Connecting the Dots of a Moving Image:
Future Teachers' Undergraduate Experiences With Science

by

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M. Sc., The University of Toronto, 1987

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIRMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

in

The Faculty of Graduate Studies

(Curriculum Studies)

THE UNIVERSITY OF BRITISH COLUMBIA
(Vancouver)

March 2011

ABSTRACT

Elementary students are taught science by teachers from social sciences and humanities backgrounds, begging the question about when and how these elementary teachers learn science content. This study explores the experiences of four future teachers in Bachelor of Arts (BA) science elective courses. More specifically, in terms of their perspectives as non-science majors learning science, their conceptions about the nature of science, and their views about how activities in their university classroom might apply to their future careers. The methodological framework borrows from Giorgi's phenomenological inquiry as one way to interrogate students' experiences in a university science course. Aikenhead's Border Crossing perspective emerged as an interpretive frame to understand student's experiences *as lived*. Data collected from interviews and personal journal testimonies led to individual stories about four future teachers, represented by unique metaphors from the natural world. The stories are not the same, nor is there an intention to represent universal generalizations about all future teachers. The analysis resulted in the generation of a Structures Table that locates particular characteristics or traits of aspiring teachers across a spectrum of possibilities that might be informative for science education instructors responsible for similar programs or courses. In addition, interpretation of Aikenhead's Border Crossing perspective prompted the creation of a Border Crossing map that might also be of use to science educators. Further, the analysis illustrated that the participants: held preconceptions that learning science was hard, complex, and boring; perceptions of science varied between something independent of human perception to something that was embedded in the culture in which it was constructed; social science backgrounds and their interest in environmental issues influenced how they viewed the usefulness of scientific knowledge; felt that learning science is most effective through direct, hands-on activities; and were most engaged when they could make direct connections between the content of the courses and their future career as classroom teachers. Attention to improving science learning for future teachers during the earliest phase of their university experiences may facilitate developing teachers of science who pass on their vision of science as a tentative, subjective, creative and socio-cultural pursuit.

PREFACE

The research presented in this dissertation was approved by The University of British Columbia, Office of Research Services, Behavioural Research Ethics Board.

Certificate of Approval Number: H08-01562

TABLE OF CONTENTS

Abstract ii
Preface iii
Table of Contents iv
List of Tables vi
List of Figures vii
Acknowledgements viii
Dedication ix

Chapter 1: Introduction 1
1.1 Background 2
1.2 Outline of the Study 4
1.3 Chapter Overview 5
1.4 Clarification of Terms 7

Chapter 2: Overview of Science Education 9
2.1 Roots and Origins of Science Education 12
2.2 Contemporary Issues in Science Education 19
A) Curricular Issues 19
B) Assessment 31
2.3 Future Directions of Science Education Research 36

Chapter 3: What Science and For Whom? 39
3.1 Perspectives on Nature of Science 43
3.2 Assessing Views of Nature of Science 54
3.3 Nature of Science in the Science Classroom 59
3.4 Review of Research 63

Chapter 4: Methodological Framework 70
4.1 Phenomenology as a Philosophy 71
4.2 Applied Phenomenology 77
4.3 Phenomenology as a Methodological Framework 82
A) Connections to a Theoretical Framework 83
B) Epoché and Bracketing 84
C) Methods 85
D) Analyzing Data 88
i) Model #1: van Manen 89
ii) Model #2: Hycner 91
iii) Model #3: Giorgi 92
4.4 Studying University Students' Experiences with Science 98
4.5 Stances on Knowledge and Truth 99
4.6 Ethical Considerations 104
4.7 Limitations of the Study 106

Chapter 5: Theoretical Framework 115
5.1 Cultures and Sub-Cultures 116
5.2 Border Crossing as an Additional Frame for Analyzing Data 124
5.3 Models of Students' Cultural Heterogeneity 128
5.4 Theoretical Assumptions and Implications 133

Chapter 6: Data and Results 136
6.1 Data Collection 137
6.2 Data Analysis 139
A) Explication: Familiarization 140
i) Metaphors Visuals as a Representational Form 141
ii) Four Stories 144
Terry's Story 145
Kelly's Story 150
Chris' Story 155
Sammy's Story 161
B) Explication: Meaning Units and Transformed Meaning Units 172
C) Explication: Integration and Synthesis of Structures 175
i) Using Border Crossing as a Lens for Thinking About Participants' Experiences 180
D) Summary of the Explication 184
6.3 Claims 185

Chapter 7: Discussion, Conclusion, and Implications 188
7.1 Discussion 188
7.2 Conclusion 201
7.3 Implications 203
A) Implications for Theory 203
B) Implications for Curriculum and Instruction 207
C) Implications for Research in Science Education 209

References 214

Appendices 237
Appendix A: Ethics Documentation 237
Appendix B: Interview Documents 239
Appendix C: Journal Documents 246

LIST OF TABLES

2.1 Variants of Constructivism 16
2.2 Driver and Erickson's Theories-in-Action, 1983 18
2.3 Broadening the Perspective on Science Curricula 21
2.4 Models of Teacher Knowledge 28
2.5 Examples of Models for Science Education Program Evaluation 34
2.6 Filling Gaps in the Study of Assessment 35

3.1 Conversations in the Literature: Traditional Perspective 44
3.2 Conversations in the Literature: Contemporary Perspective 48
3.3 Contemporary Views of Nature of Science 53
3.4 Instruments Used to Assess Understanding of Nature of Science 55
3.5 Evolution of Approaches to Assessing Nature of Science 56
3.6 VNOS-C Sample Questions 59

5.1 Overview of Anthropological Development of Cultures and Sub-cultures 122
5.2 Phelan's Classification Model 129
5.3 Costa's Classification Model 129
5.4 Aikenhead's Classification Model 131

6.1 Examples of Deriving Transformed Meaning Units 174
6.2 Structures Derived from Transformed Meaning Units 176
6.3 Detailed Summative Cross-Reference of Structures by Participant 177

LIST OF FIGURES

1.1 Cycles and Pathways for Learning and Teaching Science 3

2.1 A Pluralist View of Science and Culture 26

3.1 Arguments for the Importance of Nature of Science 50
3.2 Interdependent Aspects of Nature of Science 53

4.1 Branches of Phenomenology 73
4.2 Representation of Husserl's Units of Consciousness and Experience 75
4.3 Phenomenological Methodology: van Manen's Model 89
4.4 Phenomenological Methodology: Hycner's Model 91
4.5 Phenomenological Methodology: Giorgi's Model 93

6.1 Representations of Participant Profiles 143
6.2 Map of Participants' Experience as Cultural Heterogeneity 181

ACKNOWLEDGEMENTS

One does not begin or complete this type of work in isolation. When my journey into doctoral study began with a rather naive vision of professional growth and development, little did I know that the path would lead to profound personal enrichment. Someone once told me that the horizon is curved so that we cannot see too far ahead. These words rang in my head many times over the past few years. I feel fortunate indeed to have experienced the wisdom and mentorship of an exemplary research committee, the gratification of membership in a new academic community, and the blessings of family and friends.

