modelling with regards to how well I moved through the five sections of the lesson (as they did in this activity), and second, examine how I modelled a whole-to-part approach. Being intentional may help my students more.

Congruent finding: Discussion regarding mid-term examination.

Lead-up to the teaching episode. My plan for this teaching episode reflected my intention to introduce the concept of teaching from whole-to-part with a primary focus on the purpose of assessment that occurs within the C&I course. In other words, the primary concept I intended to examine was the purpose of the assessment. I wanted my students to think about what (and why) we should measure in our course. Instead of looking at what high school students need to learn, I planned to turn the focus on my students, ask them to think about their learning and assessments, and apply that understanding to their future teaching. If a certain pedagogy is appropriate for them, would it also be beneficial for their future science students?

In this lesson plan, I designed a discussion to introduce the term project and examine the structure of the upcoming mid-term examination. The plan called for me to point out the massive amount of details that we had covered, including various teaching strategies, several planning styles, and multiple programs of studies. I planned to ask if a focus on specific details (e.g., memorizing each program of study) matched the overarching outcome of the C&I course. For example, I planned to ask, "Since science teachers are required to teach all outcomes in the Program of Studies (POS), would it be reasonable to expect you to memorize all the outcomes within the POS?" The primary concept I planned to examine was the purpose of assessment of teaching competencies through a traditional summative examination.

What happened during the teaching episode. I began the discussion about the upcoming mid-term examination by asking the planned question. My students likely assumed that I planned to administer a traditional multiple-choice mid-term examination and consequently they looked alarmed. Next, I asked if memorizing all the details of the POS would be consistent with a constructivist perspective of teaching and learning. One student suggested that it was not. I then asked, "Aren't the Alberta outcomes important?" The students replied that they understood that the outcomes were important, but that the information could be easily found when needed. Next, I asked, "Ok, then what should I require you to understand for the exam?" One student responded that we should focus on the big ideas and another suggested I should focus on the important aspects of the programs of study and where to look when we need specific information.

Teaching Episode Reflection. My students seemed to understand what the primary concepts were. This lesson suggests that I was able to help my students think about assessing primary concepts. I see now that I did not encourage the class to apply the same understanding to assessment in their future high school sciences courses. Nevertheless, the language I used in my reflective journal describes the planning and executing of a lesson that reflects assessment focused on primary concepts. My reflections following this activity indicated that I was happy with my planning and execution.

Today, upon reflection, I see that my students may have focused on the burden of memorizing all the outcomes in multiple POSs. It is possible that they argued for an assessment that reflected a big picture approach in order to reduce their burden of memorizing each POS. Yet during the class and when re-reading my reflections, I believe that my students did wrestle with the concept of what should be assessed in our course. They identified what content was worth assessing. Although this discussion worked well for my class and our professional outcomes, we did not examine how this same approach to assessment could work in a high school science course. I did not ask if our decisions would be helpful to high school science students. I could have concluded the discussion by examining how my education students might apply this procedure to a science classroom. For example, I could have asked questions such as "Can you suggest a way that we could apply this same reasoning to a Science 10 examination?" and/or "When do you believe you could use this same approach in a high school course?"

Prior to the mid-term of the C&I course, I felt that my self-study efforts were beginning to pay off. It felt good to plan and implement this activity.

Synthesis of Findings: My Practice and Brooks and Brooks' Second Principle.

The high school teaching episodes analyzed above indicate I struggled with understanding what a big concept was and how to teach from a whole-to-part perspective. When I did plan with primary concepts in mind, I consistently ignored my planning and taught the lesson with a focus on knowledge details.

The inconsistencies on display during the high school teaching episodes were reduced, yet were present in some of the teaching choices I made in the undergraduate education course.

At the university level, the analysis suggests that my students found it difficult to envision how to design and teach a science lesson based on big ideas. However, in regards to their C&I course, they had no trouble identifying big ideas when it came to discussing assessment. As I write this dissertation now, it occurs to me that I could have fostered their understanding of the big ideas in science if we discussed the assessment of science concepts. Also, I see now that I did not encourage my high school students to examine how big ideas in the science curriculum were connected to their assessments. It is possible that my lack of proficiency was passed on to my C&I students.

Looking over all the episodes coded for this principle, I see that the congruent activities increased in number during the teacher education course, suggesting that I integrated this principle of constructivist-oriented teaching better in the university setting than in the high school setting. Although the shift noted in this section was a tentative change, it is encouraging to see a shift did occur. Perhaps my struggle with this principle at the high school level resulted in some progress in the teacher education course.

Today, I feel comfortable as I speculate on how I could alter my actions in order to conduct an activity that allows my students to experience a lesson that focuses on a primary concept. For example, I believe that the debriefing after a modelled activity could provide an opportunity for my students to perceive my intended actions. One way I could improve my students' learning is to follow Berry and Loughran's (2012) example of explicit modelling in teacher education. In this case, I would point out my intention and then allow the students' analysis and concerns to lead the debriefing process.

Seeking and Valuing Students' Point of View

Brooks and Brooks (2001) argue that "Seeking to understand students' points of view is essential to constructivist education" (p. 60). These authors suggest that students must be encouraged to speak out and develop a critical voice during the learning process. They argue that teachers should look for students' individual perspectives and use these understandings in the following lessons.

In this section, the findings illustrate how I organized topics during my high school and subsequent C&I course in response to Brooks and Brooks' third principle. I show how I sought to integrate the students' point of view in the high school, and I then reveal two teaching episodes from my university teaching experience to examine my efforts to adjust my teaching practices.

High school teaching experience.

Incongruent finding: Ecological footprint.

Lead-up to the teaching episode. Approximately halfway through the high school teaching experience, I planned an activity intended to encourage the students to examine their environmental impact. I planned for the students to use an online simulator that would calculate their personal ecological footprint. Using a calculator provided by the Global Footprint Network, the students worked to answer the question, "How do you personally impact the environment around you?" Based on student input, the calculator estimates the land required to support the student's lifestyle. The result of the calculation is contrasted with the national average, the parts of the student's lifestyle that use the most resources are identified, and suggestions are provided to reduce the individual's environmental impact.

My intention was to encourage the science students to examine the resources required to maintain their lifestyle. I planned to ask if they were happy with their impact, if they thought they should change how they acted, and if the suggestions for change given by the website were valid.

What happened during the teaching episode. The video shows that as the results of the calculation appeared (the land mass required to support their lifestyle), most of the students displayed no reaction. I then asked, “Are you happy with the results of the calculations?” (Video class 15, 31:00). Although we discussed the validity of an online survey for a few minutes, the general reaction of the group was that yes, they were happy with the results.

An exception was Sophia. She was very surprised. The calculation indicated that she impacted the environment significantly more than her classmates and considerably more than the average Canadian. Sophia’s energy provided the impetus for a class-wide discussion. I asked what could be a reason that someone’s footprint would be larger than the average and why the average in Vancouver and Calgary would be different. Sophia suggested that her vacations in Hawaii and Florida may have made her footprint larger. Another student suggested that we need to heat our houses in Alberta more than people in Vancouver.

We discussed other facts regarding general energy use, and I then asked, “Do you agree with the suggestions as to how you could reduce your ecological footprint” (Video class 15, 34:00). The activity ended with multiple students agreeing that the footprint calculator suggestions were reasonable. The students said they believed that they influenced the local ecology and thereby the larger issue of climate change.

Teaching episode reflection. At the time of the lesson, I felt I had accomplished my goal. The students communicated their perspective regarding the ecological footprint calculator.

Unfortunately, my questions allowed superficial acceptance of the calculated results, thereby missing the intent of the lesson. The conflicting perspectives that the students likely held were not elicited or examined. When Sophia's ecological footprint was revealed to the class, I steered away from examining the other students' perspectives. I need to work on how I might examine issues that could cause a student discomfort without making that student feel unsafe in my class.

I now see that the questions I asked encouraged shallow thinking. The students did not seek deep personal understanding, and they did not communicate their personal perspectives. Upon reviewing the digital recordings, I concluded that the students appeared disinterested. Their responses appear as if they were saying, "What do you expect? Of course, we are affecting the environment."

One way I could have encouraged students to examine their perspectives includes asking the students in small groups or in pairs to compare their results. This may have allowed Sophia to examine her footprint without being singled out. Also, I then could have asked questions that probed deeper. I could have asked questions such as, "What if we do nothing?", "Will it matter?", "What would your reason for changing be?", and "Why do you think our personal change makes a difference?"

My actions during the ecological footprint calculator activity did not effectively expose the students' points of view. It appeared that I did not expect their calculations to be interesting either. Did I really value their individual results? During the summer, when I watched this recording, while I did not feel physical pain, I felt a letdown. I questioned the value of my efforts toward pedagogical change. Was this endeavour a waste of time?

Congruent finding: **10 Common Misconceptions.**

Lead-up to the teaching episode. In the seventh high school class, I planned an activity aimed to identify and provide an opportunity for students to explain their perceptions regarding the article, *10 Common Misconceptions about Global Warming*, *Prevention* (2011), by Al Gore. My goal was to uncover the students' perspectives regarding common climate change understandings. I planned to encourage the acceptance of multiple perspectives and use the understandings I gained for future lessons. For example, I could challenge suppositions better if I understood what the individuals in this class believed.

The evening before the lesson I altered the activity from one where groups summarized and described a section of Gore's article to one where small groups of students summarized, evaluated, and provided their opinions regarding their section of the article. My intent was to change the activity from one where the "right" answers were gleaned from the paper to one where the students would reveal their beliefs and then defend their understandings.

I designed the activity where I provided small groups (three to four students) with a section of Gore's paper containing two of the 10 "misconceptions." The task was to read and discuss their understandings within their group. Next, they were to prepare a summary and an evaluation of the two assigned misconceptions. As they prepared their summary, I planned to inform them that I would like them to identify other viable alternatives, take a position, and defend it. Following each presentation, I planned to record their response to the misconception (agree/disagree) on the front whiteboard. The activity would conclude with a global evaluation of the article, prompted by two questions: "As a class, do we feel that Gore's misconceptions are important for the general public to examine? Why?"

What happened during the teaching episode. As I introduced the activity, specifically the requirement that each group would evaluate the misconception, one student stated, "This is the worst thing ever." Yet, after the groups formed, and during each step of this activity, the classroom was filled with productive noise. The students were engaged in the topic. The students appeared motivated to present their points of view regarding the misconceptions. During the small group discussions, I circulated through the classroom, asking each group to explain to me what they believed. What caught my attention was that each group was engaged and focused on their task.

Twenty minutes later, the five small groups presented their summaries and evaluations. At the time, I worried that the students would simply parrot the article back to me. Instead, the resulting activity was very engaging. Each group accurately described and eagerly explained their group's belief regarding the validity of the misconceptions. The members of the final group declared that they had changed their point of view and then explained why. Prior to this course, they had not considered how different wavelengths of energy entered and exited the atmosphere. They explained that they conflated cancer-causing waves with the radiation emitted as heat waves (i.e., ozone holes cause cancer, they do not cause global warming).

After recording each group's evaluation, I noted, "You all agreed with Gore's 10 statements. It appears that you believe climate change is happening." I then asked why their evaluation, the complete acceptance of all of Gore's statements, was "so different" from past surveys I conducted. Felix replied, "We have more scientific evidence for climate change now." I pressed the class, asking if the current hot summer was the reason they believed in climate change. Multiple students disagreed. They believed the science. One student explained that even in his lifetime, he had noticed a consistent warming trend.

Teaching episode reflection. When I initiated this lesson, I was worried that the students would not express their perspectives. I wrote in my reflective journal that I feared that I might have allocated too much time for the activity. If the students superficially examined their perspectives we could have finished the lesson 20 minutes early. To my relief, the students accepted their role in the lesson.

This activity was the only time in the science unit that I designed an activity that exclusively dealt with the students' perspective. In other lessons, I asked for student perspectives, yet their responses did not significantly impact the lesson . I typically asked students to present information (e.g., what are the greenhouse gasses?), not whether they believed something (e.g., most scientists agree that climate change is occurring).

Additionally, I see that I almost entirely ignored the survey data that I obtained prior to teaching the unit. I intended to use the survey data to inform my instruction, yet I rarely used the results. Collecting the students' perspectives and then ignoring the information is contrary to Brooks and Brooks' advice. If I periodically reviewed the survey data, I could have planned better, prepared better questions.

With regards to Books and Brooks's principle, seeking and valuing the student's point of view, I felt that the activity met my intention. I am certain that the students believed I valued their point of view. Yet, their responses matched my climate change beliefs. It is possible that they were influenced by my biases? Were the students simply reflecting my beliefs? Possibly they were motivated by the knowledge that they would present their work to their peers and that I would be watching them explain why they made their choices. They might have sought evaluations and explanations that reflected a different personal perspective if they felt that their beliefs would be received negatively.

Although the episode described above demonstrates that I altered my lesson to meet Brooks and Brooks' constructivist principle, this happened near the end of the teaching experience. It took me nearly the whole teaching experience before I put the theory to practice. Also, it is evident that this teaching episode had a significant impact on me. I wrote three pages in my reflective journal (pp. 36-38) about the interactions and still have vivid memories of the event. This class was interesting because the students were actively engaged as they explained and defended their points of view. As a teacher, I felt that I successfully engaged the students in the content. Making this connection was gratifying.

University teaching experience.

Brooks and Brooks (2001) argue that teachers following a constructivist approach should identify students' points of view and then respond to that understanding. The following two examples provide insight into how I incorporated this understanding into the science teacher education course.

Incongruent finding: How we can recruit women and girls to Science, Technology, Engineering, and Mathematics (STEM).

Lead-up to the teaching episode. During the planning for the education course, I searched for ways in which I could create opportunities that would encourage the university students to connect my lessons and current literature. In the following teaching episode, instead of telling the education students what to think about the article, I sought to encourage them to share their thoughts and perspectives. I planned to pursue their opinions and understandings regarding the issue being examined.

I assigned the students to read the article, *How can we recruit women and girls to the STEM classroom?* by Donna Milgram, *Technology and Engineering Teacher* (2011). I planned to then facilitate a discussion of the issues within the article in the next class period. I chose to explore this article based on the importance of the inclusion of a feminine perspective in science and in society in general. It is likely that based on the students' experiences, they may have different outlooks regarding this issue.

The article examines the recruitment of female students to STEM classrooms. Milgram suggests that women and girls need to see female role models in STEM workplaces and that educators must "repeatedly send a corrective, strong, positive message to women and girls: Yes, You Can!" (p. 5). The importance of female role models is discussed as well as their work-life balance. The second half of the article highlights successful recruitment strategies, for example, reaching out to school counsellors, using the colour pink, and appealing to female interests (making a difference in the world).

What I hoped my students would take away from this lesson is their role in encouraging female students to choose STEM careers. I planned to seek the students' general reaction to this article by first asking, "What are your thoughts regarding the reading?" I did not anticipate that my class would resist the idea of encouraging females to enter STEM. Therefore I planned to guide the discussion towards how we can make a difference. I intended to let the students' perspectives drive the discussion, but planned to ask leading questions if needed. For example, why do you think that there are so few females in technology-related fields? How might you change this? How would STEM be different if more females were in the field? My intention was to convey the understanding that an increased number of women in STEM subjects would benefit the field by providing new perspectives.

What happened during the teaching episode. During the class, when I announced that we would be examining Milgram's article next, the students appeared eager to discuss the issues. I noted that a number of the students had underlined sections and written comments in the margins. When I asked for their reaction to the article, the students eagerly described their perceptions. This is a serious issue, stated one female student, while another said that she had received a great deal of support from parents and teachers, yet little from her classmates.

When I asked how they might apply the author's recruitment ideas, the students made multiple suggestions. They gave concrete suggestions, connecting the content of the article to their future classrooms. For example, one female student felt that presenting role models in STEM subjects had a significant impact on her decision to take science courses. She would do this in her classroom. It appeared that my students felt safe discussing these issues. Another female student voiced her opposition to the use of the colour pink in recruitment efforts, but conceded that if it works, she would likely use the colour.

Near the end of the discussion I asked, what is the main point you will take away from this discussion? David focused on the numbers, the percentages, saying that change is needed because "the numbers of males/females in a STEM career should be equal" (Reflective Journal, p. 75). He appeared to view this topic as similar to affirmative action. I dismissed David's point of view, for I was locked into the point that the author was making, that females bring different interests to STEM, resulting in a workplace that is more diverse and equitable. I stated that forcing the numbers to be equal will not change gender bias. One of the female students then made a compelling argument that validated the author's point of view. She said that she enjoyed learning about how science has positively changed people's lives, for example, how prosthetic limbs help people live their lives. I remember feeling that the class period was nearing an end and I did not want to end the class without resolution, thus I did not allow David to make a counterpoint. I essentially ended the class by stating he was incorrect and that Milgram (2011) was correct, "The absence of women from STEM education and careers affects more than the women; it is a missed opportunity for those fields. Women bring a different perspective that shapes and influences STEM disciplines" (p. 5).

Teaching Episode Reflection. If I were teaching in a traditional manner, I would have informed the students of the points I thought were important in the article, and the students would have listened passively. After teaching this class, I wrote in my reflective journal that I believed this lesson I had run was effective. I began by seeking student opinion. During the discussion it appeared to me that the students clearly understood the issue and felt free to express their perspectives.

Unfortunately, during the discussion about the article, I did not seem to value David's point of view. "When a student focused on an aspect of Milgram's argument that differed from my understanding, I reacted in an authoritarian manner" (Reflective Journal, p. 75). The class was coming to an end, and instead of encouraging David to reflect on the points made by the author and reflected by his female classmates, I essentially told him that focusing only on numbers was wrong. I did not want the students to leave class with the idea that forcing equal numbers of females and males into STEM was the most important point in the article.

Within one teaching episode, I both followed and failed to follow Brooks and Brooks' (2001) advice to value the students' points of view. I began by seeking students' points of view and concluded by invalidating one student's point of view. In my reflections, I indicate that I felt I had sufficiently failed to shift my pedagogy during this activity, yet I also note that it "appeared that my students felt safe" (Reflective Journal, p. 75).

I see that I did not consistently allow the students' understandings to steer the discussion when their interpretation did not match my understanding of the ideas presented by Milgram. I treated the article like a textbook that contained only correct answers. If I had respected all the students' arguments, I could have guided the discussion differently. I could have asked, "Instead of focusing on percentages, what are the positive and negative aspects of this type of affirmative action?" I now feel that guiding the students toward this point of view is acceptable. Regrettably, I did not guide; I informed the class of the "correct" perspective.

I discussed this teaching episode with one of my critical friends, who pointed out that there are a number of unconscious biases impacting the issue of STEM. She agreed that it is something that a science class should examine, and also that I did not guide my students to explore their hidden biases. What deserves closer examination are the obstacles that females experience in STEM fields. I did not facilitate this examination in my lesson. I can now see that we could examine the hidden ways that females are discouraged from entering STEM courses and examine the things that science teachers could do to make positive change, for example, when interacting in groups, teachers could encourage girls to manipulate an apparatus, not watch and record the results made by males.

In a future class, I should consider preparing myself to accept views that are counter to my own. When seeking student perspectives, I would like them to feel that their opinions, although different than mine, are valued. This can be time-consuming and, as in this case when the class was almost over, I quickly resorted to what was efficient. Telling the students what I believed they needed to know was efficient. Timing, within my classes, is something I need to work on.

Congruent finding: Seeking math perceptions.

Lead-up to the teaching episode. Many of the science education students in my course are also working to obtain a mathematics education minor. Therefore, when planning for this lesson, I chose to add an activity that encouraged these students to voice their opinions regarding mathematics teaching strategies and then present an alternative to the traditional teaching style that I anticipated they would report.

I planned to begin this part of the lesson by asking my students to describe their own math learning experiences and their perceptions regarding the effectiveness of that teaching approach. After establishing their understanding of that experience, I planned to point out that some teaching authorities would like us to add non-traditional activities into our programs—for example, problem-based math activities.

To illustrate this non-traditional type of activity, I prepared a problem-based activity to elicit student perspectives. I chose to challenge the students with the Monty Hall problem that was used in the Let’s Make a Deal television game show. I presented the problem and then asked them to solve it in any way they desired. Weisstein (2019) provides a description of the problem:

> Assume that a room is equipped with three doors. Behind two are goats, and behind the third is a shiny new car. You are asked to pick a door and will win whatever is behind it. Let’s say you pick door 1. Before the door is opened, however, someone who knows what’s behind the doors (Monty Hall) opens one of the other two doors, revealing a goat, and asks you if you wish to change your selection to the third door (i.e., the door which neither you picked, nor he opened). The Monty Hall problem is deciding whether you do. (para. 1).

After the students presented their arguments for why they would open a new door or not, I planned to ask them if they would use questions like this in their classroom and why or why not.

What happened during the teaching episode. The mathematics experiences described by my students reflected Brooks and Brooks' (2001) description of a traditional classroom. Their teachers lectured, modelled how to complete textbook or workbook questions, and then provided class time for independent and, sometimes, group practice. When asked how they envision teaching in the future, my students said that they planned to teach as they were taught.

When I pointed out that teaching authorities, including Alberta Education, suggest that we should include alternative teaching activities, multiple students voiced skepticism. One student stated she hoped her school district would not require non-traditional teaching and that she heard that some teachers are retiring because of curriculum changes. Nevertheless, when I asked if the traditional teaching method engaged their high school classmates, many education students stated that traditional teaching did not engage the students as much as they would like to engage their future students. One stated that he believed that high school students simply did not understand how struggling with mathematics would help them in their lives. I responded, is this a teaching problem or a student problem? If we taught differently could we change this attitude? The facial expressions of my students revealed that they did not see how changing teaching practices could engage those who were not currently engaged.

I then described the Let's Make a Deal show and the Monty Hall problem. My students immediately stated that this type of activity would be preferable to another worksheet. Next, I asked the students to solve the problem. They could solve it however they liked. One took out a sheet of paper and started drawing while others began to use their calculators. I encouraged them to make a choice (open the first door they chose, or switch to another door) and then explain why they had made that choice. Although my students appeared confident when describing their thought processes, they could not agree on a solution.

Next, I played a video clip in which a professor (from the Department of Statistics at the University of California, Berkeley) explained what she thought was the best choice. In the video, she indicates that not all mathematicians agree with her solution. I asked my students if they agreed with the professor. Not only did some disagree with her, they disagreed with each other as to why they did not believe her. We did not come to a consensus, and one student said that he was going to research this question over the weekend.

During the debriefing teaching strategy, I asked the students if they would use the Monty Hall problem in their classrooms. Multiple students stated that they found the problem fun and would use it if they taught about probability. One student suggested that she could use the problem when she taught about probability in genetics. Others were unconvinced. One student acknowledged that the activity was fun, and then asked, can we do this with every outcome?

Teaching Episode Reflection. My intention for this activity was to encourage my students to think about how they will teach in the future. In this regard, I believe it was a success. I also met my goal with regards to teaching by seeking and valuing the students' points of view. I introduced the Monty Hall problem to encourage my students to examine their own perspectives about using problem-based strategies to teach math. During the debriefing, I accepted their points of view by allowing them to wrestle with the idea that this engaging question was time-consuming. They would be required to balance how much time they allocated to this type of teaching.

My students' description of their high school experiences is not surprising; each of them had experienced only traditional teaching. Their common experience provided validation as others described their plans for the future. It was interesting how much excitement the Monty

Hall Probability Problem created. Each student worked hard to solve the problem and then passionately sought to convince his/her classmates that his/her choice was best.

These students had all succeeded in high school mathematics, that is, they had at least met the minimum requirements of the program, while those in the math minor program likely excelled in mathematics. In this lesson, I asked my students to evaluate a teaching technique that was different from the one at which they had succeeded. During the debriefing, I believe that they saw the advantages of alternative teaching techniques. When my students reflect on this activity in the future, I believe that they will remember the feelings they experienced during the activity and how positively it was perceived by their peers.

At one point I almost fell back into my traditional teaching role. When the students began presenting their choices and explanations for how they would answer the Monty Hall game question, I began to provide the "correct" answer. I stopped myself, even saying to the class that I should not be pushing my point of view. Nevertheless, in my reflections, I noted that I felt that at times I preached (Reflective Journal, p. 86). My personal bias influenced the extended discussion we had regarding the need to create math lessons that require more than using algorithms to find the correct answer. Although my students appeared to accept this sentiment (they nodded their heads, etc.), they said many times that other than adding questions like the Monty Hall problem, they could not envision teaching mathematics in a manner other than the way in which they had been taught.

Synthesis of Findings: My Practice and Brooks and Brooks' Third Principle.

My analysis of the data specific to Brooks and Brooks' principle of seeking and valuing students' point of view indicates that there were a few instances where I allowed the high school students to share their perspectives. I assumed that seeking the students' understanding of concepts and adapting classroom instruction would be easy. When I taught the high school science class, I knew what the students did and did not believe about climate change because I had administered a survey on 15 common environmental science misconceptions. However, for whatever reason, I did not take full advantage of this information in planning my lessons and only addressed some of the misconceptions. Also, I did not provide opportunities for them to discuss beliefs about climate change.

Although the Science 10 curriculum provides many openings for students to express multiple perspectives in discussions about science, technology, and social issues, I rarely encouraged the high school students to express their views. In the future, I need to ensure that I plan activities and questions to encourage students to share their perspectives. I need to work on strategies to facilitate those discussions and be careful not to dominate or stifle the conversation.

During the university teaching experience, the data indicated that I often elicited and respected the students' points of view. The preservice teacher post-course interviews provided validation, as the students reported that they felt safe presenting beliefs in the classroom that differed from mine. The two students interviewed were very appreciative of my efforts specific to this principle. David emphatically stated, "I think it was refreshing just to speak your mind, be able to express and not be afraid, have that voice in you and express it" (Student interviews, p. 7).

I also asked these students if they believed they were able to implement Brooks and Brooks' third principle in their practica. Victoria responded, "For sure. I taught Science 20 and Religion 35. The group of students that I had were very opposed to religion, so I went in there with the position that it's okay if you want to believe something different than I do or what I'm presenting. I feel like a lot of students caught on to that, and they were okay saying 'okay, I don't agree with that' or 'why this, why that.' I thought that was cool that they felt okay to question" (p. 13). I believe I have had some success in implementing this principle, however inconsistently, as my actions in the teacher education course were well received by my students. In the future, I believe I could increase the depth to which my students express their points of view if I also show vulnerability by expressing my point of view. If, early in the course, my students see that I trust them by voicing my perspectives, they may also feel safe to express theirs.

It is evident that implementing this principle was much easier for me in the teacher education course than in the high school science course. I often told the high school students my opinion but held back more with my university students. I am not sure if it was because I believed the high school students did not know enough to voice an opinion or if I was concerned about the content we had to get through. Either way, I made assumptions that resulted in treating the high school students like blank slates.

Adapting Classroom Activities to Address Students' Suppositions

This section contains the data that reflect Brooks and Brooks' (2001) contention that constructivist-oriented teachers should identify students' understandings and adapt their instruction to challenge the students' suppositions. When explaining this principle, these authors state, "All students, irrespective of age, enter their classrooms with life experiences that have led them to presume certain truths about how their worlds work" (p. ix). In this study, I defined suppositions as presumed truths about the world.

Students' suppositions can be identified during student-to-student communication or student-to-teacher communication. In this section, I also report on teaching episodes of student-to-student interactions during the POE strategy. This is one way to support the identification of student understandings as well as to allow these understandings to be challenged.

High school teaching experience.

Incongruent finding: Will Sea Levels Rise?

Lead-up to the teaching episode. When examining how climate change may impact humans, it is important to consider the influence that rising temperature has on water. I planned to begin the class with a demonstration that I believed would challenge the students' understandings of what happens to the volume of water when it is heated. One misconception that we had discussed earlier was that the melting of icebergs would not cause a rise in sea level. I planned this lesson to examine another possible explanation for rising sea levels (i.e., the expansion of liquid water when heated). I planned to use a POE strategy to draw out the students' understandings and then challenge them with the results of a demonstration.

Prior to introducing the demonstration, I planned to ask the students if they believed that sea levels are rising. If they answered yes, I would ask why the levels were rising. After a discussion of the possibilities, I would introduce the demonstration.

The demonstration: An Erlenmeyer flask filled with water and crushed ice was sealed with a cork. The cork had one hole with a glass tube extending from the bottle of the flask to 10 inches above the cork. This was placed on a hot plate and heated slowly, past the point at which the ice melted. After the apparatus was set up, the students' attention was directed to the water level in the glass tube.

I planned to use the same POE procedure I used earlier in the unit. The students would first individually predict what would happen to the water level inside the flask as the ice/water mixture was heated. Next, while the mixture was heating, the students would share their explanation with a peer. Finally, when the demonstration was complete, the students would record and explain the actual results. I hoped to surprise the students with the results of the demonstration or connect the results to concepts that we had discussed in the previous class with regards to what happens to liquids as they are warmed.

What happened during the teaching episode. I began this activity by asking if sea levels are rising. Felix immediately said water levels are rising, while Tom and others agreed. I confirmed that the levels are rising about three mm a year. I then asked, since this is so small, does it really matter? Sophia replied that it does if it happens every year. When asked to explain the rising water levels, the students suggested that melting icebergs and glaciers were a possible cause. At this point, I brought out the flask and hot plate.

I asked three students to conduct the demo. They filled the flask with ice water while I handed out a paper and the students wrote their predictions. After the students wrote and discussed their predictions with peers, I asked for volunteers to voice their opinions on what they believed would happen when the flask was heated. Felix predicted that the water level would drop because the ice would melt and the volume of ice is larger than liquid water.

While the mixture heated and the ice melted, the students did not appear surprised or even interested. I attempted to create interest by stating, “It appears that the water level is dropping in our experiment, as Felix predicted. If we apply this to the world, shouldn’t the sea levels be decreasing? But the levels are rising. Do you have any ideas why?” The students did not have an explanation. I then asked, “What will happen when all the ice is melted and the water continues to heat?” Andrew suggested that everything in the Erlenmeyer flask would “scrunch down” and become even smaller.

I planned to allow the demonstration to continue, therefore possibly surprising the students as the water level eventually began to increase. I did not wait. I asked, “What happens to the atoms when the air is warmed?” Chloe stated that atoms move faster. I then asked, “Will the water molecules get farther apart as they heat up?" With additional questioning, I was able to direct the students to the theoretical understanding of why global water levels would rise when the temperature rises. Warm water takes up more space than cold water. We then watched the water levels in the demonstration rise 25 centimetres above the flask and overflow.

The demonstration confirmed what I had just taught.

Teaching Episode Reflection. Although I planned for a teaching activity that challenged the student's suppositions, I did not implement the lesson as planned. I did not allow the students to be surprised by the expanding water. I explained what would happen before it occurred. I did not wait.

The students were able to predict that the level of water in the pipette would decrease as the ice melted, yet none predicted that the water level would rise after the ice completely melted. This is exactly what I thought would happen, yet I did not wait for the experiment to conclude before I informed the students of what was happening.

When teaching the lesson, I used the questions that I believed would uncover the students' prior knowledge and understanding, yet as I watched the video recordings of my teaching, it is not clear why I did not allow the students to develop their own understandings. It appears that I feel the need to inform the students about what they need to know. After the class, I recorded in my Reflective Journal, "I need to accept the role of a facilitator as I help students make connections while using constructivist strategies" (p. 29). My actions in this activity reflect the idea that teaching is telling. My teaching reflected a traditional approach. I believe it would be helpful to let the students have more control over their learning. In doing so, I could adapt the learning activities to more strongly reflect their suppositions.

Incongruent finding: Water chimney activity

Lead-up to the teaching episode. An important issue in climate change is the impact that temperature has on water. I intended to use the POE strategy to identify the students' suppositions and then adapt my line of questioning based on their understandings regarding how density changes impact water movement. I planned for groups of students to conduct a POE experiment, while individually recording their POE responses. First, a student would place a small jar filled with coloured hot water into a two-litre bottle. Water may move into or out of the small jar through two straws embedded in the lid. Second, the large two-litre bottle is filled with room temperature water. I planned to walk around the room placing an ice cube into each two-litre bottle.

After conducting the experiment, I would encourage the students to explain their results. Based on their explanations I planned to ask questions that encouraged them to develop an understanding of movement based on density. For example, what was the temperature of the water that rose (and dropped)? What does temperature do to atoms of water? Does this happen for all liquids?

What happened during the teaching episode. When asked to predict what would happen in the experiment, Tyler suggested that the high concentration of dye in the small jar would diffuse into the low concentration two-litre bottle. I agreed that the dye would slowly move out of the jar based on a concentration gradient. I then asked if the water temperature would affect the movement between the bottles. Three students explained why temperature might affect the movement of water. Emile suggested that the hot water in the small bottle would have higher pressure, and Mia said she thought that the water and dye would slowly mix, "creating an equilibrium."

I encouraged the student to test these explanations by conducting the POE experiment. The students then followed the POE procedure, recording their predictions and explanations prior to initiating the experiment. While conducting the activity, a few students requested that I provide them with the correct answer. I did not tell them the answer, but suggested that they work as a group to determine an explanation. These students were not happy with my response — one suggested that it was my job to tell them the right answers.

In their groups, the students examined whether the results of their experiments matched their predictions. I walked around the class placing the ice cubes in the 2-litre bottles, and I commented that the ice seemed to affect the movement of the dyed water. Then I asked each small group to explain if their predictions were accurate and how they might change their explanation based on the experiment results.

I felt, at the time, that the students understood that changes in temperature caused a change in density, resulting in the rising and later descending dyed water. Unfortunately, time did not allow a class-wide discussion of the results during this class period. Instead, I called the students' attention to the front of the room and explained why the dyed water rose and then descended. The class ended as I spoke about the hot and cold water.

Teaching episode reflection. I began this teaching episode by encouraging the students to identify their understandings, yet as the POE activity concluded, I informed the students of the correct understanding. Not only did this teaching episode illustrate how I quickly fall back into a traditional teaching approach, but it also illustrates that I mistimed the completion of the activity. I did not allocate enough time for group discussions and for the groups to present their predictions. In the past, I controlled the time of activities effectively, yet my time management of constructivist-oriented activities appears to be weak. In the future, during my planning of constructivist-oriented activities, I will think back on this experience and allocate more time for student-student discussions.

University teaching experience.

In the following episodes, the data reveals my efforts to look for and react to student understandings. Specifically, I began this course with the desire to challenge my students to think differently about how they would teach in their future science classrooms.

Incongruent finding: Challenge students' supposition regarding teaching.

Lead-up to the teaching episode. This teaching episode occurred in the second class period of the C&I course. I anticipated that my students would enter this course with traditional teaching beliefs; therefore, during this lesson I intended to challenge this understanding by presenting an alternate perspective. My specific purpose for this activity was to introduce the constructivist learning theory and encourage my students to consider the possibility of teaching with constructivist-oriented pedagogies.

I planned to open the activity with a general question, "What do you understand about constructivism?" Likely the students would not have a clear picture of what this means, so I planned to distribute a one-page description of Brooks and Brooks' (2001) five teaching principles and use it to challenge the students' traditional perspective about teaching. Finally, I would encourage my students to examine constructivist-oriented pedagogies that they might find useful.

What happened during the teaching episode. When asked the question, "What do you understand about constructivist pedagogy?" the class responded that they did not know anything about this type of pedagogy. One student began to guess, "It has to do with the construction of something" (Reflective Journal, p. 73). I handed out a one-page description of Brooks and

Brooks' principles and then provided a brief description of constructivism and constructivist-oriented pedagogy. I stated, "First, prior knowledge is sought and, based on that understanding, teachers encourage students to add to their knowledge. Teachers also help students reshape or transform personal understandings as new information is encountered" (Reflective Journal, p. 73). I concluded that constructivist-oriented teachers believe that students need to be actively engaged in the process of learning, that we learn less by being passive observers.

My students indicated that they accepted this view about learning. Some agreed by nodding while others stated that the approach made sense. I then asked if they believed that our minds worked like computers. That is, when presented new information, does each student input identical information into his/her mind? One student pointed out that we come from different backgrounds and that even our genetics are different. This would prevent the input of knowledge from being the same for everyone. Another student responded by stating that she believed that our past experiences also impact our current learning experiences. I then asked, do you think that knowledge is given (by the teacher) or constructed (by the student)? At this point in the class, my students stated that knowledge is constructed.

After the group indicated this understanding, I pointed out that many teachers do not teach with this perspective. Traditional teachers want their students to remember the content exactly as it was described. I asked the class, "Is that how you were taught?" Next, I encouraged my students to contrast the differences between a traditional lecture and our discussion. "Would a traditional lecture allow their students to explain their understanding of concepts?"

Finally, I sought to challenge the students' understandings by asking if a constructivist approach seemed plausible for their future classrooms. They agreed that this type of teaching seemed to fit how they would like to teach.

Teaching Episode Reflection. Following this lesson, I was confident that I had successfully introduced Brooks and Brooks' (2001) principles and that I had challenged my students to consider the possibility of teaching with these principles in mind (Reflective journal, p. 75). As I analyze the data now, although I allowed the students to present their understandings and then I responded to each of their statements, I am less confident that I identified and challenged my students' understandings effectively. That is, we did discuss constructivism and Brooks and Brooks' principles, yet I was "selling" the idea that a good teacher used a constructivist approach.

Nevertheless, I provided an activity where I sought the students' understanding of constructivist pedagogy and then established my response based on their comments. I challenged some of the students' understandings and provided a new way to view teaching. Thus, I exhibited some of the teaching qualities that Brooks and Brooks' (2001) fourth principle proposes.

This group of students had no understanding of what constructivism meant; therefore, their acceptance of the learning theory was superficial. The lesson could have better challenged their understanding if I had spent more time searching for their experiences that reflected constructivist-oriented teaching, experiences that they may now interpret as excellent or ineffective teaching. I did not connect the concept to their past experiences, therefore, do not believe that I challenged their thinking deeply.

Additionally, my teaching approach during the lesson leaned towards the traditional. I informed my students that I would teach from a constructivist perspective, yet I provided much of the information and told them when I believed they were right. Today I wonder why I ended up teaching traditionally while intending to model a constructivist perspective. I entered this class believing that it would be easy to state and then model the principles. I underestimated how much I needed to prepare for this lesson.

Congruent finding: Developing a teaching philosophy.

Lead-up to the teaching episode. I created this activity as a direct result of a discussion with my critical friend (CF1). I explained to her that my science preservice teachers often chose to present didactically, almost ignoring the learner. CF1 acknowledged that the new teachers she hires inevitably revert to a lecture-based teaching style that ignores student input. She suggested that I model a class in which my students would work in groups. She suggested that I give them some scenarios to work on together. Ask them to work in small groups, she suggested, and allow them to examine their understandings. This may allow them to see that student input is important.

I applied my CF1's advice during the fourth class of the teacher education course in which my students explained their personal teaching philosophies. I intended to allow my students to identify their understandings. Then I planned to encourage them to deconstruct their understandings by identifying whether their intended behaviour reflected a traditional classroom or an inquiry-based classroom.

My intention was to help my students develop an understanding that their teaching philosophy influences pedagogical decisions. That is, there is an explicit connection between values and beliefs and our teaching decisions. Also, as we would be examining their peers' reactions to the teaching scenarios, I wanted the students to realize that there are multiple perspectives. These perspectives are not really right or wrong. Yet, I did want my students to understand whether their beliefs regarding teaching aligned with traditional teacher behaviours or inquiry teacher behaviours (Using Hammerman's (2006) self-evaluation survey tool).