A good deal of this enrichment is credited to my mentors, Professors ***Anthony Clarke, Samson Nashon, and Dan Pratt****, who I hold in the highest regard. This is not only because of their skill and prowess as supervisors and committee members, but also because of their willingness to deal with my endless questions, their intellectual generosity with a natural scientist who is making her best efforts to cross the border to social sciences, and especially for the professional kindness and thoughtfulness they extended as I struggled over each hurdle on my path. As experienced teachers, they pointed out every hurdle along the road and offered their guidance and encouragement while wisely leaving it up to me to walk under, over, around, or through the hurdle on my own. My gratitude for the profound impact these people have made on my professional work as a teacher/educator/researcher cannot be captured in words. Instead, I hope that my scholarly endeavors with my own students and any future research programme will demonstrate how much I have learned from each of them.*

Moving to Vancouver to begin my studies meant leaving family and friends behind. The resulting deep void in my personal life was short-lived, and thankfully quickly filled by new friendships. Special thanks to ***Dug Adler, Sandra Scott, and Mac*** *for whisking me off to Point Roberts when I really needed a break, feeding me turkey at Easter when I missed my family the most, and the endless chauffeuring with loads of books and boxes. Thanks to* ***Wendy Nielson*** *who taught me the true meaning of paying it forward, selflessly spending many hours of her own time to read my earliest work, focusing on improvement rather than telling me how bad it truly was! Now, I pass Wendy's guidance forward to my own students. Similarly, my friends* ***Michelle Tan, Veda Abu-Bakare, Ashwani Kumar, and Nancy Li*** *stood by me through the difficulties of my coursework when I felt completely lost in the complex world of philosophy and social sciences. Through these friendships, I had found a new community of friends and scholars. In recognition of friends at home, hearty thanks to* ***Jan Yorke*** *and* ***Sherri Steele****, the role models who inspired me to continue my studies, and also to* ***Janice Schulze*** *who, along with* ***Kim****, has always believed in me and spent endless hours spent supporting, reading, and editing my work.*

The final acknowledgements are to my beloved family, Mom ***Marion****, sister* ***Wendy****, and* ***Margit*** *(S.O.T.H.) for believing in me. Saving the best until the end, I want to thank* ***Paul****, my 'rock' and best friend, who comforted, tolerated, and inspired me along this journey, always quietly and strongly by my side, motivating me to take one small step at a time along this solitary and often lonely path. Ever accepting, ever tolerant, ever kind.*

Dedicated to John Arthur, "Art", war hero, beloved father, and role model.

Like many Canadian boys surviving the after-effects of the Great Depression of the '30's, Art's time with formal education ended at Grade 8 when the need to get a job to help support his family outweighed the need for continuing formal education. Soon, WW2 was on the horizon and volunteering for service overseas piqued his sense of adventure. At 20 years of age, he was one of the first to volunteer to serve his country and soon found himself learning to drive a tank at Camp Borden, Ontario's military training ground. Art drove many tanks through the great battles of Italy, Holland, and Belgium, but like many men and women who experienced the horrors of war on the front lines, he rarely spoke of these times. After the war was over, he returned home to his new wife, Marion and baby Wendy and took a job working for the City of Toronto. In his young life he had known poverty, war, death, and, love; however, continuing his education was not part of his future plan. Art was always much happier riding in the Handy Boy 'up the Musquashe' than he would have been pondering the meaning of life in the halls of the academy.

Time passed, great political leaders rose and fell, women burned their bras, humankind landed on the moon, a wall came down, the internet became a virtual reality, and I had the opportunity to do things that were not possible for my father. As my number one fan, he (and my Mom) made great sacrifices so that I could pursue the educational opportunities that were not open to him. He supported me financially and emotionally during my undergraduate studies, then several years later, he was happy to learn about my plan to apply for graduate school, even though this level of schooling was *terra incognita*. After completing my Master of Science program, my family attended the convocation ceremony. My father loved the regalia of the processional and the piper who lead us into Convocation Hall, all reminiscent of the traditional elements of his military career. I remember walking up the steps to kneel in front of the Chancellor, taking a quick glance over at my family in the audience. My father was a man of few words, but in that glance I saw him utterly beaming with pride.

To our great sadness, my father passed away very suddenly only a few short years after that convocation. Some may remember him as a man who lived a simple life, with *only* a Grade 8 education, but the life lessons he taught me about honour, courage, inspiration, and love prove that he was more than a war hero for Canada; he was also a hero to me, and for this reason I dedicate this work to him.

Even though Dad could not be with me during my PhD program and will not be with me for this convocation, I know that somewhere he will be with me in spirit, beaming with pride again, and I will bask in the light of a priceless legacy that continues to resonate with the vibrations of my heartsongs.

Chapter 1: Introduction

> ***We also need to do a better job of explaining science and technology to our grade school children so that, as citizens in the future, they will have some idea of what's affecting them, and what's being done to make their lives better, and where these improvements come from. I believe everyone should have some sense of where science fits into the affairs of the human race.***
> ***Norman Hackerman, Former Chair, National Science Board (1996, p. 78)***

> ***The need to place more emphasis on elementary teachers as learners has been apparent for some time but is perhaps a part of the science education research that has not garnered sufficient attention in the mainstream research literature.***
> ***John J. Loughran (2007, p. 1049)***

This dissertation presents renderings of four future elementary teachers' experiences with undergraduate science. Their stories are not the same, but they do speak to larger problems of students' low level of interest in science and how an overall low level of understanding impacts the everyday lives of a global citizenry (Linder, Ostman & Wickman, 2007). Some parts of the stories are common to all participants while other parts are unique to certain individuals. The challenges outlined above will not be solved by one doctoral study; however, the intention of this work is to provide the reader with more insight into connecting some of the dots in the circle of science education captioned above.

This work is an exploration of questions about how potential elementary teachers from social science and humanities backgrounds experience science courses in Bachelor of Arts programs, with the aim of improving the earliest phase of developing teachers' post-secondary experiences with science; a turning point which is often ignored in science education studies.

1.1 BACKGROUND

Elementary school teachers are expected to teach a variety of subjects, including the natural sciences[1], yet the majority of these teachers hold Bachelor of Arts (BA) degrees in the humanities or social sciences. Scholarly literature focuses on how Bachelor of Education (BEd) programs prepare pre-service elementary teachers to teach school science[2], but little attention has been given to science curriculum in the BA programs that prepare future teachers for BEd programs. Science elective courses in BA programs are a key step, but often ignored, along the pathway to becoming a lifelong science learner, an essential quality of an elementary science teacher. Consider the path of a typical elementary school teacher as shown in Figure I.1.
As a child, s/he begins her career in Elementary School (learning science), progressing to High school science (until Grade 10), often completing Grades 11 and 12 without further science courses. Graduates advance to university for a BA (science elective courses) and BEd (science pedagogy), and finally to a professional position in an Elementary School where s/he will teach science. By the time this person begins to teach science, she has *experienced* science in many different ways and established *conceptions* and *attitudes* about what science is and what it means to teach, learn and do science. These conceptions and attitudes will influence another generation of learners who are beginning their own journey.

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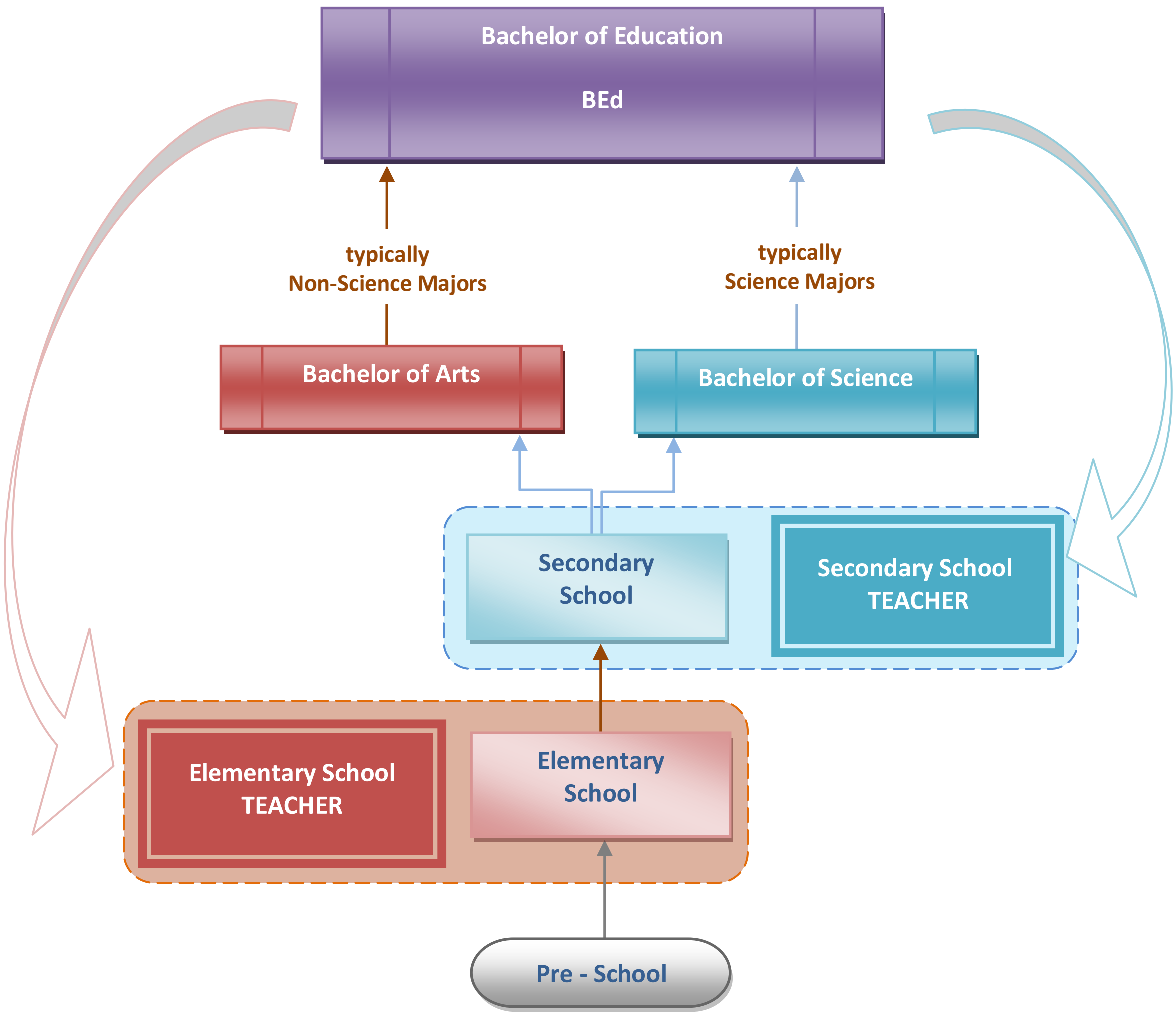
[1] See the beginning of Chapter 2 for clarification of the term *natural sciences*.
[2] See Clarification of Terms later in this chapter, p 5.

Figure 1.1: Cycles and Pathways for Learning and Teaching Science



Given that all elementary teachers are expected to teach science, and that many new teachers enter the profession with minimal exposure to the natural sciences at the upper secondary and post-secondary levels because it is not uncommon to major in the humanities and social sciences, and given that teachers' conceptions and attitudes about science will have a significant impact on K-8 students, then it is of paramount importance to consider future teachers' experiences with the natural sciences during their university programs.

1.2 OUTLINE OF THE STUDY

This study attempts to answer the question: What are the university BA students' a) perspectives, being non-science majors, on learning science; b) conceptions of nature of science, and; c) expectations of how experience in a university elective science course might apply to their future career as elementary teachers?

The study is framed by four assumptions. First, in general, non-science majors face significant inhibitions about learning science. Second, these inhibitions originate in the socio-cultural and cognitive contexts of learning science. Third, despite being fraught with inhibitions, future teachers will be expected to educate a general population (who will require knowledge and skills in the natural sciences) alongside those scientifically knowledgeable students (who will satisfy the anticipated requirement for increased numbers of highly trained scientists). Fourth, curriculum-developers and instructors at post-secondary institutions face enormous pedagogical challenges in establishing and revising curricula for non-science majors.