I planned to present three teaching scenarios to draw out the students' understandings. Individually, the students would choose a response to each scenario, pair up to discuss and defend their position with a peer and, finally, present their combined points of view. I hoped to encourage my students to leave the class with a more developed acceptance of others' points of view. The first teaching scenario: Friday the students will collect water from a nearby pond. Monday the students will examine the life in the water. Over the weekend, the heating system fails. The water freezes. What do you do on Monday? 1) Skip the pond life lesson, 2) Instruct the students to read about pond life in the textbook, 3) Spend the class looking for other forms of life, or 4) Ask the students to look for life in the water.

I did not intend simply to categorize what the students believed but rather to examine their beliefs as they justified their choices. Specifically, I aimed to examine the attributes of instruction that they envisioned for their future classrooms.

What happened during the teaching episode. To initiate this activity, I provided a paragraph-long handout of the first teaching scenario. The handout also included four teacher responses. I asked the students to read the scenario, make an individual decision regarding how they would react to the scenario, and then discuss their individual decision with a peer. "Do you agree? Explain your rationale to your partner." When it appeared that the pairs had reached a consensus, I provided two more scenarios for them to examine and determine how they might react. The following is an example of a scenario that encouraged the students to perceive how one's teaching philosophy impacts teaching practices:

> It's Monday, and you planned to guide your student through an examination of life in a pond. On Friday, the class collected water from a local pond. Over the weekend, the heating system failed and killed everything in the water. What would you do? Skip the

> lesson on life in a pond, tell the students to read the section of their textbook that explains pond life, instruct the students look for other life on the school grounds, or ask the students to look for life in the water, and when they realize that there is no life, ask them suggest why there is no life in the water. (C&I handout)

Next, I asked if we could decide on a course of action as a group. As the whole class debated the solutions for each scenario, the discussions focused on their justifications for their choices. I asked questions and sought clarification, but I did not provide a correct answer. For example, I asked if the suggested solution would work if a course had a very specific outcome that was required to be met, or if the students were of low/high academic standing.

The chosen solutions for the scenarios depended entirely on the individual's teaching approach. In general, one group of students argued for traditional teaching practices that sought to ensure that a student learned the correct content, while and another group focused on stimulating students with inquiry-like problems. Thus, we concluded the activity with multiple acceptable solutions for each scenario.

Teaching Episode Reflection. As I conducted the activity, I felt good (Reflective Journal, p. 79). I had initiated a lesson that identified student understandings and conducted an activity based on their understandings. I plan to conduct a similar activity in my future courses. Examining scenarios allowed the education students an opportunity to present their understandings and justify their choices. I allowed the students to use their prior knowledge and then cooperatively we sought solutions for the scenarios. I feel that I met my goal which was to challenge my students to develop a better understanding of how their teaching philosophy will influence their teaching.

Based on the data, I classified this teaching episode as congruent with the constructivist approach advocated by Brooks and Brooks (2001). I identified the students' suppositions and conducted an activity based on the students' understandings.

Encouraging multiple perspectives and justifications was effective, yet today I believe that I could better challenge the education students' suppositions. This particular activity could help my students more if I were to choose teaching scenarios that targeted specific teaching approaches. I believe that deeper debates would result if I were to select scenarios that illuminated the contrast between lecture and inquiry. If positive aspects from each view were noted by the education students, it may encourage them to develop more tolerance for teachers with differing perspectives.

Synthesis of Findings: My Practice and Brooks and Brooks' Fourth Principle.

At the high school level, teaching inconsistencies are present in the data pertaining to Brooks and Brooks' (2001) principle of adapting classroom activities to challenge student suppositions. Overall I did not alter my instruction based on my interactions with students. For example, when misconceptions came up that I had not anticipated, I did not have a good series of questions to use.

A second finding that can be drawn from the high school teaching episodes is that I lacked the skills to do a good job facilitating constructivist-oriented activities. Specifically, I often misjudged the amount of time required and was impatient at the slow pace. Therefore, although I planned to act as a facilitator, I taught didactically in order to cover material expediently. It is possible that this reflects impatience. When the high school students wrestled with a new concept and a lesson slowed, I felt pressure to give students the correct answers.

The data from the university course suggests that I was better able to facilitate activities that challenged student suppositions, although this was inconsistent throughout the course. I encouraged the education students to reveal their understandings and cooperatively examine their responses. I acted less like the expert; instead, I encouraged the students to accept the ambiguity of situations, allowing them to examine their own personal theories. Nevertheless, I often overlooked opportunities to challenge my students' suppositions.

Berry and Loughran (2012) suggest that teacher educators must be explicit with their intentions, thereby allowing preservice teachers to critically examine various teaching strategies. I informed my students that I personally found that a constructivist perspective matched my beliefs and that I was eager to examine this perspective in the university course. In general, I did encourage my students to examine their strongly held teaching beliefs, although I could have developed a more explicit approach. The teaching episodes examined suggest that at times my lessons only superficially examined and challenged my students' thinking. Although I found I could elicit student responses and provoke discussions with the education students, the situations I presented did not always facilitate deep discussions of specific issues. Often the issues discussed were overly simplified. In the future, I would like to develop better teaching strategies that encourage students to evaluate and defend understandings. For example, unlike my lesson where I randomly chose teaching scenarios to examine in class, I would like to develop lessons that delve more deeply into the issues that my students find pressing, for example, how to introduce the concept of evolution in a Christian school.

Assessing Student Learning in the Context of Teaching

Constructivist-oriented teachers create classrooms where "the student is not assessed in isolation, but in conjunction with the teacher: both learn as a result of assessment" (Brooks &

Brooks, 2001, p. 87). The student gains a deeper understanding of the content, and the teacher gains an understanding of the student's current thinking. "Student conceptions, rather than indicating 'rightness' or 'wrongness,' become entry points for the teacher" (Brooks & Brooks, 2001, p. 88). In the following sections, I describe two learning episodes from the high school teaching experience and two from my university teaching experience that speak to assessing student learning in the context of teaching.

High school teaching experience.

Incongruent finding: Introducing the greenhouse effect.

Lead-up to the teaching episode. In the high school lesson from which the first example is drawn, I planned to encourage student knowledge development of the greenhouse effect through the use of formative questions. In general, I wanted the students to envision the atmosphere as an insulating blanket that envelops Earth. Specifically, I intended to encourage the students to differentiate between the impacts of short- and long-wave (high energy vs. low energy) radiation on air temperature. I chose to meet these intentions by using two analogies, a greenhouse and a car. I planned to discuss how these two objects are similar to our planet.

The activity was to begin with the presentation of a picture of a greenhouse and a car. The illustration indicated that the temperature inside each structure was significantly greater than the outside air. Arrows, indicating light waves, extended from the sun to the car/greenhouse. The entire text from the lesson plan reads:

> There are two analogies that may help us look at how heat is retained by Earth. Show the two pictures. Only a few of us have been in a greenhouse, yet we all have sat in a car that has been in sunlight. Show the students pictures of both greenhouse and a car with the sunlight shining on them. Why do you think that the energy can enter the car, but cannot

leave? Does the idea of a blanket around the Earth fit with the GHE [Greenhouse Gas Effect] analogy? (High school lesson plan 5)

The lesson plan does not include any additional planned questions or instructions for this activity. I assumed that I would ask questions based on student interactions.

What happened during the teaching episode (Video 6, Part 2: 27:30 - 37:52). After projecting the picture on the whiteboard, I drew the students' attention to the car, asking if anyone had recently entered an extremely hot car. Many of the students groaned as they reported that their car had been very hot on that particular day. Next, I (TB) asked, "What is happening here? There is obviously energy coming into your cars. Why isn't it leaving?"

Zack: The light was magnified.

TB: That would explain it if we had a lens. The window is not a lens so that would not explain it in this case. The light is not focused on one little spot in the vehicle. But that is a good guess.

Will: Is it because the cars are insulated?

TB: You're thinking that the heat can come in, but it cannot get out because it is insulated. What part is insulating it?

Will: The leather seats… the interior of the vehicle

TB: Oh, you're thinking that the seats are holding the heat and not letting it back out [I did not complete my sentence before Ben asked…]

Ben: Is the light just reflecting around inside the car?

TB: Yes, somehow it stays inside the vehicle, and [points towards the picture of the greenhouse] stays in the greenhouse.

TB: This is a problem that most of us have not thought about, so it is not surprising that we do not have a clear understanding of what is happening. Heat is coming in the windows. Why doesn't it leave through the window? [The students started guessing, but when I turned and looked at the clock, I continued to the next question without responding to the suggestions.]

TB: Should I tell you how it works? [The students agreed, but before I explained the phenomenon, Zack made a suggestion.]

Zack: Is it like that thing when the light disperses into a bunch of different forms?"

I affirmed his statement that the greenhouse effect is impacted by different types of light. Then, after looking at the clock again, I stated, "I do not think we have enough time for you guys to come up with the reason" (Video 6, Part 2, 34:21). I stopped asking questions and simply explained how Zack was on the right track, that sunlight has a spectrum of different waves. I explained how high energy waves go straight through the window and air in a car/greenhouse, eventually hitting the interior. The high energy waves warm the surfaces, causing infrared (heat) waves to be emitted. Infrared waves are then absorbed by the air in the car/greenhouse, preventing the heat from leaving the vehicle.

Teaching Episode Reflection. Although the plan included a few questions, the video recording of this teaching episode revealed that I used a number of formative questions to search for student understanding. Based on the students' answers, I asked more questions or provided more explanations. However, consistent with the majority of the high school activities that I analyzed, most of the questions I asked did not help the students to develop a deep understanding of the concepts. The purpose of my questions was to enable me to speak more. The questions set up what I intended to say next. I sometimes even ignored student responses, while at other times I explained that their concept was wrong. I did not encourage students to connect new concepts with their current understandings. For example, although Zack stumbled upon a connection between concepts, I did not ask questions that led the students to recall what they had previously learned. (In a previous physics unit they had examined high energy and low energy waves.)

Following the class, I noted that I could have asked more questions, guiding the students to develop an understanding; instead, I provided the details of the mechanism (Reflective Journal, p. 30). I could have ferreted out their understanding of the light spectrum and compared the types of wavelengths entering the car and leaving the interior surfaces. I could have said, “Zack suggested that light may come in different forms. Is there anything from your study of the spectrum (in the physics unit) that may help us understand what is happening here? How does the energy entering the car change before it attempts to leave the car?” Based on their earlier studies I could have led the students to identify the difference between infrared and ultraviolet waves; I could have asked questions such as, “Do the windows in your house keep heat in your house?”, “How is it that you feel warm when sunlight comes in the window?”, and “Shouldn’t the window keep the heat out, too?” This would have encouraged the students to wrestle with the concepts and make the connections instead of passively listening to me.

As Moate and Cox (2015) point out, instructors should not immediately answer questions. I rarely probe for deep understanding and I often answer the questions I ask. In this case, when the students made suggestions as to why the car was heating up, I listened. However, except for Zack’s comment, I did not use the students’ suggestions for further investigation. Instead, I provided the answer. I could have deferred to the collective knowledge of the class. After Zack’s suggestion, I could have followed up with more questions. Instead, I provided the answer, possibly because I believed that the students could not come to a deep understanding of the concept without my help.

I entered this activity with the belief that since I understood the greenhouse concept, it would be easy for me to ask the right questions. This assumption was incorrect. If I had used the set of questions I had suggested earlier, I could have encouraged the students to recall information and actively construct new understanding. This teaching episode suggests that I struggle with allowing students to take an active role in their own learning. I did not meet Brooks and Brooks' (2001) principle. I did not assess student learning in the context of teaching, thereby allowing them to explain what they knew and inform my questioning.

Incongruent finding: Questions of rain production.

Lead-up to the teaching episode. During this teaching episode, I planned to transfer the understandings gained from an earlier lesson (*Water Chimney Experiment*) to the phenomenon of rain production. During the previous experiment, the students had examined the cyclical movement of water particles due to temperature differences. I intended for the students to combine two concepts, movement of cold/warm atoms based on density, and condensation of water as the air cools. I expected the students would leave the class with an understanding of how rain is produced.

I had planned for this interaction to occur immediately following the experiment, but because of time constraints, I moved this discussion to the beginning of the next class. Due to the direct correlation between water movements and air movements, I allocated only 10 minutes for this discussion. First I planned to draw a picture of light striking the ground, heating up the air in that area causing the air to rise (i.e., a low-pressure area). I would then draw arrows from the ground to a cloud, indicating that the air would eventually produce rain. Next, I planned to ask the students if they could see the connection between the concept of moving liquids and the concept of moving air. I planned to use the students' answers to inform my questions.

What happened during the teaching episode. When I drew the picture on the whiteboard, one of the brightest students in the class, Chloe, stated, "It makes no sense." Chloe was visibly frustrated that she did not understand the picture. She recalled a peer explaining that water rose due to high pressure in a small bottle. I drew the opposite in my picture of rain production. My drawing indicated that warm air rose, resulting in lower pressure. The following is an interaction between a student (Chloe) and myself (TB) during this activity (Video recording, Class 4, 16:50-20:55).

TB: [Referring to a picture of the experiment] "Looking at the atoms inside the warm bottle, would the atoms be closer together or farther apart?"

Chloe: Farther apart.

TB: Ok, would this cause the density to increase or decrease?

Chloe: Decrease.

TB: That would mean that the atoms would rise, right?

Chloe: Yes.

TB: If some atoms move out of that area, what would that mean? Would there be more pressure in this area or less?

Chloe: Less pressure.

TB: That means other atoms will rush into this area. Does that make sense?

Chloe: Yes.

TB: This occurs in our atmosphere [I refer to a picture drawn on the whiteboard]. What happens to the air that rises? Will it heat up or become colder?

Chloe: Colder.

I then stopped asking questions and simply explained the concept. Cool air holds less moisture than warm air. When warm moist air rises, it cools, creating clouds, and possibly rain. I asked Chloe if this made sense. She nodded and appeared to understand. I did not check with Chloe's peers before moving on to the next activity.

Teaching episode reflection. I began this teaching episode in accordance with Brooks and Brooks' fifth principle. I sought to assess student understanding, or lack of understanding, in order to inform my teaching. Yet when Chloe showed her frustration, I became frustrated. I entered the classroom believing that my students would easily transfer the previous lesson's concept to the next concept. Since one of the top students expressed frustration, I felt that I had failed. What would prevent these students from making a connection? Maybe they did not learn anything last class. As I initiated the exchange recorded above, I felt I had failed. Yet as the exchange progressed and Chloe began to show that she understood the concept, I began to relax and I quickly moved to the next activity before another student asked a question.

Although I felt comfortable at the end of this teaching episode, today I see that during this exchange I fell back into my old patterns. The high school students seemed to want me to provide a black and white, correct answer and I felt the need to provide that answer. I want to encourage students to ask their own questions and search for answers themselves without being the arbitrator of truth. Yet, in this example, I provided the one "truth." I started by asking as a facilitator and ended by teaching didactically. In the above scenario, if I asked more leading questions, it is possible that Chloe would have made the last connection between rising warm air and the production of rain. In the future, I would like to work on allowing more students to make connections between concepts without telling them the correct answer.

University teaching experience.

The following two sections examine two significant examples of assessments that reflect my intent to match my belief (Brooks and Brooks' fifth principle) with my teaching practices (assessment). The two examples discussed below were significantly affected by a discussion I had with a colleague prior to the university teaching experience. While preparing for the teacher education course, I asked my critical friend (CF2) if she had any suggestions for how I could assess student learning in the context of teaching. I described the traditional tests that I had used in the past C&I courses and my desire to assess more in the context of teaching. She began by probing for clarification, asking, "How do those tests reflect student learning" (Critical Friend Discussion, p. 7). My response made it clear that the type of learning that the students were able to demonstrate via the examinations was superficial. They could have stored much of the information in their short-term memory and then forgotten it soon after the exam. My colleague told me that in teaching methods classes, she does not give final exams. I had no response to that, for I had not considered that possibility. I immediately fell back to my past understanding of teaching and asked, "How do you create a grade?" She explained that she asked the education students to create projects that reflected the content of her course. The capstone assignment for her course was directly applicable to the students' future practice. I immediately saw the connection between her suggestion and the pedagogy that I intended to implement in my courses. Students' learn-by-doing while completing these types of assessments. They engage in real-world activities that reflect their future profession, creating personal relevance. The students were also allowed to choose the design and the content covered in their project, thus using their personal preferences. I followed this advice as I planned for my C&I course.

Congruent finding: Changes made to the mid-term assessment.

Lead-up to the teaching episode. Based on my high school teaching experience and the discussion with CF2, I sought to better align my assessments with my emerging constructivist perspective. In my past science C&I courses, the mid-term examinations were composed of multiple-choice questions, short-answer questions, and one extended-response question. The examinations were administered during one specified time period.

For this iteration of the course, I changed the mid-term evaluation, removing the multiple-choice questions and I created a take-home mid-term that was more project-based. Instead of requiring students to memorize lists or definitions, I aimed to create an assessment that encouraged them to learn about teaching science by working for an extended period of time, investigating and responding to complex questions. I still intended to use the assessments to create a grade, yet the main intent was to create an opportunity that allowed the students to learn through the process. The questions reflected my commitment to creating relevance by connecting the course content with the professional aspect of the students' future science teaching. For example, I planned to ask the students to identify an influential teacher from their past and describe what was influential about that teacher's pedagogies and how that could inform their future teaching. In another section of the mid-term evaluation, I planned to integrate my goal to create personal relevance, thereby encouraging the students to grow during the evaluation. The question tied the preservice teachers' future practice to their growing understanding of differences in pedagogy: "Describe a science activity that reflects the POE strategy. Compare the differences and similarities between a traditional classroom science experiment and an experiment using the POE strategy. Explain why/when you would use a traditional experiment and why/when you would use the POE strategy during an experiment." I intended for this question to encourage my students to identify teaching strategies that differed from those they had experienced as students. I hoped it would inspire them to test these strategies in the practicum.

I also hoped that the students would use a common method, "backwards by design," that many Alberta teachers use when planning. I introduced the concept and then asked, the students to define "backwards by design" and when they might use it. After the students themselves identified the method, I hoped that they would view the examination of this type of lesson planning as relevant to their future.

During the class period following the mid-term examination, I planned to discuss some of the questions on the exam. My intention for this discussion was to encourage my students to develop a broad range of situations in which they could use the teaching strategies we examined.

What happened during the teaching episode. Following the mid-term examination, I initiated a discussion that examined the mid-term assessment procedure. I asked my students if the alterations I made to the assessment affected them, for example, focusing on long answer practical questions and allowing them to complete the assessment at home. They stated that they believed that the examination style did indeed impact their learning experience. Victoria stated that she felt that although the take-home mid-term examination was harder, in that she spent more time working on it, she believed that she learned more from that experience than she would have from a traditional test. Another student stated that he appreciated the ability to choose the content around which he built his answers. He explained that when working on the exam, he chose subject matter he knews he would teach in his practicum. This allowed him to learn for the future as he worked on the exam.

Since I had not yet graded their examination, I asked the group to describe how they had answered some of the questions, for example, how and when would they use the POE strategy? A number of the students described a typical POE demonstration, yet one student explained that he believed that POE could be used for any hands-on activity in his classroom. When he described how he could use this strategy prior to any demo or example, his peers agreed. One student stated that she might try incorporating a POE into her science lectures.

Teaching Episode Reflection. Although the students reported that they learned while taking the examination, it is difficult to assess this assertion. One student who said she learned during the test was Victoria. She stated that she did not simply memorize facts for the exam, facts that would eventually fade, but worked on developing an understanding of practices that she believed she would use in the future.