One way to study and understand these human experiences is by using a phenomenological approach. Phenomenological research programs are used to "gain insightful descriptions of the way [students] experience the world pre-reflexively, without taxonomizing, classifying, or abstracting it" (van Manen, 1990, p.9). A phenomenon is considered to be anything of which one is conscious (Husserl, 1970), and **in this study, the phenomenon is BA students' experiences in terms of attitudes toward learning science and conceptions of teaching and learning science in a science elective course.** The underlying assumption of this phenomenological stance is that "perceptions present us with evidence of the world – not as it is thought to be, but as it is lived….the lived world, or the *lived experience*" (Richards & Morse, 2007, p. 49). As such, phenomenology might be used as a lens to “reflect on concrete experience…determine what is essential… and imagine the phenomenon from all aspects” (Richards & Morse, 2007, p. 171) where the participants are future teachers, exploring their experiences as learners in an undergraduate science course.

Finally, while there are many aspects of science teacher education that could be tackled, the study is delimited to the dimension of BA students registered in first year science elective courses at one Canadian university. There are wider applications of this study of how science education conceived in post-secondary institutions, particularly for those students entering teacher education programs.

1 .3 CHAPTER OVERVIEW

Following the Introduction are literature reviews of science education (Chapter 2) and a construct of science education called Nature of Science (Chapter 3). The review of **Science Education** in **Chapter 2** offers insights about the historical and developmental aspects of various paradigms associated with science education, and then directs the reader’s interest toward more complex contemporary issues of curriculum, such as the professional, social, cultural, and political influences on science education. The final section of the chapter provides a short synopsis of instruments used to assess science education programs (national and international levels) followed by a brief section that outlines a number of directives for future research.

Chapter 3 is entitled, **What science and for whom?** This title was selected to reflect the vast landscape of positions, debates, and arguments about science as a philosophy and as a subject in education. The review speaks to certain aspects of the philosophical debate that help focus the reader's attention onto a construct of education referred to as *Nature of Science* or NOS. Literature from the past 60 years indicates an evolution of researchers' views about what science is important for students to know in science education. The elements of NOS are discussed in detail alongside instruments used to assess students' and teachers' conceptions of those aspects.

The reader is introduced to the research study being reported in this dissertation in **Chapter 4, Methodological Framework** and **Chapter 5, Theoretical Framework**. The methodology borrows from Amadeo Giorgi's (1985) philosophical principles and conceptualizations of applied phenomenology as a method to explore and interrogate students' experiences in university science courses. Glen Aikenhead's Border Crossing perspective (1996) is used to understand a new and unexpected view about certain anthropological issues involving non-science majors that emerged from the phenomenological explication of the participants' descriptions of their experiences, as seen within a context of their intention to become elementary teachers.

Chapter 6 presents the **Data and Results** of the analysis including profiles and metaphoric visuals of the participants, vignettes of their experiences, and claims about the findings. These claims are discussed in detail in **Chapter 7, Discussion, Conclusion, and Implications** where the reader is invited to consider the implications of the claims for educators and future science education researchers.

1.4 CLARIFICATION OF TERMS

Throughout this dissertation, the reader will encounter discipline-specific terms such as: school science; science teachers; science educators; science teacher development; science-majors and non-science majors; and science education researchers. To clarify the intended meaning and reduce the chance of any misinterpretation, a definition of each term is provided below.

School science is the curriculum[3] of the natural sciences studied in Grades 1 to 12. ***Science teachers*** are the accredited professionals employed to teach Grades K-12. ***Science educators*** are faculty members teaching at post-secondary institutions (college & university) in Faculties of Science (Bachelor of Science, BSc) and Faculties of Education (Bachelor of Education, BEd) and graduate level (Master of Arts and Doctor of Philosophy) programs. ***Science teacher development*** refers to university programs in teacher education (BEd and graduate levels). ***Science majors*** refers to undergraduate students (as science learners) registered in BSc programs or graduate programs in science (for example, M.Sc. or Ph.D.). ***Non-science majors*** refers to undergraduate students (as science learners) registered in BA programs who are required to take natural science electives as part of their degree program, typically as first year level courses. ***Science education researchers*** refer to a diverse group of professionals engaged in research programs in science education, and may include the following: the traditional university/college educators and K-12 science teachers, along with professionals working in

[3] [3] Curriculum in this context borrows from Pinar's reference to *currere* – "the Latin infinitive of curriculum – to denote the running (or lived experience) of [a] course." (Pinar, 2004, p. xiii).

non-traditional university/college educators and K-12 science teachers, along with professionals working in non-traditional settings[4], such as museums, science centers, and media.

In summary, this introductory chapter presents background information highlighting some of the missing links related to teaching and learning science and orients the reader to a research study that proposes to connect some of these missing links. The reader is also introduced to discipline-specific terms such as *school science* and *science teachers* that are used throughout the upcoming chapters. Clarification of such terms early in the work is relevant and important to readers' deepening understanding of issues and claims that surface later in the dissertation. With this short orientation to the study in place, readers are now invited to delve deeper into the study, beginning with a review of the body of literature about science education.

[4] Out-of school context for learning science, as described by Leonie J. Rennie, 2007, p. 130.

Chapter 2: Overview of Science Education

> We concur with Schön's (1995) call for a new epistemology that must be developed both in universities and in schools. Thus we must consider conceptual change [about teaching and learning science] not just as change in how students –*and* prospective teachers – think about phenomena but also as change in how students – *and* prospective teachers – think about education....The entire argument always needs to complete the circle of reasoning about theory and practice.
>
> (Russell & Martin, 2007)

Current discussions about teaching and learning science turn on at least two main points: the origins and roots of science education; and contemporary thoughts and innovations in the field. Recently, the literature has been enriched with reviews from around the globe about the advancement of science education in this context of historical, contemporary, and future perspectives. Two of these reviews are explored in this chapter: the *Linnaeus Tercentenary Symposium* held in Uppsala, Sweden (2007); and Abell & Lederman's Handbook of Research In Science Education (2007). A number of contributors to these reviews explore how science as a discipline that is taught in schools compares to science as a professional pursuit that is practiced by professional scientists. Drawing on historical aspects of science education that provide an idea of how knowledge and understanding of science have evolved, contemporary research programmes inquire and interrogate current trends, phenomena, and developments, and pose important questions for future research.