Following the discussion of the mid-term examination, I felt that I had responded to the assessment for which Brooks and Brooks (2001) advocated. That is, the students could learn as they completed the assessment. Also, I felt that this assessment allowed my students to show what they had learned during the course, not simply prove that they had memorized a specific list of facts or procedures. In fact, I specifically added questions that encouraged them to develop pedagogical content knowledge while they completed the assessment process.

This activity worked as intended. I sought to move the focus of the exam from memorizing facts and procedures to assessing understandings applicable to the students' future teaching practices. It was gratifying that when I described this intent to my students, following the mid-term exam, they stated that they believed the exam had met this intent.

Based on the students' statements and my analysis, I feel that this type of assessment is congruent with Brooks and Brooks' (2001) intent. Although this was a summative assessment, I feel it more closely reflected a real-life situation rather than hewing to the time-worn traditional in-class exam that measured memory and not learning. In the future, I plan to include questions that will reflect specific discussions we had during the semester. The exam questions in this particular instance could have probed for better understanding if they had reflected understandings of this specific course. As for the procedure of the assessment and debriefing, I am content. I will continue to implement these procedures.

Congruent finding: Changes made to the final evaluation.

Lead-up to the teaching episode. As I sought to create congruency between a constructivist-oriented teaching approach and assessment, I changed the final evaluation for my C&I course. I substituted a project in place of the traditional final examination and planned to guide my students through a peer and self-assessment process. I made this substitution with the intent to follow Brooks and Brooks' (2001) advice to tie assessment to learning in the context of teaching.

I planned to allow a large degree of flexibility with regards to creating the final projects. I asked for a semester plan, including a unit plan and a minimum of five lesson plans. The School of Education provides teacher candidates with a template stipulating the basic requirements of a unit plan. My intent was to ask my students to create a plan that reflected information covering each category included in the template (e.g., unit outcomes, lesson plans, assessment methods), yet I would not dictate the method by which the student included these pieces in their project. I intended for my students to create a project that was unique to them. The only stipulation was to include some constructivist-oriented pedagogies.

During the final class period, I planned to guide the students through a peer-assessment, a self-assessment, and a reflective activity. This process began in the prior class period when I randomly paired students together. The pairs then exchanged final projects via Google Drive. I asked each student to submit a peer feedback paper prior to attending the final class.

The first planned activity, what I termed a reflective activity, involved analyzing a past student's final project. The pairs would use a rubric to assess the project and then discuss the effectiveness of the plan. The second activity, the focal activity of this class, was the student-to-student discussion of the peer assessment. I intended for my students to develop a deeper understanding of unit planning. By examining the different methods, each student had the potential to realize ways to improve his/her own plans. We would conclude the course with a self-evaluation. I would encourage the students to identify their strengths and weakness and would suggest a method of professional development.

What happened during the teaching episode. The reflective activity began on a positive note. The students seemed happy with examining a project instead of taking an exam. As the pairs began to analyze the past student's final project, I watched them realize that the project I provided lacked some crucial details. For example, only one lesson plan was present. The pairs used a rubric to assess the student's project and then discussed their assessment. They did not like the project. This is boring, one student said. Another commented that the project did not include any POE activities and that the lesson was entirely written from the teacher's point of view.

As a class, we compared the results of the rubrics. When individual groups assessed portions of the sample project differently, I asked them to explain their evaluative process.

During the entire process, my students appeared engrossed. This established the tone for the one-on-one discussions of the peer feedback (Casey, D. et al., 2011) portion of the activity.

I provided a printout of the personal peer feedback for each student. I then provided time for the pairs to read and discuss the feedback. Although this activity was significantly different from traditional assessments, the students readily accepted the task. They appeared to want to provide authentic feedback as well as help their partner grow. This section of the class lasted approximately 20 minutes.

The students then completed a self-evaluation.

Teaching Episode Reflection. I felt that the final class began successfully and that the sandwich feedback (peer-review) procedure stimulated a lively student-to-student discussion. I felt gratified that although the activity deviated significantly from my past practices, the students cheerfully completed it. The students appeared to learn during this process, for I saw that "the students recognized when their peers failed to plan with a constructivist or student-centred perspective, yet they did not realize that they themselves displayed the tendency to plan for didactic teaching" (Reflective Journal, p. 103). The peer-to-peer discussion provided an opportunity for the students to see this oversight.

During each of these activities, I felt that I was succeeding in assessing the students as they learned. Although this was the final class, during the activities I guided the students' learning and encouraged them to reflect on their future practice (Hannafin & Land, 1997; Jonassen, 1992).

The result of this project and the final class matched my intention. In reflection, immediately after the course, I felt that the final project provided the students with an opportunity to exhibit their knowledge and skills while creating a product they could use in their future teaching (Reflective Journal, p. 104). The last class of the C&I course also demonstrated a change in my assessment pedagogy as a result of my desire to close the gap between my teaching beliefs and practice. The students' final project became the capstone product that guided the activities of the last class, and because it reflected a product that an in-service teacher would produce, the students revealed that they understood that their projects were relevant.

Today, I still feel that the final assessment aligns well with my changing beliefs. This feeling is partly due to the two post-practicum interviews I conducted. During these interviews, I sought to identify the students' perceptions about the purposes of a traditional final examination and the purposes of a final assessment. One of my intentions for this course was to model a constructivist environment such that my students would be motivated to use constructivist-oriented strategies in the future. During the interview, I specifically asked Victoria if she believed that the final project helped her remember the course content and if it might have helped her develop her own teaching practice. Victoria stated, "Definitely, because I actually used those plans in my teaching. While I was doing them [final project], I was thinking 'okay, how can I use some of what you taught in the class and apply it to what I'm teaching. So it was very helpful." When I asked how much of the content from the course she would have remembered if I had administered a traditional examination, Victoria said, "Honestly [I] would have forgotten it by now [seven weeks after the course]" (Student Interviews, p. 22). This suggests that my change in teaching approach had a positive impact on and made a difference for this student.

One of the C&I course outcomes was to provide the students with knowledge and skills to use in the ever-changing domain of teaching. I believe that this assessment helped meet this outcome. I did not demand that the students use a specific style of the lesson plan. Assigning a flexible project in a domain that has more than one correct answer is consistent with the

Schwartz, Lindgren, and Lewis (2009) argument that the instruction and assessment must match the domain being taught.

Finally, the last project met Brooks and Brooks' (2001) requirement that assessment should be authentic:

> Authentic assessment, like learning, occurs most naturally and lastingly when it is in a meaningful context and when it relates to authentic concerns and problems faced by the learner. Encouraging teachers to teach in a manner that fosters individual construction of knowledge and then requiring them to assess students in a traditional, test-oriented manner communicates mixed messages to teachers and students. (p. 96)

I believe that I succeeded. The final assessment did not portray mixed messages.

Synthesis of Findings: My Practice and Brooks and Brooks' Fifth Principle.

When I analyzed the data specific to Brooks and Brooks' (2001) principle of assessing students in the context of learning, I found little evidence of a congruent teaching practice at the high school level. I vacillated between assessing learning and assessing for learning. I conducted formative assessments, yet most were designed for the students to prove to me what they had learned. The assessments often did not inform my teaching.

Overall, during the high school teaching experience, I was overconfident in my ability to conduct formative assessments. The questions I asked did not uncover understanding or inform my subsequent questions. Additionally, I did not connect current learning with past experiences. I often did not ask the students to think back to previous learning. Finally, when the student answers strayed from the understandings I sought, I stopped asking for input and instead provided the correct answer.

During the university education course, I more effectively integrated assessment in the context of learning. The two assessments activities examined above illustrate how I encouraged the students to grow and learn while participating in their own assessment. I sought to connect the assessments to their future professional activities. Nevertheless, I realize that I can further develop my formative assessment skills, my questioning skills, such that I may better understand my students and better model formative questioning. One way I can improve my assessment skills is to incorporate activities where the university students and I practice one-on-one interactions similar to the one I had with Chloe. Deconstructing this type of interaction may improve my skills as well as those of my students'.

The different success I experienced between high school and university may have to do with some of the constraints or the reality of teaching in a high school. With regards to assessment, the Science 10 Program of Studies lays out what must be taught and assessed. For a teacher, this encourages traditional teaching and assessing. Within a teacher education program, there is no program of studies. I have a large degree of freedom to choose the content and assessment procedures. It is possible that this allowed me to feel free to make more changes and thus experience more success in implementing Brooks and Brooks' fifth principle within the university classroom.

Overall Summary

In this section, I use the modified Theory of Planned Behaviour (TPB) to display the Brooks and Brooks (2001) analysis. The result is a condensed analysis and a visual illustration of the teaching episodes examined in this chapter that were labelled as congruent or incongruent with the Brooks and Brooks' principle. Since the two teaching contexts provided different constraints and freedoms, the high school and university teaching experiences are examined separately, resulting in the creation of two constructivist belief structures (see Figure 8 and Figure 9).

When I analyzed the data (lesson plans) according to Brooks and Brooks' (2001) principles, 20% of the total high school teaching activities reflected constructivist-oriented teaching practices. The 10 teaching episodes examined in this chapter, summarized in Table 4, reflected the same ratio. My analysis of the university teacher education course lesson plans shows that 70% of the activities reflected a constructivist-oriented teaching approach.

Table 4

Summary of Data from the High School and University Teaching Episodes

B & B	High school teaching experience			University teaching experience		
Principle	Congruent	Incongruent	mTPB	Congruent	Incongruent	mTPB
#1	1	1	Peripheral	2		Core
#2		2	Peripheral	2		Core
#3	1	1	Peripheral	1	1	Peripheral
#4		2	Peripheral	1	1	Peripheral
#5		2	Peripheral	2		Core

Note: Table 3 contains a tally of the teaching episodes analyzed (congruent or incongruent teaching episodes) and denotes if the principle was a core or peripheral belief.

Using Haney and McArthur's (2002) interpretation of the modified TPB, my constructivist belief structures are graphically illustrated. As mentioned earlier, core constructivist beliefs are both stated and enacted while peripheral beliefs are stated but not enacted. Beliefs, in this case, are my intention to teach in accordance with Brooks and Brooks' (2001) principles. An explanation for how I decided if a belief is core or peripheral is found below. Other important beliefs include subjective norms (SN), which are socially influenced beliefs regarding people interested in the behaviour, and perceived behavioural controls (PBC), which are variables that either support or impede the behaviour. Therefore, the figures provide a summary of my intention to teach using constructivist teaching and my actual teaching practices. Figures 8 and 9 guide the reflection and discussion in Chapter 6.

Figure 8 shows the constructivist belief structure that I adhered to during the high school teaching experience.

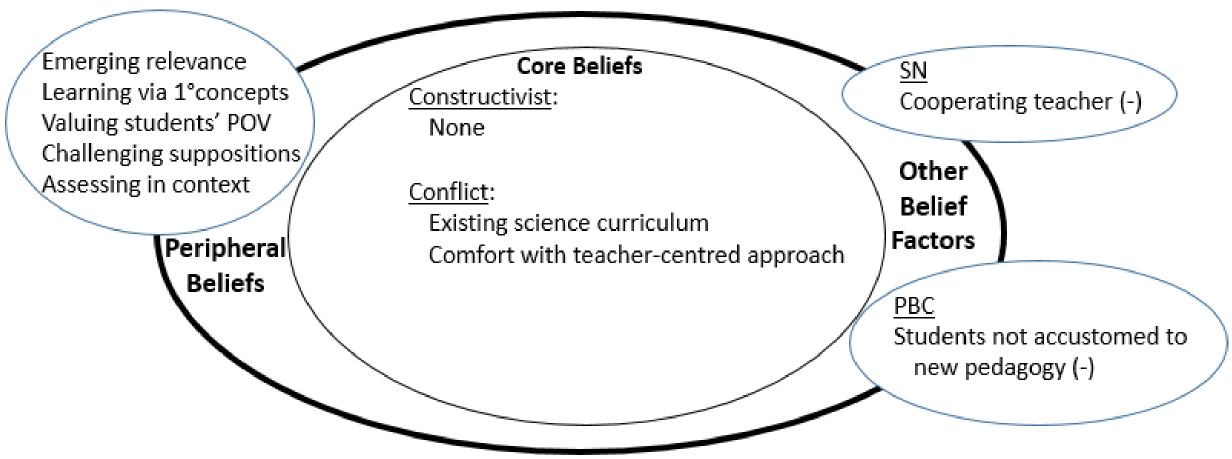

Figure 8. High School Teaching Experience Constructivist Belief Structure. Core constructivist beliefs are both stated and enacted, peripheral constructivist beliefs are stated but not enacted, subjective norms (SN) are socially influenced beliefs regarding people interested in the behaviour, and perceived behavioural controls (PBC) are variables that either support or impede the behaviour (see Chapter 3 for details).

Looking at the overall high school teaching experience, I would not consider any of Brooks and Brooks' (2001) principle as core beliefs although two teaching episodes (near the end of the experience) demonstrated congruency between beliefs and practice. The overall experience was not congruent with Brooks and Brooks' principles. The core beliefs that conflicted with constructivist-oriented principles included my commitment to the existing science curriculum and my comfort with teacher-centred practices.

Through my relationship with the cooperating teacher, subjective norm beliefs—salient beliefs regarding the people important in the context of my teaching—impacted the high school experience. The teacher was supportive of my presence in the school, yet she exhibited traditional teaching beliefs, and throughout my time in her classroom, expressed skepticism about constructivist-oriented pedagogies. The perceived behaviour control, beliefs regarding resources or obstacles that either facilitated or impeded my teaching, may have impacted my experience. Based on my understanding of the cooperating teacher's pedagogy, I entered the classroom believing that the students were not prepared to accept new pedagogies. Later discussions with my critical friend (CF1) reinforced my sense that the students might resistant constructivist-oriented pedagogies.

Figure 9 illustrates the constructivist belief structure that I exhibited during the university teaching experience.

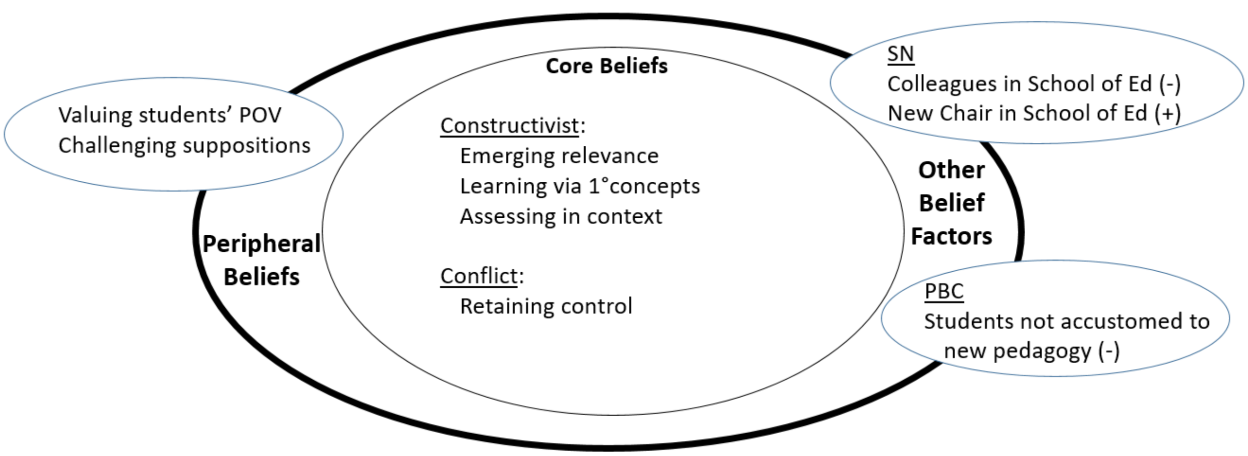

Figure 9. University Teaching Experience Constructivist Belief Structure. Core constructivist beliefs are both stated and enacted, peripheral constructivist beliefs are stated but not enacted,

subjective norms (SN) are socially influenced beliefs about people interested in the behaviour, and perceived behavioural controls (PBC) are variables that either support or impede the behaviour (see Chapter 3 for details).

My intention to reflect the five constructivist principles advocated by Brooks and Brooks (2001) in my teaching did not always occur in the teacher education course. As noted in Table 4, I did fall back into my old habits at times in two of the 10 teaching episodes examined. Based on the data presented in Chapter 5 and reflected elsewhere, I categorized, valuing students' points of view and challenging student suppositions as peripheral constructivist beliefs. While I successfully integrated these principles at times, I often found that it was difficult to consistently incorporate them into my teaching.

A subjective norm that influenced my university teaching experience involve my relationships with my education colleagues. During the initiation period of my self-study, I discussed with my colleagues my efforts to bridge the gap between my constructivist beliefs and teaching practices. I received responses that ranged from skepticism to fear. One professor went so far as to provide me with a journal article that labelled constructivism as the reason that parochial schools are dying. After these reactions, I stopped discussing my research with any of my colleagues. Recently, a new individual became the chair of the School of Education. This person immediately became a critical friend with regards to my self-study. She has become one of my best resources in my efforts to increase constructivist-oriented pedagogical competency.

The perceived behaviour control beliefs that influenced my teaching involved my belief that the preservice teachers in my courses were not prepared to accept constructivist-oriented pedagogies. The majority of the education students at this university come from a parochial school system exemplified by the high school in this study. Traditional teaching environments dominate these schools. Therefore, I believed that the students would resist constructivist-oriented pedagogies.

Chapter 6

Conclusions and Implications

> True education is not the forcing of instruction on an unready and unreceptive mind. The mental powers must be awakened, the interest aroused (White, 1903).

Introduction

My research initially began with a pilot study in a local high school. I intended to examine how I might introduce a constructivist-based pedagogy in a science classroom. The internal and external resistance I experienced during the pilot study led me to the realization that I did not fully understand constructivist-oriented pedagogies. This realization brought me to self-study. As a teacher educator, I realized I was not fully prepared to help the preservice teachers in my courses. In fact, my practice did not reflect the theory I taught. The realization that I was a living contradiction led me to my research, guided by these two questions:

1. What were my teaching practices?
2. How can my practice more closely align with my emergent beliefs about teaching and learning?

Teacher education is in need of reform (Christou & Bullock, 2014). One reason is that the contemporary approaches to teaching contrast starkly with the approaches modelled by teacher educators (Korthagen et al., 2006). Often, teacher education courses are taught in a traditional manner; therefore innovative teaching approaches discussed in teacher education courses are not seen in practice (Harfitt & Chan, 2017; Zeichner & Tabachnick, 1981).

In this research, I endeavoured to develop my constructivist-based teaching so that I could better address the needs of my education students. Many factors impact preservice teachers' development, a great number of which teacher educators cannot influence—for example, the understandings their students developed during their K-12 experiences. Nevertheless, teacher educators can influence pedagogical understanding through their interactions with their students. Kitchen (2009) argues that student-teacher interactions require more examination: "In light of a growing body of knowledge on effective teacher education practices and programs, more attention needs to be given to faculty development" (p. 3). As with many science teacher educators, I brought my teaching approach to teacher education unchallenged and without reflection (Berry & Loughran, 2012; Martinez, 2008; Nelson, F., 2015). "In the absence of effective professional induction and mentoring programs in most universities, it falls on teacher educators to attend to their own professional development" (Gallagher, 2011, p. 881). In my case, I entered graduate studies at the University of Alberta in order to develop professionally. I believed that graduate studies would provide depth to the teaching strategies that I had successfully employed as a high school science teacher. What I learned did not support this preconception. Throughout my graduate program, I realized my pedagogical knowledge was limited and that I was not exposing my science education students to some of the most effective teaching strategies. Thus, I gravitated towards self-study of my practices. Self-Study of Teacher Educator Education Practices (S-STEP) focuses on improving preservice teachers' development through the teacher educator's personal analysis of his/her educational practice and a subsequent change in practice. In this study, I focused on how I might improve and model constructivist-based teaching.

During my graduate studies, I left the tried and true and moved into a liminal state as I accepted that I was a living contradiction. My teaching practices did not align with my beliefs about learning and teaching. This self-study begins the part of my journey in which I work to reduce my belief-practice misalignment.

Within this chapter, I summarize the findings of my self-study in relation to my research questions. This is followed by a discussion of insights and the implications of this work and some recommendations.

Addressing Research Question 1: What Were My Teaching Practices?

This self-study primarily focused on a high school teaching experience and a university teacher education teaching experience, yet in order to understand my teaching practices, it was important to discuss what occurred prior to this study. Chapter 2 provided information regarding the teaching approach I used prior to the study, the dissonance I experience in graduate studies, and my desire to change my teaching practices. I used the modified Theory of Planned Behaviour (TPB) as a way to categorize the findings from my high school and university experiences. That is, I examined whether my beliefs were exhibited in my teaching practices. Congruency between belief and practice was examined through the lens of Brooks and Brooks' (2001) principles of constructivism.

Prior to this study, my teaching practices reflected a traditional teaching approach (Brooks & Brooks, 2001). I believed that I was the knowledge keeper; thus I taught didactically, focusing on disseminating knowledge. I covered each curricular point and each page of the appropriate textbooks. I created lesson plans that could be used time and time again without change. Although I may have spontaneously asked slightly different questions, I made only minute changes in regards to the particular group of students sitting in neat rows in front of me. I assessed every student product and recorded the results permanently in a grade book. There was no opportunity for students to demonstrate growth after I recorded a grade. I was not worried about the students' learning; it was each student's responsibility to learn: my job was to present the information. I administered assignments, quizzes, and examinations so that the students could prove that they had learned. I rarely allowed students to work in groups or cooperate when completing assignments; I believed that this might inflate grades as the weaker students might hide their lack of understanding behind their classmates' work.

During the self-study, while teaching the high school science lessons, I struggled to change my teaching practices. Yet, as the high school teaching experience drew to a close, I felt more comfortable altering my teaching based on my desire to identify and challenge student understandings. My changing comfort level may have been due to the development of my teaching skills during the teaching experience, or it may have been due to the development of a positive relationship with the students. I believe that the constructivist-oriented pedagogies I intended to use worked better as the students and I became more comfortable with each other. I was able to ask questions that better related to the individual students, and they likely felt more comfortable answering these questions.

In the high school, when I experienced resistance, I consistently fell back on traditional teaching strategies. I also found it difficult to identify and build lessons around the big concepts; thus I focused on facts and details as I taught. When designing lessons I did not plan for the specific group of students I taught. I targeted specific conceptions that typical students have problems with. When conducting the lessons, I often misjudged the length of time constructivist-oriented activities took. Thus, I was forced to split some lessons between class periods. When I conducted formative assessments, they rarely informed my teaching. I almost completely ignored the pre-course science questionnaire I administered.

In general, my teaching did not match my intentions. Why did I keep falling back on traditional pedagogies? Is it possible that I did not truly believe I should change my teaching practices? Did I simply lack the experience required to change successfully? These are questions that I examined during the period of time between the high school and university teaching experience.

Following an extended period of reflection, the small changes that I made during the high school experience translated into greater changes during my teacher education course. As noted in Table 4, more of the teacher education episodes that I examined reflected a constructivist-oriented pedagogy. The teaching context of the course likely influenced my ability to align my beliefs and practices. When I taught the teacher education course, I entered the classroom with an understanding of each student. We knew each other, for I had taught them in earlier courses. This immediately allowed for richer examinations of the Curriculum and Instruction (C&I) course content through deeper discussions. I asked questions that were relevant to the individual students and, I believe, they were comfortable answering the questions. At this time, my actions began to reflect those of a facilitator, not those of an expert in the room.

During the university teacher education course, I carried out assessments more consistent with Brooks and Brooks' (2001) principles. I was able to overcome my desire for traditional testing and grade creation, and instead sought to assess learning within the context of teacher education. For example, I believe that the mid-term and final evaluations supported student learning. These assessments were not designed so that the students could prove that they had learned, but to allow the students to develop a genuine understanding of the course material.

In the university setting, my teaching practices exhibited fewer of the incongruities noted in the high school. The differences in the two teaching situations may have influenced the results. In the high school setting, an “artificial” teaching relationship began as I dropped into a classroom for one unit of study. I did not have an extended period of time to build deep relationships and rapport with the high school students. They knew I was leaving in a few weeks. In the university setting, I had interacted with and taught many of the students for three years. Little time was spent getting to know each other, and they knew I might supervise their future practicum experiences.

It is also important to note that the two student populations were different in nature and motivation. For example, the education course is populated by older, more mature students who want to connect the content studied to their future professional lives whereas Science 10 students were required to take this course. Students who are simply trying to survive a course may be more resistant to change.

Finally, the curricula differed. The high school curriculum was prescribed by the Alberta government while the teacher education curriculum was open for me to develop. In the high school setting I taught content I preferred not to (e.g., specific heat calculations), while in the university course I taught only the content I desired. It was also easier for me to teach the university course with an eye on the students’ future teaching practice. For example, it was easier to create assessments in accordance with Scholtz’s (2007) assertion that meaningful assessment should reflect the professional practice in question. The high school setting did not afford this possibility.

When comparing my high school and the subsequent university teaching practices, it appears that I moved forward further at the university on my journey to incorporate constructivist principles into my teaching repertoire. However, even though I did demonstrate constructivist elements in my teaching, I could have done better. Overall I believe that constructivist-oriented core beliefs did not manifest at all in the high school experience and were only emerging in the university experience.

Addressing Research Question 2:

How can my practice more closely align with my emergent beliefs about teaching and learning?

To answer this question I examined each of the teaching episodes (high school and university) in Chapter 5, focusing on what I identified as practices that I could improve. A synthesis of the findings suggests that my teacher education practices would improve if I provided more opportunities for my students to experience constructivist-oriented teaching strategies, deconstruct models of teaching, and examine time management issues related to teaching strategies. This would entail better lesson plans with a clear purpose for activities. Such lesson plans would allow me to prepare purposeful questions and facilitate my skills, for example thinking on the spot. The students have preconceptions and time has to be allocated for their ideas to surface and then be examined.

I found it easy to encourage discussions in my classroom, yet I as noted in the synthesis sections of Chapter 5, the discussions were often superficial. I would like to improve my ability to dig deeper, asking the students to explain why they believe as they do. Also, I exhibited a tendency to fall back into my traditional teaching strategies when I felt resistance to constructivist-oriented pedagogies. Nevertheless, when comparing the high school to the university teaching experiences, I saw that there was much less resistance to change, internal and external, in the university setting. This last generalization is especially important. My students will teach in a high school setting while I will continue to teach in a university setting. Articulating how one might teach with a constructivist perspective in a high school setting while modelling constructivist-oriented practices in a university setting remains a challenge of mine. These findings reveal three themes (Bogdan & Biklen, 2007) that encompass how I might further align my beliefs and practices. These relate to the questions I ask, the role I encourage students to take in their own learning, and the context of teaching.

Change the Questions I Ask

Throughout this study, I employed traditional questioning techniques. I often asked questions that focused on my understandings, ignoring the students' points of view. During my teacher education course, I continued to ask close-ended, convergent questions that produced superficial responses. I asked students to express opinions that were reflected in the literature. Asking more divergent and evaluative questions would encourage my students to think in new and complex ways (Smith, Vernon & Szymanski, 2013). Encouraging student teachers to uncover their beliefs, asking questions relevant to them, and challenging them to evaluate their preconceptions would make the lessons more meaningful. Developing effective questioning skills allows for assessment for learning, which is integral to teaching and learning (Heritage & Heritage, 2013).

I often focus on the transfer of information, for example, teaching strategies. As I shift my focus to a constructivist-oriented line of questioning, I would like to create interactions that permit my students' understandings and opinions to drive the sequence of questions. This process of co-regulation (Heritage, 2018) would change the student-teacher dynamics in a classroom. I would like to foster this competency within my students. I would also like to alter my questioning strategy to mesh with the belief of Erickson, et al. (2017), that artful teachers "engage students emotionally, creatively, and intellectually to instill deep and passionate curiosity in learning" (p. 6).

As a teacher educator, I now challenge myself by asking, "if I am unable to model these types of questions, how will my students begin to develop the ability to ask these questions?" In the future, I would like to develop my Socratic questioning skills. I would like to effectively model a series of questions intended to prompt and guide student thinking. Modelling questions designed to elicit thinking and modelling questions that uncover a student's thought process will support my students as I grow as a teacher educator.

Change the Students' Role

The second theme that transcends my journey through this study was the role I allowed learners to have in their educational experience. Throughout this study, I wrestled with my relationship with the students. It is important to note that Brooks and Brooks (2001) argue that their five principles should not be examined in isolation, but should be regarded holistically. A teacher must synergistically combine the principles in all lessons. This is not how I applied the principles. Overall, I see that I focused on one or two of Brooks and Brooks' principles at a time. This specific yet erratic focus impacted my interactions with the students. For example, I sought prior knowledge and then ignored it, or sought the students' points of view, yet did not challenge them or adapt lessons based on the students' understandings. Bonk (2012) argues that problems arise when "concepts, strategies, and tools are abstracted from the theoretical viewpoint that spawned them [, because] they are too often stripped of meaning and utility" (p. 25).

As I fought to step out of my liminal space, I vacillated between teaching strategies. The role of the students in my classroom therefore also vacillated. Today I question why I treated preservice teachers as passive learners when I believe that they must actively make sense of the material we examine. I believe that we are co-creators of understanding, yet I easily slip into comfortable didactic strategies.

I feel that I am stepping out of my liminal space, yet until I have a solid foundation of constructivist-oriented pedagogies that feel comfortable, I will continue to reflect on how I am positioning the students in my classroom. Focusing on my students, encouraging them to closely examine their own pedagogical understandings, may help. For example, together, examining teaching dilemmas that contrast constructivist-oriented and traditional pedagogical solutions. This may effectively facilitate the development of the education students personal pedagogical understandings.

Although my university teaching approach was often traditional, I desire to continue to change. I am not frustrated; I am not discouraged. I no longer have a knot in the pit of my stomach as I did when analyzing the video recordings of my first high school lesson. I now acknowledge that I am on a life-long journey.

Adapt to the Context of Teaching

It was much more difficult for me to teach with a constructivist perspective in the high school than it was to do so in the university classroom. Looking specifically at my teaching practice, the difference in success between these two teaching contexts might have resulted from the development of my personal teaching skills. Previous to this study, I had not intentionally used constructivist-oriented pedagogies. As noted, as my high school teaching experience progressed, I began to feel that I was aligning my beliefs and practices. The continued alignment of beliefs and practices at the university level may have resulted from my additional experience with constructivist-oriented pedagogies.

A second possible explanation for the difference in resistance to constructivist-oriented pedagogies between the high school and university settings has to do with the school contexts. The intrinsic motivations of the high school students may have impacted the teaching environment. For example, I sought to apply Brooks and Brooks' (2001) principles, which include the goal of making school content relevant for the student. If the student is required to take a course, creating relevance may be more difficult. In comparison, the university students I taught were third-year science education students. They had chosen to be in this course, and it was not difficult to demonstrate how the topics we examined were relevant to them.

Curriculum and learning outcome differences between the high school and the university settings may also have played a role in the increased success I experienced in the university setting. The tightly controlled high school curriculum differs significantly from the more flexible university curriculum. The high school science curriculum contains a great deal of knowledge-related learning outcomes. These outcomes are fairly stable over time. For example, CO_2 either absorbs or does not absorb infrared radiation. Within the university setting, the learning outcomes were more flexible. For example, we examined multiple attributes of effective science teachers. I found it easier to seek students' points of view and then adapt the activities to challenge the students when flexible outcomes guided my teaching.

Finally, there is another significant external influence in Alberta's high schools: the provincial diploma examinations. Before I began my brief teaching experience in the high school, the students were being prepared for their future multiple choice examinations. When I began teaching, some of the high school students, those who planned to attend university, stated that they worried that the non-traditional teaching approach might not prepare them for the government examinations. When I taught in the teacher education course, I changed the examinations to better match my teaching approach. This did not happen in the high school. I used the cooperating teacher's unit examination. This created considerable anxiety for the students. Schwartz et al. (2009) contend that it is important to match a teaching approach to the assessment.

In conclusion, the teaching strategies I employed and modelled in teacher education courses may not directly apply to high school settings. Therefore, I intend to continue to explore ways in which I might improve my teaching practices in this area. I believe that I need to work to balance modelling both traditional and constructivist pedagogies to help my students prepare for their teaching contexts.

Insights and Possible Implications

As I sought to answer the self-study questions that my paradigm change stimulated, the research led to several additional insights. Two of the significant insights are discussed below.

My Current Living Contradiction

One of the things I realized is that there are many constraints within the high school system. When I discarded my belief in traditional teaching approaches, I developed an unrealistic expectation of the number of constructivist-oriented pedagogies a preservice teacher could use in a practicum or later as a teacher. I now ask my students to look for opportunities to use constructivist-oriented pedagogies. In the appropriate situation, with the right mentor teacher, my students may successfully incorporate a non-traditional teaching approach in their practica.

I now ask myself, how can I expect student teachers to teach in a way that I struggled with? If I could not successfully teach a high school science course with constructivist-oriented pedagogies, how can I suggest that this approach is appropriate for future high school teachers? Specifically, during this study, I struggled to "practice what I preached." My intentions and beliefs did not consistently align with my teaching practices. In retrospect, it is unsurprising that my first conscious attempt to implement new pedagogies was unsuccessful. I was attempting to use new practices that did not match my tacit knowledge. Changing teaching practices requires time (Haney & McArthur, 2002; Tam, A., 2015).

An alternative interpretation of the events that occurred during my high school teaching experience involves the teaching context. The different contexts of these two schools impacted the teaching experiences. As mentioned above, the two student bodies differed. Also, the science teachers in the participating high school taught with a traditional perspective, which the high school students likely viewed as normal. Conversely, some of my education colleagues use constructivist-oriented strategies and the university students expected different styles of teaching, which made them more likely to accept my approach even if it did not match their teaching beliefs or previous experiences.

Ritter (2014) describes the frustration experienced by a teacher educator (with a strong sense of purpose) who returned to high school teaching, stating the “harsh truth: A vision for teaching and learning, even one that is thoughtfully forged over the years and derived from educational theory, will likely cease to meaningfully inform practice if the conditions for its execution are not right” (p. 42). During this study I have learned that although I value a constructivist approach, it might not be applicable in all teaching contexts. Some contexts might have too many constraints.

Today, if my teaching assignment was at the high school in this study, I believe I would still struggle to use many constructivist-oriented pedagogies. In this school, the student population, staff, and teachers continue to resist non-traditional approaches. Nevertheless, some constructivist-oriented pedagogies should be applicable to any classroom, for example, creating relevance, seeking students' points of view, and listening to student responses. Conversely, I feel that I could comfortably apply a constructivist-oriented approach at the high school where John (see Chapter 1) is employed. Within that school, inquiry-based teaching is promoted, the students have experienced non-traditional teaching approaches, and the administrators advocate for such pedagogies.

Based on what I learned through this self-study, I contend that teacher educators should prepare their students to teach in a wide variety of school contexts. My desire is that my students succeed in their first teaching assignments. Therefore, I desire to prepare them for a traditional or constructivist-based teaching placement. Today I am better prepared to meet this intention. The extensive introspection and reflection on practice that has occurred through this self-study provided an opportunity for me to develop teaching practices that I would not have sought to develop. Also, adding constructivist-oriented teaching practices to my repertoire has provided flexibility that my traditional teaching practices alone did not afford.

I Was Not Prepared for Teacher Education

The second significant insight uncovered during this study focuses on my lack of preparation prior to assuming the role of a teacher educator. I was unaware of the significant differences between teaching contexts and the significant shift I was making as I transitioned from high school teacher to teacher educator (Allen, Park Rogers, & Borowski, 2016). Ironically, although teacher educators facilitate preservice teachers' learning processes, the teacher educator's education is often overlooked (Korthagen et al., 2005; Korthagen, 2017), resulting in little or no guidance for most as they transition into teacher education (Dinkelman, Margolis, & Sikkenga, 2006). My entrance into teacher education reflected this. I received no formal education regarding the teaching practices specific to teacher educators.

This lack is now unsurprising to me. Casey and Fletcher (2012) and my critical friend (CF3) state that organizers of educational doctoral programs are in a difficult position with regards to providing pedagogical education for teacher educators. Few doctoral education candidates intend to become teacher educators. Therefore, the demand for graduate pedagogical education is low. This observation matched my experience, for within my cohort in graduate school, few of my peers indicated a desire to move into teacher education.

There is a growing body of research regarding the professional development of in-service teacher educators (Ping et al., 2018). For example, Robinson and McMillan (2006) identified some of the significant tensions that teacher educators experience and suggested participative action research as a way of developing an understanding of those tensions. Gallagher et al. (2011) describe the benefits of instituting S-STEP for a group of new faculty members, thereby creating a community that together develops its practice and scholarship. Both of these suggestions, as well as this current study, focus on development after an individual has assumed the role of teacher educator.

It is important to note that most doctoral programs require no engagement in pedagogy that prepares the graduate student for teacher education (Casey, A. & Fletcher, 2012). Specifically, Demirdögen et al. (2015) argue that doctoral programs rarely support the development of teaching practices of prospective science teacher educators. There is little research that focuses on the graduate preparation of teacher educators (Dinkelman et al., 2012; Martinez, 2008; Ritter, 2011). “It seems that higher education programmes are focused on helping students to obtain the degree, with little regard to preparing them to actually use it” (Kosnik, 2011, p. 353).

This oversight is beginning to be addressed. Butler et al. (2014) report that graduate programs have increasingly aimed to support future teacher educators by providing training and support spaces to assist doctoral students moving into teaching in higher education settings. For example, Dinkelman et al. (2012) describe an approach that supports the development of the scholarship and practice of future teacher educators. These researchers examined the impact of a doctoral seminar, Pedagogy of Teacher Education (PTE), on graduate teaching assistants' later teacher education practices. The PTE seminar classes examined the "problems of practice" (p. 174) occurring in the courses the teaching assistants facilitated. This was followed by an examination of teacher education research. The core themes of collaborative inquiry and teaching as reflective practice led the discussion. Butler (2014), a current teacher educator, argues that PTE assisted the development of his pedagogies through guided support from knowledgeable teacher educators.

Kosnik (2011) describes a similar initiative, Becoming Teacher Educators (BTE), which also aims to support doctoral students who plan to become teacher educators. This informal group of 12 doctoral students met for three years, discussing scholarly articles and teaching experiences, analyzing course outlines, and interviewing and observing strong teacher educators. The participants reported a sense of community and said that the ongoing support was the reason for their continued growth. As a result of the BTE meetings, the majority of the participants reported that they felt more confident in their teaching practices as they assumed teacher education positions.

Multiple studies use self-study methodologies to examine and reduce the tensions experienced by novice teacher educators (Allen et al., 2016; Casey, A. & Fletcher, 2012; Wiebke & Park Rogers, 2014). Casey and Fletcher (2012) specifically examined the impact that BTE had on Fletcher's transition into teacher education in comparison to Casey's transition. Based on the comparison, these researchers concluded that future doctoral students who desire to be teacher educators would benefit from structured learning about teaching teachers. They also suggested that providing graduate students with opportunities to observe experienced colleagues and engage in discussion about curriculum and practice with mentors would smooth the transition between K-12 teaching and teacher education.

Unfortunately, during my graduate studies, I did not experience anything comparable to PTE or BTE. I believe that if I had received guidance prior to teaching education students, the tension I experienced would have been reduced. Expert feedback regarding my developing constructivist-oriented teaching approach, prior to assuming the role of teacher educator, could have eased my transition into teacher education. Prior to this study, I lacked constructive feedback regarding the application of constructivist-oriented pedagogies.