At the *Linnaeus Tercentenary Symposium* (Linder, Ostman, & Wickman, 2007), a diverse group of researchers focused on global issues of science literacy. The conference sought "a future vision for science education research and practice by articulating a more expansive notion of scientific literacy" (2007, preface). One distinguished member of this group, Gaalen Erickson, articulates the essence of our work as science educators (in reference to Archbishop Wejryd's conference address about the work of Linnaeus) as follows:

> We have a moral responsibility for the stewardship of life so that future generations will have the opportunity to continue in the never ending quest to deepen our understanding of the inter-dependence of the biotic and abiotic world in which we live and to sustain hope in our collective future. (Linder et al., 2007, p.19)

Several themes emerged from the conference papers including: teachers' and researchers' grave concerns about students' low levels of interest in science; how much of the school science curricula under-emphasizes creativity, ingenuity, and intuition involved in the scientific enterprise; and the low level of understanding about how science impacts the everyday lives of a global citizenry.

Abell and Lederman's *Handbook of Research on Science Education* (2007) provides a comprehensive review of traditional and contemporary conversations in science education research. The editors organize historic, contemporary and future views about science education into five categories: science learning; culture, gender, society and science learning; science teaching; curriculum and assessment in science; and science teacher education. Three themes emerge from this NARST[5] endorsed publication. First, learning theories have dominated science education for over 100 years and have thereby influenced how science educators' theoretical and practical views relate to matters of the discipline. Second, following this

[5] NARST is the National Association of Research in Science Teaching (*www.narst.org)*

evolving domination of learning theories is a parallel evolution of research methodological frameworks. As the early mental discipline theories were replaced by behaviorist learning theories (of the 1970's) and then to more recent theories of learning (for example, constructivism), there was a parallel shift in methodologies from process/product to qualitative methodological frameworks, respectively. Third, teaching and learning science is sometimes discipline-specific. Learning biology is different from learning physics and different again from learning chemistry. What counts as effective instruction for photosynthesis is not the same as for quantum mechanics, or as for stoichiometry and moles; therefore, the various disciplines of the natural sciences[6] often involve distinct and unique approaches to teaching and learning. Building on this theme are thoughts about how the processes of teaching and learning the natural sciences are different from the processes of teaching and learning the humanities and social sciences (Abell & Lederman, 2007).

The Conference focus on education for a scientifically literate global citizenry dovetails with the Handbook's attention on the vast landscape of educational research. Respecting the diversity and scope of literature in the field, the limited space of this dissertation does not present a synopsis of these reviews. Instead, this chapter highlights several important discussions and questions about the evolution of science education from traditional to contemporary approaches, on-going complexities of science curricula and scientific literacy, assessment and curriculum reform, and future directions for science education research programs.

---

[6] The *natural sciences* is a collective term referring to the disciplines of *physical sciences* (physics, chemistry, and related fields), *life sciences* (biology, genetics, environmental sciences, and related fields), and *applied sciences* (health sciences e.g. nursing, medicine, pharmacology, and engineering e.g. chemical, mechanical, biomedical, etc.). In this context, the natural sciences represent distinct and different disciplines from the social sciences, such as sociology, political science, education, and psychology. See Chapter 2 for clarification and elaboration of terms.

2.1 ROOTS AND ORIGINS OF SCIENCE EDUCATION

The roots and branches of science education have been growing and evolving for more than 250 years with the majority of journal articles appearing in the literature over the past 100 years (approximately). The foundational goals of enriching our understanding about the natural world are evident, albeit in different forms, with each new educational generation (Atkin & Black, 2007). Over the past century, one of the most significant markers on the science education timeline was World War II. Scientific developments during the periods immediately preceding, during, and following the war, resulted in expansive changes that affected world events in a way that had never been seen before. Atkins and Black speak to these historical aspects of science education in their 2007 review of developments in the United Kingdom (UK) and United States (US) (Atkins & Black, 2007).

Atkins and Black's work reveals that science education in the UK can be traced back to Cambridge University in the early 1850's, where Dawes and Henslow, two noted scholars in mathematics and botany respectively, saw the need for schools to teach science that is relevant to everyday life (e.g., a nugget of coal or a garden snail). Dawes and Henslow spoke of *tensions* between science as something "pure and conceptual" and science as something "applied and everyday" (p. 792). It is interesting to note that these tensions persist to this day. Science did not hold a prominent place in the elementary schools of the late 19th century due to limited funding and lack of qualified teachers. Developments in school science curriculum continued to wane due to WW I and WW II. The economic state of the UK following WWII was a country in bankruptcy. Schools had suffered major damage due to bombing and many, many citizens (teachers/students) had been conscripted into military service. Due to a lack of trained teachers and a poor economy, science education did not gain a place in the curriculum of UK schools until later in the 1960's. Of particular note, is the social structure of the UK where the elite private schools (secondary level) placed an emphasis on science education to meet the need for professionals in medicine and engineering, especially for military purposes.

The situation in the US shared some similarities (e.g., attention to science in everyday life as electricity in the home, and gasoline engines of automobiles), but there were also some distinct differences. In the post-WW II US, scientists assumed a place of social prestige - identified as a group of people who helped *win the war* (inventors of radar and the atomic bomb) and by making *victory* possible. Science became an important focus of the school curriculum with a primary aim of training more scientists across the broad spectrum of science disciplines. The success of Russia's launch of the satellite Sputnik in 1957 prompted a period of post-Sputnik reforms in the USA that integrated more scientific research issues into school science programs. In addition, there was a call for devoting more public funding to science curriculum in schools. The result was that in 1960's US, the teaching of science had become an important feature of US scientific advancement.

Concurrent with an increasing emphasis on science on both sides of the Atlantic, during the 1960's, the UK adopted a new national policy based on a child-centred philosophy of education with a focus was on *how* students learn (not *what* they learn); however, this policy seemed to lack developments with direct relevance to science education. Unlike the UK, the post-Sputnik US was almost in a state of panic about their need to bolster their military strength. With the success of the Apollo 11 moon landing in 1969 and the eventual decline of the Soviet Union, concerns about military strength were eased for a while. The focus of school science on preparing future scientists to address concerns of the scientific enterprise began to shift as the aims of education, particularly science education, moved to address the needs of *all* students as part of a future workforce. These improvements to science education were seen as one way to address the "perceived decline in the USA's economic competitiveness" (Atkin & Black, 2007,p. 792, citing National, 1983). This triggered a focus on *educational standards* that has continued into the new millennium.

The UK, under the new conservative government of 1989, established the National Curriculum, which tested children at ages 7, 11, 14 and 16. This assessment made science a compulsory subject for students age 5 to 16 because one of the content targets was experimental investigation. Of course, there was a parallel need to improve teacher education and increase efforts to develop more teachers who were qualified to teach science.