Recommendations for Teacher Educators

The tensions I experienced as I transitioned from high school teaching to teacher education eroded my professional confidence. The additional pedagogical content knowledge required for teacher educators pushed me to question myself. For example, I could not adequately explain or critique constructivist-orientated pedagogies. The trajectory of my teacher educator identity was challenged (Ye & Zhao, 2019).

It was the self-study methodology that supported my professional development as I sought to reconstruct my professional identity. Although questioning my teaching beliefs and practices was personally threatening, the self-study process provided an avenue through which I began to align my beliefs and practices. This resulted in personal and intellectual growth as well as the development of my current, robust teacher educator identity. Based on my experience with self-study, I recommend teacher educators, especially beginning teacher educators, consider this approach for their own self-improvement. My personal self-study journey provided a rich and meaningful examination as I refashioned my identity while I sought to practice what I preached.

A second recommendation that surfaced through this self-study is based on the frustrations and challenges I experienced. I suggest that graduate programs explore strategies aimed at developing prospective teacher educators' university level pedagogies. Dinkelman et al. (2012) argue that doctoral programs play a crucial role in preparing emerging teacher educators to be scholars and practitioners. Although it is clear that the "one size fits all" approach does not benefit most doctoral graduates because they move into diverse teaching situations (Casey & Fletcher, 2012), I recommend that doctoral programs include courses or programs such as PTE or BTE. Peer and expert support for those developing university teaching pedagogies would have a lasting impact.

Recommendations for Future Research

This study focused on how, as a science teacher educator, I sought to align my beliefs and practices. Few studies report on research that begins in a high school science teaching setting and continues into a science teacher education setting. Additional research conducted by teacher educators who teach in both secondary and postsecondary contexts would serve to better inform teacher education practices. This impact is evident in Russell's (1995) return to a high school physics classroom and Northfield's (1998) return to a mathematics classroom. These teacher educators returned to teacher education with new personal insights.

Based on the insight I developed during this study, I would like to continue my research in two areas. First, I would like to continue to use self-study to develop a more nuanced understanding of how I may facilitate the development of my students' skills as they identify opportunities to use constructivist-oriented pedagogies. Modelling a constructivist perspective and encouraging students to deconstruct my teaching strategies may allow them to ally the strategies in the secondary classroom.

Second, I aim to refine my teaching practices that support students attending parochial universities. As my appreciation of constructivist-oriented pedagogies has grown, there remains resistance from other teacher educators who advise Christians to be wary of constructivism. This is a concern that I intend to study. The methods I choose to employ when introducing constructivist perspectives should reflect the parochial setting of the university. Others have studied this intersection between religious education and constructivism (Deulen, 2013; Thorne, 2013). I would like to build on these studies. I want my students to be able to teach effectively with either traditional or constructivist-oriented pedagogies; thus research aimed at identifying how constructivism fits within a parochial school of education now seems prudent.

Final Reflections

Writing this dissertation has been enriching, transformative, and constructive. Although I sought to address my liminal state by changing my teaching practices to reflect my educational beliefs, I still have a tendency to fall back on past practices. Nevertheless, I continue to grow. I am developing a new foundation for my teaching. Instead of discarding what I had developed over a lifetime, I am adding a new understanding (constructivism).

Countless teacher educators have worked for years to improve teacher education (Clandinin & Husu, 2017a; Loughran & Brubaker, 2015) and while some aspects of teacher education remain tenaciously locked in place, many aspects have changed (Darling-Hammond, 2012). As I write this paper, I understand that I have not completely moved out of my liminal state and therefore I must continue to alter my teaching practices. Similar to the history of teacher education in Canada, at any point in time, both continuity and change are at play in my development (DeLuca & Pitblado, 2017).

In accepting the interplay of continuity and change, I believe that the changes that I have made in my practices during this study are only the first steps of my journey. There are aspects of my teaching practices that may not change, and there are aspects of my pedagogical competency (Korthagen et al., 2005) that I must continue to develop. These changes will impact my role as a teacher educator and, more specifically, my role as a science teacher educator. I am more conscious of my limitations and have strategies for moving forward. Accepting these realities has allowed me to begin to move out of my liminal state. I began this self-study feeling that I was a living contradiction, requiring change. The desire to align my teaching beliefs and my teaching practices has manifested in a desire to shift from traditional behaviourist-oriented practices to constructivist-oriented practices. I now feel comfortable with how I am moving forward to meet that intention. It was emotionally rewarding as I identified how my teaching practices have changed. Today, I have increased confidence, I feel more self-assured, and I also feel more capable about how I am preparing my students, even though I know so much more can be done. I will not ignore my past understandings of teaching, yet I realize that I must continue to develop my constructivist practices and explicitly model them in the classroom. For example, following the advice of Shirrell et al. (2018), I will observe my critical friend (CF2) teach on multiple occasions. This on-the-job professional development will expose me to a constructivist-oriented colleague's teaching practice, providing me with a model from which to learn.

Sixty years ago, Kerlinger and Kaya (1959) criticized the bipolar distinction between teacher-centred (traditional) and student-centred (constructivist) pedagogical beliefs. They suggested that teachers may hold both. Today some educational researchers still encourage a multi-dimensional approach to teacher belief systems (Tondeur, van Braak, Ertmer, & Ottenbreit-Leftwich, 2017). As I continue to develop an understanding of constructivist teaching practices, I find that I appreciate more aspects of all constructivist approaches. Entering the study with a conceptual change perspective, I gravitated first to the views of cognitive constructivists. My perspective slowly changed, resulting in practices that began to reflect more of a social constructivist perspective (Luckay & Laugksch, 2015). I began to value social interactions and group construction of understanding that is personally relevant, an understanding that includes the students' critical opinion, and encourages students to think beyond my classroom, connecting the lessons to their future. Finally, the radical constructivist perspective also contains elements that inform my understanding of the nature of science. Yet, I continue to be warned by my peers and critical friend (CF2) that Christians should be wary of this form of constructivism.

Traditionally, science has been taught from a teacher-centred approach (Nelson, A., 2017). I look forward to continuing my journey of learning and growing as a scholar while supporting the growth of education students as they are pursuing their educational dreams. Science teacher educators like myself, who have taught via a traditional approach, should develop an understanding of teaching practices that support a constructivist-oriented approach so that they can help preservice teachers to benefit from these practices and pedagogies. This becomes crucial in teacher education programs that are populated with preservice teachers who enter the classroom with the expectation that they will be taught in a traditional teacher-centred manner. To be prepared for teaching today, these education students must be exposed to a constructivist-oriented, student-centred teaching approach. With an increasing number of teaching districts requiring science teachers to use progressive approaches, it will be the responsibility of teacher educators to appropriately prepare the next generation of science teachers.

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Appendix A

My Educational Life History Timeline

Dates	School/Employment/Research Event
1977 - 1986	College Heights Christian School: Student
1986 - 1989	Parkview Adventist Academy: Student
1989 - 1993	Canadian University College: Student
1993 - 1995	Logan College of Chiropractic: Student
Spring 1999	Red Deer Alternative School: Educational assistant
1999 - 2000	Burman University: Bachelor of Education student
2000 - 2010	Parkview Adventist Academy: Science teacher
2006 - 2010	La Sierra University (summers): Master of Education student
2010 - present	Burman University: Teacher educator
2012 - present	University of Alberta: Doctor of Education student
Spring 2014	High school pilot research: Science 10, Unit 4 – Environmental science
Spring 2015	High school pilot research: Science 10, Unit 4 – Environmental science
Spring 2016	High school teaching experience: Science 10, Unit 4 – Environmental science
Fall 2016	University teaching experience: EDCI 468 – Curriculum and Instruction in Secondary Science

Appendix B

Example - Pilot Lesson Plan

OUTCOMES FROM ALBERTA PROGRAM OF STUDIES	LEARNING OBJECTIVES	ASSESSMENTS (Observations, Key Questions, Products/Performances)
Students will: 10-D1sts: Describe how the relationships among input solar energy, output terrestrial energy and energy flow within the biosphere affect the lives of humans and other species 10-D4sts: Investigate and interpret the role of environmental factors on global energy transfer and climate change	***Students will:*** 1. Thermal energy and the biosphere (Inputs/outputs and variables: insolation, latitude, angle of incidence, albedo, particulates, etc.). 2. The natural greenhouse effect	***Misconception:*** • Greenhouse gases form a thin layer around the Earth and trap heat inside • The greenhouse effect occurs where solar rays are trapped by the ozone layer, by a layer of dust created by pollution 13 • The atmospheric gases make a barrier bouncing back heat from the Earth • Changes in solar irradiation have caused climate change

MATERIALS AND EQUIPMENT

- **Whiteboard and accessories**
- **Computer with digital projector and internet access**
- **Lab supplies and Student-Handout**

PROCEDURE

Introduction (min. 10)**:**

Attention Grabber: Demonstrate ExploreLearning's Gizmo, Summer and Winter. This simulation allows for, and study of the tilt of Earth's axis and the angle of inclination as sunlight strikes Earth. The length of daylight, temperatures, and the angle of inclination can be compared for any latitude. Does the angle of light rays impact your life?

Assessment of Prior Knowledge: Brainstorm words that are associated with the greenhouse effect

Body (min. 65)**:**

Learning Activity #1: Draw a model of the greenhouse effect. (10 min.)

1. Initial Explorations: Introduce the anchoring phenomena (the greenhouse effect). Familiarize the students with the driving questions: How can climate affect your lives and the lives of other species? What is the greenhouse effect? How does it really affect our lives?

2. Construct an initial model: Students create an initial model articulating their current understanding/knowledge. Instruct the students to draw a picture of the greenhouse effect and a CM of the greenhouse effect. The initial concept maps of the greenhouse effect will be made individually.

Learning Activity #2: (30 min.)

3. Test the current model through observation or experience: The students will then conduct the lab, Modeling the Greenhouse Effect. In this lab, the temperature in two 2-L bottle is measured over time as a light source illuminates the bottle. As the data is produced, the question will be asked, "Does your model support/explain what is happening?", "Does your model account for the results of the lab?" See Lab experiment handout below.

4. Evaluate the model: The students will be allowed to alter their models if they like and then compare their model with the observed findings. In their group, a group consensus model will be created. Explanations will be required for the decisions made by the group.

5. Test the model against other ideas: As a group, students will gather further information via simulation from ExploreLearning. The simulation, *Greenhouse Effect*, allows the student to control a model of a region of land where the temperature rises and falls as heat flows in and out of the system. Students

control the amount of greenhouse gases present in the simulated atmosphere. Short and long term effects can be explored (www.learnalberta.ca/search.aspx?lang=en).

6. Revise the model: At this time the consensus models will be examined and modified to fit any new evidence. Following that revision, consensus models will be compared, analyzed and criticized by the entire class with the purpose of constructing a class consensus model.

7. Apply the model to predict or explain other related phenomena: As a class, the student unearth will be encouraged to apply their model to the Albertan weather and climate.

Learning Activity #3: (5 min.) Evaluate/modify the personal climate change CM (5 min.)
Give the students an opportunity to examine their personal climate change CM. Is there anything they would like to modify?

Learning Activity #4: Evaluate/modify the group's consensus climate change model (10 min.)
As a group discuss any changes that should be made to their group model.

Closure (min. 5)**:**

Consolidation/Assessment of Learning: Discuss how the creation of the students Climate Change model is developing. Successes and roadblocks?

Transition To Next Lesson: How do you think that energy moves around the oceans and atmosphere? (Convection Lab next class).

Handout: Modeling the Greenhouse Effect

The surface of the Earth, warmed by solar radiation, has an average temperature around 18 degrees ºC. The energy emitted from the objects is affected by the temperature. Thus Earth's surface emits energy with much longer wavelengths than the incoming solar radiation. This terrestrial radiation (energy emitted from Earth's surface) is between 4 and 100 micrometres (µm) in length and is the infrared band of the electromagnetic spectrum. Infrared is the heat you feel when you hold your hand near a warm radiator. Everything in the universe radiates energy, but the effects are different. For example, heat and light are both forms of emitted energy, but unlike visible light, infrared radiation can be absorbed or "trapped" by certain gases.

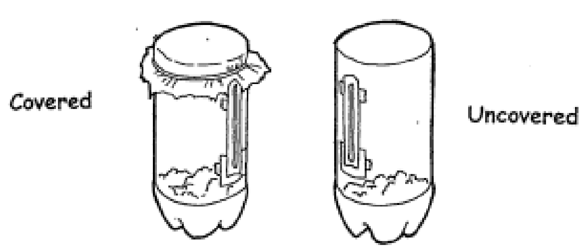
The infrared energy that is absorbed in the atmosphere makes the air warm. The air, in turn, radiates heat which is still at infrared wavelengths. Some of this heat goes back toward the surface, warming the land, the water and the living organisms. This atmosphere-surface cycling of heat energy is known as the *greenhouse effect,* and the gases involved in this process are called *greenhouse gases*. The greenhouse effect is a natural, integral part of the Earth system. Without it, we would be here. Our planet is comfortably warm for life because it is surrounded by a "blanket" of air keeps the Earth some 33 degrees ºC warmer than it would be otherwise, and allows for the existence of oceans of liquid water and living creatures like ourselves.

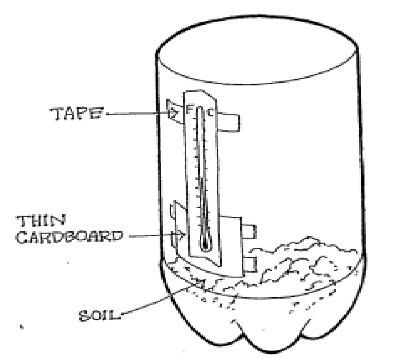
Objectives:

- To form a model of the healing of the Earth's atmosphere
- To provide an opportunity to build and test a physical model analogous the atmospheric greenhouse effect
- To practice setting up a controlled experiment, recording data, graphing and analyzing results

Important Terms: Greenhouse effect energy, greenhouse gases, long-wave radiation, short-wave radiation, electromagnetic spectrum, infrared heat, visible light.

Materials: Two cut-off plastic soda bottles, 2 Thermometers, Masking Tape, plastic wrap, scissors, coloured pencils, graph paper, dork soil, sunlamp





Procedure:

1. Tape a "thin piece of cardboard over the bulb of each thermometer to protect it from direct heat

2. Add 2 cm of soil to each bottle
3. Tap a thermometer to the side of each bottle, about 3 cm from the top and above the level of the soil (See diagram). Record the temperature of the thermometer on the data table.
4. Place plastic wrap over the top of one of the bottles and tape it shut. Leave one bottle uncovered.
5. Both bottles should then be placed in direct sunlight or directly under a sun lamp.
6. Begin measuring and recording the temperature in each bottle every minute for 15 minutes. Use the Data Table.
7. At the end of the investigation, students should complete the activities in the Collecting and Analyzing Data and the Drawing Conclusions sections.

Collecting and Analyzing Data

1. Create a graph. Label the Y-axis: Temperature (ºC) and label the X-axis: Time (minutes)
2. Plot the data from the Data Table onto the graph. Use a different coloured pencil for each line.
3. Analyze your data
    a. Which bottle heated up more rapidly?
    b. If aluminum foil or waxed paper were used instead of plastic wrap, would the results be different?
    c. Which bottle is more like a model of the atmosphere? Why?
    d. In what ways is the earth's greenhouse effect different from the bottles?

Appendix C

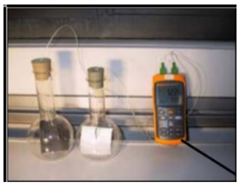
Example - High School Lesson Plan (Lesson Plan #6)

OUTCOMES FROM ALBERTA PROGRAM OF STUDIES	LEARNING OBJECTIVES	MISCONCEPTIONS
General Outcome: 10-D1.5sts: Describe and explain the greenhouse effect, and the role of various gases – including methane, carbon dioxide and water vapour – in determining the scope of the greenhouse effect. 10-D1sts: Describe how the relationships among input solar energy, output terrestrial energy and energy flow within the biosphere affect the lives of humans and other species ***Specific Outcome:*** - describe and explain the greenhouse effect, and the role of various gases—including methane, carbon dioxide and water vapour—in determining the scope of the greenhouse effect - Explain how climate affects people and other species	***Students will:*** 1. Identify the source and types of solar radiation 2. Identify the source and types of greenhouse gases 3. Explain the difference b/t the natural greenhouse and enhanced greenhouse effect 4. Explain why the greenhouse effect is necessary for life 5. Identify how climate affects human and other organisms.	***Students:*** ● Confusion about the definition of the greenhouse effect ● Confusion about the kind and source of radiation involved in the greenhouse effect ● Confusion between SW and LW radiation and Surface Temperature ● Confusion about the kinds and sources of greenhouse gases. O_3 causes GHE. ● Ozone holes let more solar energy to get into the Earth, causing global warming

MATERIALS AND EQUIPMENT
• **Whiteboards** • **Lab equipment for student activities** • **Chromebooks (or website printouts)**

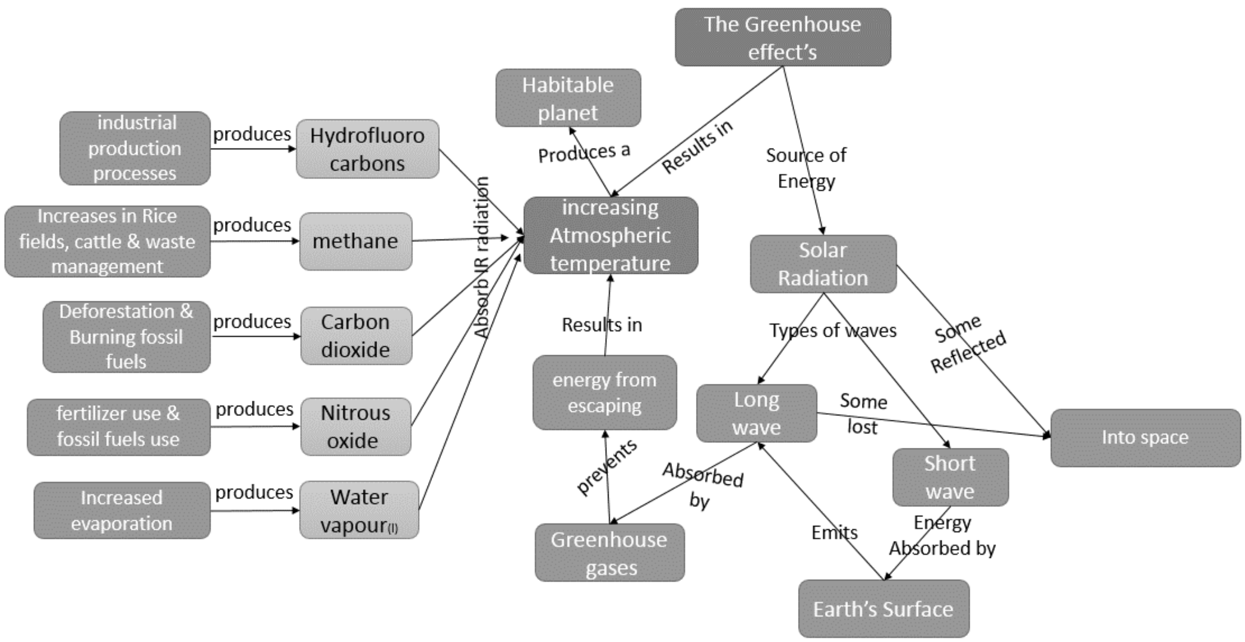
PROCEDURE

Introduction:	Rational
Devotional Thought: Read the police report describing an explosion that took place in a wood stove. A WWII hand grenade exploded. The moral, we may never see the effect of our actions, or they may take decades to become obvious, but our choices have lasting consequences.	This devotional thought is consistent with the school philosophy. It focuses on a moral issue students struggle with.
Attention Grabber: To encourage students to think about the importance of water vapour, use the analogy of camping: Many Albertans camp in the cold weather. "*Often just before crawling into their sleeping bags, some people put a hot object in the bag with them. Some accidentally burn holes in their sleeping bags by dropping hot rocks into their bag. This is not a good idea, but it brings up some questions that we will answer today. For example, what would keep you warmest on a cold winter's night? 1kg of iron at 100℃, 1kg of water at 100℃, or would they both keep you warm equally? Is water hold heat efficiently? Do you think water vapour may have the same qualities?*"	My purpose here is to review what we explored in the last class. Water's importance to climate. - The curriculum emphasizes the big questions. In this case, in global and in small ways, how does water affect our world (B & B)?
Assessment of Prior Knowledge: Before starting activity 1, assess prior knowledge. Do students understand how sunlight interacts with the air and lithosphere? Ask, "What happens to light as it passes through the air and hits the ground?" "Where does the light go after it hits the ground?"	The questions probe student prior knowledge and connect what we are exploring in class with the real world (J & M and APA (2015)).
Procedure:	**Rational**

Learning Activity #1: Does light bounce off Earth and is lost in space? *(15 mins)* *"Does light bounce off the Earth? We are going to examine how this may affect the temperature in the area.* *Some people call this the Albedo Effect.* *- During this activity, we will be looking at how light is absorbed by a black and a white surface. Does it really make a difference?"* Guide the students through the Predict-Observe-Explain strategy (as they have done in earlier lessons). Demonstration and/or pupil experiment of Albedo Effect  Two prepared flasks, one with a black sheet, the other with a white sheet. Both flasks are closed with a plug. A thermo-sensor measure the temperature inside the flasks. Shine an intense spotlight at the flasks.  - If the thermo-sensor is unavailable, view the video clips of the ice melting demonstrations. Ask the students, *"Predict: what will happen? Write your answer down. Now see what the person is sitting next to you thinks.* Watch demo/do experiment. *What happened? Why do you think that is?* "*Do you think that this same effect for the glaciers and icebergs?*"	The goal of the Experiment: The experiment shows the Albedo effect quantitatively. Allows students to make up their own mind, not telling them what the answer is. (B & B: "Students are viewed as thinkers…": link new info. with existing info.) This demo will use the POE (Predict, observe, explain) strategy. Facilitate the addition of new concepts to existing concepts (B & B Principle 3). Connect what occurs in the classroom with what occurs outside of school (J & M).
Learning Activity #2: *(15 mins)*  *"To extend our understanding, we will use a simulation of the greenhouse effect. The simulation will allow you to examine what happens in a section of land if the greenhouse gases change."* Allow students to investigate the simulation, following the directions (see assignment) provided by ExploreLearning. If Chromebooks are unavailable, conduct the exploration as a whole class. Do not provide answers; only provide the digital projection. Allow the students to direct your actions which impact the simulation. *Tell me how I should use the simulation. What should I do first?* Allow time to work, yet probe their knowledge with questions. *"Why do you think that is? What evidence is the simulation giving you that suggest that?"*	I will not provide answers but will work with the students to explore the simulation. I want them to be part of the process, not a passive recipient (B & B).
Learning Activity #3: *(5 mins)* *Does your work agree with the textbook (page 365)? What does the person sitting next to you have that you do not? Should you add that? Your job is to evaluate your own concept map. Evaluating and revising are important parts of modelling!*	This provides an opportunity to link new knowledge with existing knowledge (B & B and APA).
Learning Activity #4: *(25 mins)* Form groups. *In our groups, you will have the task of creating one CM. I suggest that you first compare your lists of concepts, looking for similarities and differences. Then compare how each of you has organized the concepts, mainly looking for how they are connected. Your job is to agree on how to create a CM on your group whiteboard.* Allow time to work.	This social situation is intentional. Learning is influenced by social interactions, interpersonal relations, and communication with others (APA principle 13)
Learning Activity #5: *(10 mins)* Choose two CMs that show different representations. Present these to the class as a whole. *Let's look at these two groups CMs. Do you see anything that is really different?* If no one speaks, prompt the students by asking, *Do he or she include all of the same concepts? Are they organized using the same groupings?* If time allows, create a class CM using the two examples as a foundation.	I want the students to have an opportunity to create meaningful, coherent representations of their knowledge (APA principle 14).

Closure:	Rational
Consolidation of Learning: "*Can you explain why how the greenhouse effect works?" "Is there anything that you would like to know about the GHE that we have not covered?"* ***Feedback From Students:*** *"Was instruction of individual, small group, and class-wide CM clear?"* ***Feedback To Students:*** Provide analysis of their in-class effectiveness when modifying their personal CMs ***Transition To Next Lesson:*** Next we will look more specifically at how humans may have an impact on climate change. Students will hand in their personal CM that they made. ***Transition To Next Lesson:*** *"In our next class We will look at how humans affect the greenhouse effect.*"	I aim to encourage students to examine what they have learned and what they would like to learn more (critical voice) Assessment of student learning is interwoven with teaching and occurs through observation and student exhibitions (B & B).

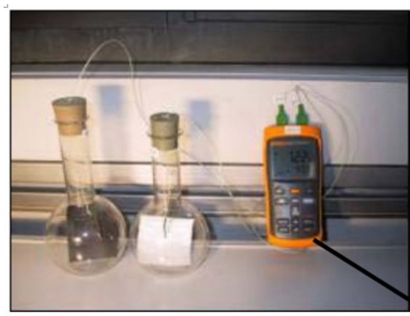
Target Concept Map: Continue to build towards this CM



<u>Student Handout</u>: Provide this <u>After</u> the POE strategy has been conducted.
Radiation absorption of a black and a white surface
(Demonstration and/or student experiment)

The goal of the Experiment: The experiment shows quantitatively how the emissions from black and white surfaces impact the surrounding temperature.

Description: Two flasks are prepared, one with a black sheet, the other with a white sheet. Both flasks are closed with a plug. Use a thermo-sensor to measure the temperature inside the flasks. With a strong spotlight.



The emission of the white paper is mostly in the short wave range, which passes the glass and escapes. The black paper emits mostly longwave radiation, which cannot transmit through the glass and heats the air inside the flask. Within a short time, a significant temperature difference can be measured between the air in the two flasks.

Climate Change importance: Two things are demonstrated by this experiment:

- The albedo effect of bright surfaces and the low transmission of long wave radiation of glass (GHE).

Application: It directly can be shown what happens when the Earth's albedo changes. The disappearing of snow- and ice covered surfaces on the earth can lead to a strong disturbance in the irradiation balance of the earth. The shift to longer wave irradiation emission lowers the amount of transmitted irradiation through the atmosphere and leads to an increase in the global mean temperature.

Exploration: Greenhouse Effect

Prior Knowledge Questions

1. What do you notice when you get into a car that has been sitting in the Sun for a while?

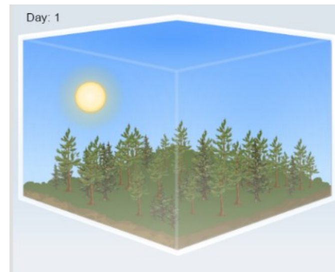
   ____

2. Why is the inside of the car so hot?

   ____

3. How would things be different if the car's windows were left open?

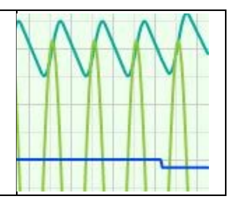
Warm-up



Set the **Greenhouse gases** to 0% and the **Simulation speed** to **fast**.

1. Click **Play** ( ) and view the BAR CHART tab. The temperature will go up and down every day, but try to look at the overall trend. What happens to the temperature over time?

2. Now set the **Greenhouse gases** to 100% and let the simulation run for a while. How does a maximum amount of greenhouse gas affect the temperature?

Activity: **Heat in, heat out**	• Click **Reset** ( ). • Set **Simulation speed** to **slow**. • Be sure the **Greenhouse gases** level is 10%.	

Question: How do greenhouse gases affect the Earth's climate?

1. Observe: Select the BAR CHART tab and click **Play**. After about 24 simulated hours, click **Pause** ( ). What do you notice about the heat flow into and out of Earth's atmosphere?

2. Analyze: Select the TABLE tab.

A. At what time of day is heat flow into the atmosphere (H_{in}) greatest? ______________

B. At what time of day is heat flow into the atmosphere (H_{in}) least? ________________

C. Does heat flow out of the atmosphere (H_{out}) change during a day? ______________

D. At what time of day is surface temperature highest? __________ Lowest? ________

3. <u>Predict</u>: Click **Reset**. When you change the amounts of greenhouse gases in the atmosphere, which factor(s) do you expect to change? (Circle your answer/answers.)

Heat flow in   Heat flow out   Temperature

4. <u>Experiment</u>: Select the BAR CHART tab, and click **Play**. While the simulation is playing, move the **greenhouse gases** slider back and forth. What do you notice?

____

____

5. <u>Experiment</u>: Click **Play**, and this time observe the GRAPH tab as you change the **greenhouse gases**. What do you notice?

____

____

6. <u>Draw conclusions</u>: The influence of greenhouse gases on temperature is called the greenhouse effect. Based on what you have seen, how do greenhouse gases affect the heat flow into and out of Earth's atmosphere?

____

____

____

____

Greenhouse gases play a significant role in regulating Earth's climate. Without the gases that trap heat in Earth's atmosphere, Earth would be a frigid desert like Mars (average temperature -55°C). Too much greenhouse gas and Earth could be a fiery inferno like Venus (average temperature 450°C).

Appendix D

Example – Curriculum and Instruction in Secondary Science Lesson Plan (Lesson Plan #3)

Subject: Becoming an Effective Science Teacher

Outcomes, learning goals, expectations
Challenge student to identify what they believe are qualities of an effective science teacher.

Materials & Context
No unique materials are required.

Lesson – Before Activities

1. Devotional Thought: "True education is not the forcing of instruction on an unready an unreceptive mind. The mental powers must be awakened, the interest aroused" (White, Education, p. 41).
   - Do you agree with this statement? (Why?)
   - What teaching perspective does this sound like? (in what ways)?

2. Review: The Test of Science Related Attitudes (TOSRA).
   - TOSRA assesses science-related attitudes along seven dimensions. Questions for discussion:
     - What do you understand about the results?
     - What do you think the social implications of the results of the TOSRA survey?"
     - Does this affect the publics': Attitude towards scientists, Attitude towards scientific learning, career interest in science?

Lesson Activities

1. Presentation: Science and the post-modern World
   - Human interpretations are dependent on the community in which they surface and the nature of reality itself. A scientific explanation can no longer be looked upon as objective and neutral
   - You are going to teach Science in the post-modern era! Are these statements relevant to a science classroom? How/Why?
2. Activity: Becoming an Effective Science Teacher
   - Set up: Ask, "What do you think the scientifically and technologically literate person should know, value, and do? When you teach a science subject, will you think about how it will affect your students as a citizen? What is the purpose of science teaching?"
   - Task: Individually: For students to identify the characteristics of their favourite science teacher?
     - In groups of two: identify the characteristics that are similar and different between your two favourite teachers (present to class).
   - In groups: Present four metaphors… ask the groups to decide how each metaphor reflects a type of teaching and learning.
     - Which best captures how teaching and learning of science should occur? (Why?)
     - Rank the 4 metaphors based on which you find most important. Explain your reasoning

- Ask the entire class to decide if they can agree with the following statement? (Explain their reasoning): Teaching should facilitate student learning about science as students need to understand and use the understandings in their personal lives and as future citizens.

3. Present: My understanding (I argue that science education should):

As I present these, ask the students how my understanding compares to their favourite science teacher (Do the students agree with everything I believe?)

1. sustain students' natural curiosity;
2. develop their skills in inquiry and design;
3. improve their scientific explanations;
4. help students to develop an understanding and use of technology;
5. contribute to their understanding of the role, limits, and possibilities of science and technology;
6. inform the choices they make in their personal and social lives.

- Concluding quote: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him or her accordingly. *(David Ausubel)*

<u>An additional concept to explore if time allows:</u>

The personal meaning has three aspects:
(1) the **physical** closeness of the materials,
(2) the psychological **interest** the individual has in the materials,
(3) the social **relevancy** of the material or topic

- "…if students are treated as objects; the teacher is less successful with students."
  - Are you teaching biology or are you teaching Billy?
- You may become significant to others by treating them with integrity, sincerity, and openness.
  - Christian influence? Canadian values?

Lesson – After Activities

1. You can become a great science teacher.
   - You are the one person who best knows what is necessary for you to become an effective teacher.

   The responsibility for becoming an effective science instructor is yours.
   - Describe the vision you have for your classroom and for your teaching.
2. Reading Assignment for next class: *Web-based science inquiry (Bodzin, 2008)*

   - Be prepared to share one or two ideas from the article in our next class

Additional information: Discuss the information available on the sites:

1. Alberta Science Council (ATA): http://sc.teachers.ab.ca/Pages/Home.aspx
2. National Science Teachers Association: www.nsta.org

Appendix E

High School Student Consent Form

Participant/Student Assent Form

Scientific Modeling in High School Environmental Science

Name (please print): ___________________________ Date: _____________________

YES, I agree to participate in this project and consent to the use of the following data for the study:

- Results from a questionnaire and a survey about the teaching environment in the classroom
- Notes made by the researcher following classroom interactions
- Copies of student-created models (Concept maps)
- Audio/video recordings of the researcher's instruction

I have read and understand the details in the information letter and consent to participate in this research project:

______________________________________ ________________________________

Signature of Participant Name of Participant

Optional: please check the box below if you would like reports on this research:

❒ I wish to receive a copy of the final report on this research.

Please keep a copy of the information letter for your records. A copy of your signed consent form will also be provided to you.

If you have any questions or concerns about your rights as a participant, or how this study is being conducted, you may contact the Research Ethics Office at 780-492-2615. This office is connected with the study investigator.

Appendix F

Introductory Letter for Parents of Students

<u>Parent Information Letter</u>

Scientific Modeling in High School Environmental Science

Dear Parent/Guardian,

I am a graduate student at the University of Alberta and an assistant professor in the School of Education at XXXX University. As part of my doctoral studies, I will be conducting research in XXXX's Science 10 class. This research involves having me teach the environmental science Unit D using a strategy known as model-based teaching. I have taught this course many times in the past.

I will be teaching these classes and collecting data from June 3 until the end of the course. I have studied model-based teaching in the past, yet through this research, I hope to examine how I can better prepare future teachers to teach using student-centred strategies like model-based teaching. As I teach this unit I will ask the question:

- What knowledge from this study will aid in the preparation of future science teachers?

I will also examine my personal understanding of science education by asking the question:

- How have my beliefs changed as I planned and initiated the model-based teaching strategies?

It is my hope that the results of this study will help inform interested university instructors, including myself, how to prepare preservice science teachers so that they can provide a more student-centred learning environment.

Study Methods
Model-based teaching is an approach that involves students in the development of models (representation of a science concept). The main difference will be that your son/daughter will create and modify detailed models of the science concepts. These are typically taught through lecture and writing of notes. I will aim to create a more student-centred method of instruction than found in many traditional science classrooms. The Alberta curriculum will be followed.

If you agree to have your son or daughter participate in this research, their involvement would include the following:

- Being in class while I direct the instruction for approximately15 classes (Unit D). I will also instruct the class on how to create and modify their models. A video camera will be pointed towards the front of the classroom (at me), recording my teaching.
- Provide me with samples of student work related to the model-based approach. I will make copies and return the originals.
- Complete a science-related questionnaire and a survey about the teaching environment that I created in the classroom.

Your consent to have your child participate in all aspects of the study would be much appreciated.

Confidentiality

All data that is collected in this study will be kept confidential. After the data is collected, student names will be removed and replaced with a pseudonym. All data will be stored in a locked file cabinet or on a password-protected computer for at least 5 years. My supervisor and I are the only ones with access to the data. All data collected will be reported anonymously. The school and students, will not be identified in any report resulting from this research project.

Risks and Benefits

There are no expected risks for students who take part in this study. There are no direct benefits to students. However, this will provide valuable information about the use of model-based teaching when examining environmental science. Your child's perceptions of this approach in teaching will be valuable. It is my hope the results of this study will help inform other teachers interested in this teaching approach.

Voluntary Participation

Student involvement in this study is voluntary and requires parental consent. Please see the consent form (attached). Return it along with the student assent form in the envelope provided. Give the envelope to XXXX by January 11, 2016.

Please note that you may choose to withdraw your child from the project at any time. Your child may have his/her data withdrawn if the request to do so is made at any point of data collection up until two weeks after they have been provided with the final analysis made by the researcher. To withdraw data, please contact Tim Buttler by e-mail tbuttler@ualberta.ca, tbuttler@burmanu.ca, or by telephone: 403-782-3381 ext. 4005.

The plan for this study has been reviewed for its adherence to ethical guidelines by a Research Ethics Board at the University of Alberta. The principal and board chair of Parkview Adventist Academy has also reviewed this study. For questions regarding participant rights and ethical conduct of research, contact the Research Ethics Office at (780) 492-2615.

Thank you for considering this request. If you have any further questions regarding this study, please do not hesitate to contact me at either the email or phone number listed above.

Tim Buttler
XXXX

Appendix G

University Student Consent Form

Participant/Preservice teacher Consent Form

Name (please print): ___________________________ Date: _____________________

For this study, your perspective will provide a means of providing an accurate analysis of my teaching strategies. Your constant contact with my teaching strategies during the semester and your familiarity with the Burman University educational setting will provide useful constructive criticism.

Your active participation (interview) will occur only after your grades have been submitted for my university course. I will ask you open-ended questions about my teaching practices. These questions will be guided by your responses to the Constructivist Learning Environment survey, which examines five aspects of the classroom environment.

YES, I agree to participate in this project and consent to the use of the following data for the study:

- Results from the Constructivist Learning Environment Survey
- Notes made by the researcher following classroom discussions
- Notes made by the researcher and recording of a post-course interview

I have read and understand the details in the information letter and consent to participate in this research project:

_________________________________ _________________________________

Signature of Participant Name of Participant

Optional: please check the box below if you would like reports on this research:

❒ I wish to receive a copy of the final report on this research.

Please keep a copy of the information letter for your records. A copy of your signed consent form will also be provided to you.

If you have any questions or concerns about your rights as a participant, or how this study is being conducted, you may contact the Research Ethics Office at 780-492-2615. This office is connected with the study investigator.

Appendix H

Coding Categories Used to Organize/Analysis the Qualitative Data

Name	Description	Example
Emerging relevance	Students' interests are awakened (via real-life, pertinent, questions or problems)	Multiple students identified actions in their lives that <u>affect</u> GHG emissions. It appeared that the students were making a connection between their <u>lives</u> and the production of GHG.
Learning via primary concepts	Whole-to-part (holistic, big ideas) vs. part-to-whole (isolated details)	I asked my class, what would be reasonable for me to expect you to remember about the details of the POSs that we had been exploring… would it be consistent with requiring you to memorize all outcomes? They said no, it would not. I then asked, what should I require then? The <u>big ideas</u>, they responded, the important aspects, "like what is held in the POS and where to look when we need specific information."
Seeking students' points of view	I sought or ignored the prior/current student understandings	TB (me): So if you let people have different ideas, isn't that dangerous in, let's say in religion and maybe science too? Victoria: <u>I think</u> it's a good thing just because you get so many more aspects, but it depends on what it is, of course. If a student is a way off topic…
Challenge suppositions	Adapting classroom activities based on students' understandings or prior knowledge	Now that I think back, I could have used this opportunity to further illustrate the constructivist pedagogy by asking the students <u>how I could have improved</u> the POE demo. When a future activity fails to work as planned, I will elicit student <u>suggestions in order to find alternative solutions</u>. Then I will point out to the students what we did… using understandings from multiple people in order to construct an alternative plan of action.
Assessment of learning	Assessment viewed as separate from teaching or interwoven with teaching	Instead of having a student create a unit plan that is handed in at the end of the course and receives little <u>constructive feedback</u> regarding the content of the unit plan, I have devoted an entire class to <u>peer, self, instructor feedback</u> for the final project… the students will come to class for the sole purpose of conducting a peer review of their peers' unit plans.