One factor common to both countries' (UK and US) increasing emphasis on science education was the concern about students' perspectives on science education; however, there has been a noticeable lack of any voice representing the majority of secondary level students, namely those who did not intend to be scientists, yet for whom an understanding of science is implicit in new national and international education imperatives. Atkins and Black (2007) speak of two forces that will drive future reform programs: first, is the worrying decrease in the number of students who chose to study science after age 16, such as, science majors in post-secondary programs in the natural sciences or engineering; and second, an overt public distrust of scientists and how many members of the scientific enterprise feel that school science does not adequately prepare students to value and utilize scientific accomplishments. Finally, at the end of their review, Atkins and Black's (2007) call for school science to make connections between science and the everyday world using curricula that engage the majority of students, including those who do not plan to become scientists, and spark “a sense of wonder, even awe, at the structures and processes to be seen in the natural world” (p. 804).

From these examples provided in Atkins and Black’s review, one can see that changes to science education and the related curriculum are driven by political, social and technological changes. There are and continue to be movements from *education for everyone* (emphasized at the primary level) to movements to educate *future scientists* (emphasized at the secondary level). These lessons of history hold a certain level of importance for the directions of science and science education as it expands into everyday culture (see Chapter 5) from a highly-specialized, value-free, unbiased, reductionist enterprise to a subjective, creative, pursuit with a closer connection to the social sciences and humanities that focus on moral questions, values, appreciation of nature, and stewardship of our planet.

Much of 20th century research on science education was dominated by theoretical frameworks drawing on early mental discipline theories such as the cognitive theories, for example, Piaget’s “stage theory” in the 1920’s -1950’s, involving adaptation, accommodation, assimilation, and self-regulation (Piaget, 1952, 1964). The 1970’s and 1980’s are described as a time when “accounts of the origins of students’ thinking about the natural world tended to be based on a Piagetian view of knower-known relationship, with knowledge portrayed in terms of entities in the individual’s head which developed through that individual’s interactions with the material world” (Scott, Asoko, & Leach, 2007, p. 34). Later, this Piagetian view of knowledge would be criticized by Michael Matthews (1992) because this stance “advanced an empiricist account of the generation of scientific knowledge ….[and]…failed to make any distinction between an individual's *beliefs* about the world and *knowledge* of the world that has been publicly warranted as reliable" (Scott et al., p. 34). Consequently, during the late '80's and 1990's, research programs saw advances to behaviorist learning theory and to constructivism, not as a rejection of Piaget but more as a re-discovery of Piaget's earlier thoughts (Sjoberg, 2007).

Like other paradigms, constructivism has its champions and its critics. Sjoberg states that even though many researchers claim that constructivism has a strong theoretical framework, there is disagreement about the epistemological and theoretical status of this paradigm (2007). As a result, many variants of constructivism have emerged (Table 2.1), including: social, radical, contextual, sociotransformative and sociocultural constructivism.

Table 2.1: Variants of Constructivism

(adapted from Sjoberg, 2007)

Sub-Type	Researchers
Individual Constructivism & Cognitive Constructivism	Paiget (1952/1964)
Social Constructivism	Vygotsky (1934/1987)
Radical Constructivism	von Glasersfeld (1984)
Contextual Constructivism	Cobern (1993a, 1993b)
Sociotransformative Constructivism	Rodriguez (1998)
Sociocultural Constructivism	Tobin (1998) Branco & Valsiner (2004)

This advancement and evolution of constructivist paradigms is similar to the advancement and evolution of the different branches of phenomenology that are discussed in Chapter 3. The difficulty with these variants is the potential for misinterpretation of meaning along with *real* and *false* disagreements about the claims made by those coming from different (and sometimes related) philosophical stances. Some critics claim constructivism is purely ideological and empty of meaning (Matthews, 1994) while others label constructivism as a fad, or fashion, or movement (Erickson, 2000) in science education. Other critics ask: Construction of what and by whom? (Sjoberg, 2007)

This opens a door to extensive debates in the literature, involving philosophers, historians, science education researchers, to name a few. A deeper exploration of the debate about constructivism is beyond the scope of this chapter; however, a discussion of the history of science education would be incomplete without reference to constructivism.

During the 1980's, many articles appeared in the literature inquiring into *HOW* students learn science (Driver & Erickson, 1983). In their landmark paper about science learning, Driver and Erickson use a theories-in-action framework to present trends and identify gaps in research programs, posing questions about existing problems, and suggesting aspects that should be addressed by future work in the field. At several points in their paper, Driver and Erickson (1983) point out the fact that for many generations, the dominant aim of the school science curriculum has been the preparation of future scientists and engineers. Roberts (2007a) validates this aim and uses the term, *Vision I curriculum* to describe this dominant curriculum focus. Table 2.2 presents an adaptation of Driver and Erickson's argument that highlights the need for future research programmes to suggest improvements that might advance science curriculum beyond this dominant curriculum by focusing on improving teacher development and education. In 2007, during his address to the *Linnaeus Tercentenary Symposium*, Erickson recalls his 1983 work with Rosalind Driver (1983) and reiterates the need to improve programmes that develop new teachers. In doing so, he refers back to their classic syllogistic argument which concludes with a call for greater attention to the interactions of learning and teaching as part of students' learning frameworks with a view to improving the development of new teaching programs.

Table 2.2: Driver and Erickson's Theories-in-Action, 1983
(generated from Erickson, 2007, p. 24-25)

Empirical Premise #1	"Many students have constructed from previous physical and linguistic experience, frameworks which can be used to interpret some of the natural phenomena which they study formally in school science classes"
Empirical Premise #2	"These student frameworks often result in conceptual confusion as they lead to different predictions and explanations from those frameworks that are sanctioned by school science"
Empirical Premise #3	"Well-planned instruction employing teaching strategies which take account of student frameworks will result in the development of frameworks that conform more closely to school science"
Normative Premise #1	"It is important to attend to pedagogical concern of how to improve student learning in educational settings. One should conduct research which will lead to a better understanding of school science by students"
CONCLUSION **"We ought to engage in research endeavors which will uncover student frameworks, investigate the ways they interact with instructional experiences, and utilize this knowledge in the development of teaching programs"**	

This dissertation attempts to respond to this call for attention to improving teacher development by exploring students' learning frameworks. The study presented in this dissertation explores future elementary teachers' experience as ***learners of science*** and their descriptions of how they experience being future ***teachers of science***. As the reader progresses from one chapter to the next, the theoretical and methodological perspectives used to frame the study will reveal findings, themes and claims that unfold from the inquiry, and connect back to Erickson and Driver's call for improving teacher development.