Curricular activities rely on	Textbooks and workbooks vs. primary data or manipulatives	One of the most significant decisions made while planning for this course was the choice to move away from a textbook-oriented course. In the past, the students and I worked our way through a textbook. That often entailed examining one chapter per day... Instead, the content of each class will originate from journal articles.
The curriculum presented via/	Didactic strategies (passive learning) vs. interactive strategies (active learning)	I watched myself describe and explain what happened in the simulation. I missed the chance to allow the students to explain what we were watching… I did not draw out of them the most significant point that was being made. I informed the class what they saw that most of the atmosphere does not interact with UV or IR, but that greenhouse gases do absorb IR.
Researcher's personal response	Response to changing teaching. e.g., confidence, uncertainty	I found that the act of asking for student input was also more comfortable. I did not feel the urge to correct faulty reasoning immediately but instead felt comfortable asking students to question their choices and change them when new information was examined.
Student response – Negative	Students' negative emotions—uncertainty, stress, frustration	There was even a little hostility exhibited by S14 (The top academic student in the class) when I continued to press the class to say why they believed David Suzuki's earlier statement. S14 said he was trying to get an education, not trying to explain a reason for a belief.
	Indications that the students are not engaged	I then asked the students to compare their predictions with a classmate. Most of the students immediately began to discuss their work, but approximately ¼ did not participate energetically. This group of students moved their bodies in order to facilitate communication but did very little talking.
	Students indicate a desire to return to traditional teaching methods	I encouraged these students with positive talk, but they slowly went through the motions. One person (S5) even stated, "Why does it matter what I think if it is wrong?"

Student response – Positive	Students' positive emotions, e.g., happiness, pleasure, etc.	These six people thought this option was great. "That is more like the kind of test I can do well on," S11 stated emphatically.
	Indication of student engagement	During the consensus concept map (CM) building time, the students happily accepted the tasks. They quickly collected their whiteboards and began working together. As I watched the greenhouse effect CM being built, happy sounds filled the classroom, and positive chatter was continually heard. The one group in the view of the camera showed students intently creating their project together.
	Students indicating that they appreciate the new teaching method	TB (me): I did not just tell you what the answer was because I was looking for you to create the answer. How did that work for you? S3: I liked that, actually. I found that was fun to learn and it got some hands-on and also it helped the people that were not as interested in the class; even if they didn't learn everything, they would have some memories and some thoughts.

Note: Data analysis and interpretation for this study followed Bogdan and Biklen's (2007) coding procedures. Examples of these authors' guidance include the development of coding categories (p. 161), preassigned coding systems (p. 168), and the mechanics of working with data (pp. 172-184). The underlined words in the examples were key to the coding of that specific text.

Appendix I

Example - Memo Category 1 (Personal Relevance)

The following data analysis chronicles my changing understanding of constructivist strategies, first during a high school teaching experience and second during a subsequent university education course. The final step of the analysis examines how these two experiences continue to facilitate my changing teaching practice. Brooks and Brooks (2001) provided the foundational understanding and constructivist lens through which the data is analyzed. Ten categories originating from these two sources facilitated the data analysis. The uncertainty I am experiencing during my changing paradigm encouraged me to use these two sources in order to establish clarity with which to analyze the data. Therefore, I chose to use these constructs to create the categories of analysis instead of using an open coding process.

In the following pages, the analysis for each category is presented in four sections. First, a description of the specific category, including the source of the category and explanation of how the category is viewed in this study. Second, an analysis of my understanding of constructivist teaching during the high school teaching experience. This includes an examination of the planning and instruction during the teaching experience and subsequent reflections following the teaching experience. Third, an analysis of my understanding of constructivist teaching as I taught a university education science curriculum and instruction course. This section of the analysis examines how the high school teaching experience was followed by a continued paradigmatic change, demonstrated in the planning, instruction, and reflection upon the subsequent university course. The final section analyses my current understanding of constructivist teaching in light of the high school and university teaching experiences. This section demonstrates how my understanding has changed based on my experiences. In other words, how my attempts at producing constructivist environments succeeded or failed and how I foresee creating future constructivist experiences that will allow preservice teachers an opportunity to develop an understanding of constructivist teaching practices.

Data Category: Personal Relevance.

The Personal Relevance category encompasses data that identifies the extent that I implemented teaching strategies that produced a school experience where learning was relevant to students' lives inside and outside the school setting. Tobias and Duffy (2009b) point out that constructivists view context and the goals of the learner as central components when understanding develops. Therefore, the category Personal Relevance encompasses learning experiences that are applicable to the student's personal ambitions or have a connection to their out-of-school issues, problems, or contexts.

Constructivist Understanding Applied to a High School Science Course.

Analysis of planning and instruction aimed at creating connections between the student and the content under investigation is evident in the planned activities and questions. The following example is taken from an introduction to the science topic of specific heat. In the lesson from which this is drawn, I planned to tap into the students out of school experience of camping. The high school sponsors a student organization that regularly conducts camping trips in the Rocky Mountains, and I planned to use this aspect of student life to connect with the science content. The lesson was intended to give the students an opportunity to develop out-of-school relevance for the science content, specifically water's large specific heat. The planned questions included, "What would keep you warmest on a cold winter's night, 1kg of iron at 100ºC, or 1kg of water at 100ºC? Or would they both keep you warm equally?" These questions were asked, during the high school class, with the desire to connect the science content to the student's lives. Today I see these questions as questions that a traditional educator would ask.

As I examine the link between these two questions and the lives of students, it is evident that it did not meet my constructivist goal. Although I desired to make a connection between specific heat and the experiences students have while camping, I believe a deeper connection could have been made. Boaler (2003) points out that, "Whereas the teachers in the traditional classes gave students a lot of information, the teachers of the reform approach chose to draw information out of students" (p. 4). In this introduction to specific heat, I provided too much abstract information that did not originate from the student. If would have asked the students to describe the experience, when they touched objects while camping, instead of presenting a fabricated scenario, the opportunity to draw the information from the students would have been present. I could have then asked if anyone had used objects to keep himself or herself warm, and only if someone had done so would have asked the questions regarding the differences they experienced with water, rocks, or metals. This example is evidence that although I made a choice to alter my strategies, the process of change was only beginning.

Later in the high school teaching experience, as I became more aware of the social structure of this science class, I attempted to incorporate Cowie (2015) suggestion that constructivist teaching includes socially relevant interactions. With this in mind, I planned to stimulate a discussion that incorporated personal relevancy the specific students in this class. During a lesson, designed to provide the students with an opportunity to examine their beliefs regarding the science of climate change and possible climate change misconceptions, I asked the students to discuss what they knew about the effect that alternative energies and electric cars might have on the environment. Earlier in the week, during a break between classes, S9 and S10 indicated their interest in Tesla's sports car as well as Tesla's Model 3 car. I initiated this discussion with the knowledge that these students held a personal interest in the subject. I intended to increase the social participation of S9 and S10, two students who were typically quiet during class discussions. During the following lessons, that touched on alternative energies and electric cars, these two students, made multiple contributions to class discussions. The in-class connection to out-of-school experiences led to increased class participation of S9 and S10.

The detailed description of electric cars and other alternative energy options reflected a perspective that the remainder of the students did not voice during the discussions. Therefore, the students, in general, benefited from the knowledge provided by S9 and S10. From a cognitive constructivist perspective, S9 and S10's participation in the classroom discussions indicate to me that they were actively thinking about the science content. From a social constructivist perspective, the knowledge that S9 and S10 brought to the discussions affected the understanding of the researcher and all of the students in the classroom.

Near the end of the high school teaching experience, I planned another opportunity aimed to provide for personal relevance. In the lesson from which this example is drawn, the intention is to connect the individual student personal actions to the more significant issue of how humans have affected their world. A calculator, provided by the Global Footprint Network, was used to determine the amount of land needed to support an individual's lifestyle. Based on the student's input, the calculator estimates the land required to support the student's lifestyle. The result of the calculation is then contrasted with the national average, the areas of the individual's lifestyle that use the most resources are identified, and suggestions are provided with which to reduce the individual's environmental impact.

I instructed the students to calculate the land mass needed to support their personal lifestyle and then we discussed the implication of the results. Upon analysis, I now see that although I intended to create a science lesson that was relevant to the students' lives, I asked questions that made the experience trivial, missing an opportunity to create deep personal connections. Few of the students showed much of a reaction to the results of their calculation. I asked, "Are you happy with the results of the calculations?" The reaction of the group was, yes. The question did not provide for more than a superficial acceptance or rejection. S18 was the only student that exhibited any emotion. She was very surprised with her results; the calculation indicated that she affected the environment significantly more than her classmates and the national average of Canadians. S18's energy provided the energy for the remaining class-wide discussion. Again, I asked a rather superficial question, "Do you agree with the suggestions that the calculator made with regards to reducing your personal ecological footprint?" Multiple students agreed that the suggestions were reasonable and that they believed that they influenced the local ecology and thereby the larger issue of climate change.

Young (2002) argues that "Careful, objective reflection helps the learner to dissect their experiences into aspects that can be integrated with other experiences and used in further stages of learning" (p. 44). A class discussion is one way Young suggests that the mind can be turned on, yet, although I included a class discussion, I believe that the questions I asked did not cause the majority of the high school students to connect the results of the activity to their out-of-school lives. I needed to ask questions that required the students to analyze the results at a deeper level. For example, I could have asked the class why someone calculation would be higher or lower than the average. If S18 choose to discuss her results with the class, I could have asked her what she believed caused her calculation to be higher than the class average. I could have asked if it is reasonable to attempt to change this number. I could have asked the students to explain to me how much of their Ecological Footprint they believed was dependent upon choices they made in their own lives and how much was beyond their control. In conclusion, although I lead an activity that required the students to use the Ecological Footprint calculator, I believe that I could have created a lesson that connects more effectively with their out of school lives.

My Understanding applied to a University Science C&I Course.

Using insights gained from the high school teaching experience, I intentionally sought to create connections between the class content and future teaching situations that my university science education students will experience. This led to a change in approach that is evident in the opening activity of each class period. Prior to this study, I would consistently read a devotional thought to students, and then inform them of the moral or ethical point of the message. During the EDPR 468 course, I shifted the focus of the worships to include a connection to their future teaching lives. For example, in the past I read a quote from one of the founding members of the SDA church, explaining to the students why we teach. "Nothing is of greater importance than the education of our children and young people…" (White, 1968). During the fall 2016 course, instead of telling the students how these statements were relevant to them, I invited the students to explain how the statements related to their future teaching. In this example, the students provided a number of concrete reasons; including U1 relating that he believes that teaching can make permanent changes in students. U1 concluded, "This is exciting and scary."

The high school teaching experience also informed my strategies in the teacher education course as I created plans aimed at connecting the preservice teachers to their future professional lives through reading assignments. My Reflective journal revealed planning aimed at connecting the university student's professional lives and the course content are evident — the specific reading assignment directly related to the students' professional practice. For example, the article titled Why are schools brainwashing our children (Reynolds, 2012), describes how some teachers are weaving social justice issues into the school curriculum as well as into cross-curricular activities, events and projects. The objective of this reading was to encourage a discussion focused on the examination of the student teachers' personal understanding of the purpose of education. The plan intended to stimulate the preservice teachers to envision how this understanding will affect their future classroom. An interesting result of this specific activity was that some of the university students felt that some schools are trying to 'brainwash' children with ideas that they oppose. The resulting discussion created a deeply personal connection between teaching and learning for these students.

Evidence from a post-practicum interview suggests that the experiences during the C&I science course encouraged the preservice teachers to incorporate an element of personal relevance in their practicum teaching. For example, U1 stated that sought to create a link between the science lessons and the students' future careers. He described how the students in his 12-grade advanced placement course were planning to attend university in a few months; therefore, he felt that by linking the content he was teaching to current research, he connected his students to their future educational life after high school graduation (e.g., graduate school). U1 continued, "I can find a modern-day research tie-in, which I think was the cool thing they didn't even know was going on and made science real world for them." U1's statements indicated that although he developed some understanding concerning connecting the content he was teaching to the students' lives, he later admitted that he assumed that all the students were interested in becoming researchers. If the students did not envision university in their future, these discussions would not be relevant to the students. Nevertheless, U1 did make an effort to connect the in-school topics with out-of-school interests and goal of his students.

My current understanding.

Connecting classroom learning to out-of-school experiences occurred in a spontaneous, haphazard manner throughout my teaching prior to the current research project. If a connection occurred, it was not intentional on my part. Examination of the high school and university teaching experiences, I am able to identify planning or implementation of teaching strategies, which relate to creating personal relevance, that I intend to improve upon.

When examining the attempts I made at connecting the lives of high school students to the investigation of scientific topics I can see that at times the connections were very thin. This tenuous connection was evident during a lesson focused on the specific heat of water. The goal was to connect the large specific heat of water to the significant effect that water has on climate. One example that missed making a personal connection between the students and specific heat was when I attempted to make a connection to the students' lives by describing a shocking scenario of heat transfer. I explained what would happen if a hot water heater discharged steam towards a technician's face. Although the students showed an emotional response to this story, the scenario did not provide a concrete connection between the science lesson and the students' lives. It is unlikely that any of the students have fixed, or even touched, a hot water heater. Thus although the story may have been interesting, it did not connect the lesson to their out-of-school lives. As a result, the description of the scenario led to a traditional didactic explanation.

A year after the high school teaching experience, I believe that helping the students understand that water, in the form of steam, can hold a great deal of energy was appropriate. In comparison to the example above, a constructivist strategy would directly include the student's experiences. For example, I could ask students to describe times when they had touch extremely hot water, possibly guiding the discussion towards cooking or brewing tea/coffee. This would be more appropriate; it is likely that each student has experienced touching the extremely hot water. From that point, I could ask how long it takes water to heat up or cool. This would provide an avenue for connecting questions regarding how large amounts of water may hold a large amount of energy and as a result impact the temperature of the local environment.

A second example where I missed making the science content relevant occurred as I attempted to confront a misconception identified by the pre-study science questionnaire. I prepared a number of questions targeting a misconception regarding the role of ozone in climate change. I began with a question that I believed would facilitate a real-world connection between school science and out of school life. The question, "Is ozone good for you?" This question flopped. The students looked at me with blank faces. Upon reflection, I understand that the students have very little real-life connection to ozone. When I asked this question, the students' provided only guesses. They had no real-world experiences that would enable them to connect the ultraviolet radiation-blocking attribute of ozone to their fear of sunburns and skin cancer. Again, the result of this lack of a connection led to a didactic explanation of the misconnection of ozone's role in climate change.

Again, a year later I ask myself, what should I have done? Climate change science and the hole in the ozone layer are two different issues, yet some students conflate these issues. I needed to realize that understanding ozone connection to our lives would be a two-step process. First, I needed to provide opportunities for students to understand that ozone absorbs ultraviolet radiation (UV) and then ask questions that would encourage students to connect this concept to their lives. When viewing the digital recording, I watched S7 spontaneously make this first connection. She explained to her small group that if there was a hole in a blanket, more UV rays would enter, but more UV rays would also exit. She concluded that the increased incoming and outgoing UV radiation would produce an equilibrium, not climate change. The second step, linking the lives of students to ozone depletion, could be facilitated through connecting the experience of sunburns to ozone depletion. I could ask the students if they experienced a sunburn. "Other than the discomfort, why should we worry about sunburns?" Popular media has well described the link of UV radiation with skin cancer. Allowing the students to make these connections themselves may allow the students to displace the misconception that ozone depletion causes global warming.

My understanding of how instruction and learning impacts how students construct their own understanding of the world they live in is evident in the changes I have made in my classroom. Personal relevance has become integral to my instruction and is exemplified in the changes I made to the initial assignment I gave the university students. In the past, I asked the education students to develop a list of criteria that they thought should be used to select the Teacher of the Year. After watching a section of the video entitled, Teacher of the Year, I gave the students an opportunity to add criteria to the initial list. The purpose of this assignment is to encourage students to think about the attributes that great teachers have.

Following the high school teaching experience, I heightened the personal relevance of this assignment by added two follow-up items. First, I asked the students to write a brief description of their favourite teacher, clearly describing why she or he is considered their favourite teacher. Second, I asked whether they have told that teacher how much they appreciated him/her. The simple addition of these two items changed the assignment from one that was theoretical to one that deeply touched many of the students. One student indicated to me that after completing the assignment, she sought out the teacher they wrote about and thanked them for the impact that the teacher had on her life.

Appendix J:

Excerpt from My Reflective Journal

Following class 1 (Sept 6, 2016):

Worship thought. Although this part of my lesson is often presented in didactic manner (reading a bible verse or devotional), I strove to include the students in the process. The quote that we examined was from one of the founding members of the SDA church. It reminds us why we teach. “Nothing is of greater importance than the education of our children and young people” (E. White). I invited the students to explain how this statement relates to their future teaching career. A number of concrete reasons were provided by the students, including S1 relating that they believe that teaching can makes permanent changes in students. “This is exciting and scary”, S1. Victoria focused on the spiritual ramification of the quote.

I intend to encourage discussion in this course, therefore spent time to introduce who I am, with the purpose to creating an atmosphere of acceptance. I also asked the students to tell the class a little about themselves. As I think back on this activity, I believe that I spoke too much. I should have drawn more out of the students. For example, I recognize that one student did not tell us where he is from or why he is in education. We know some superficial facts, which is a start, but more interaction would have helped. I do not feel like I am comfortable yet.

As I reflect on today’s class, attempting to view the event through a constructivist lens, see how I could have made more connections between the student’s current views and the course content. For example, I did not ask the students about their past science and math classes. Did they enjoy their past classes? Was there a subject or teacher that they remember fondly. I immediately discussed the reoccurring results found when students take the Test of Science Related Attitudes (TOSRA) survey. I still struggle with presenting before identify prior knowledge. Nevertheless, I believe I have made a step in the right direction. This feels right.

My goal was to introduce myself to any new students and present the overall teaching strategy that will inform the course. I purposefully presented the course as a constructivist course, one that will require student active participation. The students nodded of their heads while their faces showed acceptance. Their body language indicated to me that they understood what will occur and that they had no problem with the plan. It is interesting to me to note that the students held no bias for or against what I was proposing. When thinking back to when I was in their position, I would not have understood how a constructivist classroom may be different. I should have asked the students what they knew about constructivism. Now that I realized that I did not ask this basic questions, I will ask the students next class.

I believe that I was able to meet the goal of building rapport, for the students eagerly interacted with me throughout the class. I also believe that the students accepted the style of teaching that I proposed, for they verbally agreed with me when I stated that the teaching methods I will use in the course are ones used in schools today and are driving the development of Canadian curriculums. During the class I also presented the course syllabus, discussing the information in the document in a manner that encouraged questions. Therefore the students asked questions throughout the presentation of the course syllabus. During this part of the class, it did not appear that the students were feeling anxiety. Their faces showed either interest or acceptance and their body language was appeared calm.

One activity where students showed a cooperative spirit, which I had not observed is past classes, was during the portion of the class where the students solved a mathematical puzzle, The Petals of a Rose. Here students suggested strategies to each other in an attempt to discover that solution to the puzzle. Past classes pulled out a piece of paper and individually attempted to solve the puzzle in isolation. Possibly this is an indication that I have already encouraged this class to work together to build their knowledge.