Before moving to the study itself, the reader will benefit by moving ahead from the trends in science education research and general discourse of science education to more contemporary conversations emerging from the literature and a comparison of science curriculum that prepares future scientists to a science curriculum that includes students who do not plan to become scientists, yet still have need to be scientifically literate citizens.

2.2 CONTEMPORARY ISSUES IN SCIENCE EDUCATION

Since the mid-1990's, science educators have faced many new and some not-so-new issues in their field: conceptual clarity about scientific literacy, context-specific tensions of politics, culture, and identity; pedagogical concerns as theories of learning intersect with curricular applications; and others. In many ways, the evolution of science education mirrors the evolution of society. For educators and researchers, the complexities of science curricula and science literacy are aspects of this evolution.

This section of the dissertation presents issues related to how science is taught in schools, more specifically how school science curricula (and consequently science literacy) are being affected by social factors such as politics and culture. The final part of this section about contemporary research issues concludes with an overview of how and why science programs and curriculum are evaluated.

A) Curriculum Issues

As researchers broadened their perspectives on learning theories from constructivism and conceptual change to include perspectives such as Aikenhead's border crossing (1998) and cultural processes that impact students' science learning (Lyons, 2003, 2006; Osborne, 2007), the implications of the latter were shown to affect how students understand the meaning of science in their everyday lives. Erickson (2000) points out a noticeable transition from research programs that pose questions about HOW students learn science, to questions about WHY students should learn science, referring to Aikenhead who suggests "students learn science so they can create relationships with their world" (2007, p. 64).

By considering how students' everyday world connects with science classes in school, as opposed to relying on teachers', curriculum-developers', or scientists' ideas about the most appropriate topics and context for school science, researchers of science education propose a shift in science education from a largely decontextualized, traditional curricula to a contextualized curricula. Roberts contrasts these two schools of thought about science curricula and refers to them as Vision I and Vision II (2007a, 2007b), where:

> **[Vision I]** looks inward at science itself – its products such as laws and theories, and its processes such as hypothesizing and experimenting. According to this vision, goals for school science should be based on the knowledge and skill sets that enable students to approach and think about situations as a professional scientist would (2007a, p. 9); and,
>
> [**Vision II]** looks outward at situations in which science has a role, such as decision-making about socio-scientific issues. In Vision II thinking, goals for school science should be based on the knowledge and skill sets that enable students to approach and think about situations as a citizen well informed about science would (author's emphasis, 2007a, p. 9).

Roberts' view is shared by other researchers. For example, Sjoberg (2007) makes a distinction between ***learning science*** and ***learning about science,*** where the former refers to preparing students to become scientists and the latter prepares students to become scientifically literate. Also, Fensham (2002) writes about the level of general agreement to move beyond the traditional approaches of preparing future scientists, to topics and approaches that are appropriate for *all* students, paying attention to WHY they might benefit from learning science.

Aikenhead (2007) draws on Roberts' Vision I and Vision II (2007a) in his call for an expansion of the science education research agenda to connect the aims of policies to the practices of curriculum in the classroom, as shown in Table 2.3.

Table 2.3: Broadening the Perspective on Science Curricula
(generated from Aikenhead, 2007)

	VISION I	**VISION II**
POLICY PERSPECTIVE	Science-centred	Student-centred
	FOCUS - on decontextualized science subject matter	FOCUS - on context
	AIM – to enculturate students into scientific disciplines (pre-professional training)	AIM – to enculturate students into their local, national, and global communities (like other school subjects)
ENACTMENT	**Practices in the classroom** Instruction	Assessment
CONSEQUENCES	The record of Vision I curriculum indicates decreased interest and lower enrolment in school science, leading investigators to ask why so many students opt to drop science after Grade 10, even though they have the capabilities and proficiencies to continue (Lyons 2003, 2006). **Aikenhead suggests researchers should ask:** ***Why should these students continue with science?***	Vision II is actually practiced as a hybrid with Vision I and commonly referred to as Vision I-II. This curriculum model seeks to enhance students' scientific skills, abilities and attitudes so they are able to "function as lifelong, responsible, savvy participants in their everyday lives, lives increasingly influenced by science and technology" (Aikenhead, 2007, p.64)

Foci and aims of Vision II curriculum shift FROM a professionally focused, decontextualized, enculturation of students into a culture of science with all of its on-going problems (for many students), TO a learner-focused, contextualized, enculturation of science into students' everyday world that is enacted through classroom practices to enable students to become scientifically literate citizens.

Aikenhead's treatment of the Vision I approach to science education points out several problems. First, Vision I continues to dominate much of the school science curricula in many schools. "Historically, the politics of privilege and elitism, *not consensus,* has legitimated the ideology of Vision I endemic to science education" (author's emphasis, p. 66 citing Aikenhead, 2006; Hodson, 1994; Seddon, 1991). In Canada, this legitimized ideology goes back to the time of confederation in 1867 and perpetuates the power and influence held by those in privileged positions, including science. Educational concerns of others who are in non-elite positions are not at the forefront of curricular considerations (Aikenhead 2007). Second, Vision I is considered a Euro-centric model limited to one ideological view as the only "academic scientific culture" (Aikenhead 2007, p. 66) where scientists' professional work, thinking, and practices are framed within their own subculture (Pickering 1992). Third, *other* students reject science as offered in schools due to conflicting cultural values between school science and their own personal experiences and culture. This is especially prevalent with Aboriginal students, who in Canada are those belonging to Inuit and First Nations' Peoples. Because one individual in the study being presented in this dissertation is a First Nations Person, the notion of rejecting Vision I curriculum is a prominent finding that will be explored in depth in Chapter 6, Data and Results and Chapter 7, Discussion, Conclusion and Implications. Fourth, many researchers agree that for students, mostly those in grades 6-12, learning science is a function of self-identity formation (Brickhouse, 2001, 2003, 2007; Case 2007; Brown, Revels & Kelly, 2005; Kelly 2007; Schreiner & Sjoberg, 2007); however, it must be noted that some Euro-American students clash with the culture of the Eurocentric model of science due to aspects of their own self-identity (Aikenhead 2006a, Cobern 2000). One example of this clash involves Western students who might hold radical feminist views that reject the hegemonic notion of a male-dominated scientific enterprise that denies women opportunities and access to the highest levels of decision-making.

On the other hand, Vision II is viewed as a "popular scientific culture" (Aikenhead 2007, p. 66 citing Solomon, 1998) that "refers to the concerns of the public, so important within their own local culture and often having a scientific and technological basis" (Solomon, 1998, p. 170). This might, at first, sound well and good; however, Solomon 1998 raises the important question: "can [academic] science be taught so that it connects with attitudes, personal values, and political issues? This would indeed make [academic] science a part of popular culture. But would it still be [academic] science?" (p. 171). One problem with both Vision I and Vision II curricula is that neither takes into account the worlds of *other* sciences, such as, indigenous and non-indigenous cultures described by Battiste and Henderson (2000); Maddock (1981); McKinely (2007), and Ogawa (1995).

Given this comparison between Vision I and Vision II, many researchers see the benefits of a hybrid, commonly referred to as the Vision I-II, that combines elements of both schools of thought and enacts the combination in the classroom (Roberts, 2007a; Aikenhead, 2007; Erickson 2007), although Aikenhead (2007, p. 68) does state that when enacted in the classroom, Vision I - II is simply a form of Vision II: "in practice, Vision II in practice becomes Vision I – II (citing Roberts, 2007a). These benefits include: learning aspects that address the (learning) needs of students who will one day become scientists alongside the needs of those who will not become scientists; cultural aspects that address the needs of Eurocentric and Indigenous students; and political aspects that address the influence of politics and policy-making on science curriculum and literacy. Despite the benefits, this model is not without its critics. Egan (1996) and Hughes (2000) state that hybridizing the Vision I and Vision II models would be detrimental to students because the philosophical stances behind the two schools of thought are viewed as mutually exclusive. Aikenhead (2007) cites Orpwood (2007) and Roberts (2007b), agreeing that while science education must be educationally sound, there must also be consideration about the reality of politics and power, recognizing that "political realities and educational soundness are [often] contradictory" (p. 85).

This line of thought led Aikenhead to propose a third view (Vision III[7]) which accounts for and accommodates a social context of science education that includes the politics that drive educational practices, policy-making, and research programmes. In its simplest form, the fundamental issue of this social context involves "[the] politics of what counts as science in school science" (Aikenhead, 2007, p. 68). Vision III broadens Vision I-II curriculum by adding this third socio-political dimension, so that Vision III, when enacted, connects the academic scientific culture (of Vision I) with the cultural pluralism of science (Vision II) with the political agenda in education (Vision III). The rationale for the Vision III approach accounts for the Eurocentric stance of Visions I & II that are both based on the Eurocentric sub-culture of the scientific enterprise (Roberts 2007a).

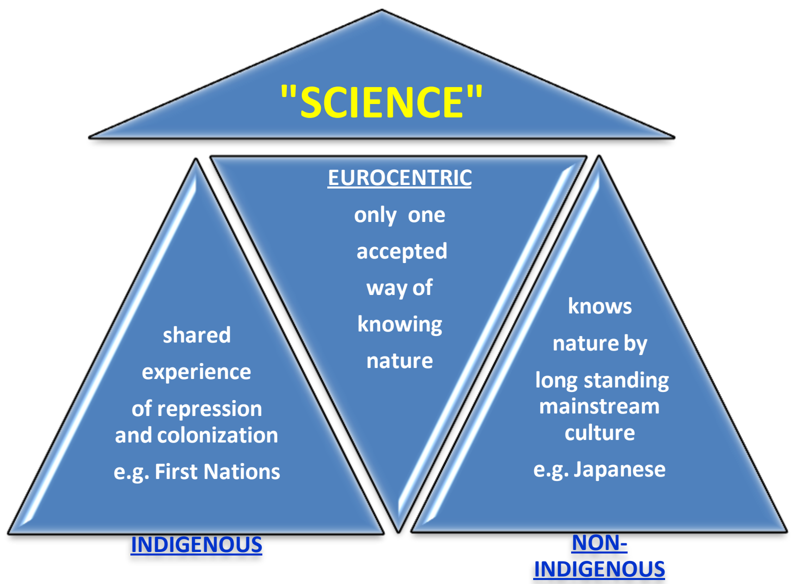
Vision III as a research agenda is taken up by Aikenhead as a humanistic perspective on science education (Aikenhead, 2006) that explores issues of the following: **policy–making**, in

[7] Aikenhead describes Vision III in practice as the hybrid Vision I – II- III (2001).

terms of the failure of traditional (Vision I) curriculum, relevance of school science, and processes for formulating policy; **classroom issues**, in terms of materials and resources, orientation of science teachers to implementing science curricula, and students as science learners; and **cultural studies**, in terms of heterogeneity of learners, cross-cultural education, and indigenous sciences. Woven throughout this agenda are the pluralist views of the socio-cultural-political views that he proposes are important to science education.

It is not realistic to expect that Vision III will be accepted uncritically by the scientific community because “identities seem to rest on their ownership of the word science, an ownership expressed in terms of singular universalist view of Eurocentric science” (Aikenhead, 2007,p. 68 citing McKinley, 2007); however, it is realistic to consider Vision III as an evolutionary advancement of school science curricula that is enacted in a diverse classroom of science learners with multiple cultural and personal interests. With this in mind, Aikenhead dovetails the academic interests of the scientific community with the cultural interests of non-Western peoples. While acknowledging that Eurocentric (or “Western science”) is a powerful and accepted way to know the natural world, Vision III considers science as a complementary integration of multiple contexts from a variety of cultural perspectives. For millennia, other (non-Western) cultures have observed, worshipped, explored, and explained the natural world (see Figure 2.1) in different ways.

Figure 2.1: A Pluralist View of Science & Culture
(generated from Aikenhead, 2007)



Vision III respects differences in philosophies and processes of acquiring and applying knowledge and integrates these views with the dominant Eurocentric, Western approach that is sometimes known as the Scientific Method.

Aikenhead's humanistic perspective on science education as expressed in the Vision III curriculum is taken up in greater detail in Chapter 5, where ideas about culture are interrogated using the lens of metaphorical border crossing. This theoretical perspective is used to understand the experiences of participants in this study.

Some highlights of the intersections of context-specific tensions of politics, culture, and identity with pedagogical concerns, such as curricular applications, have been presented; however, the picture would be incomplete without considering the context of those who occupy the classroom: teachers and students.

According to Reid (2006), any deliberations about curriculum, in terms of policy-making, theory, practice, and implementation should take into account the role of teachers and students. Regarding **teachers**, their role can vary considerably as a function of their: position in the classroom as teachers of science; role in the profession of teaching as curriculum makers; and role in the scientific community as community partners with researchers (2006). Depending on the perspective, the teacher may be seen as the prime means of implementing curriculum [systematic view] as: an instrument of hegemony [radical view]; promoters of professional development [existential view]; or "intermediaries between academic practice and the institution" [deliberative view] (Reid, 2006, p. 83). Similarly, views on the role of **students** are often "a reflection of how [curriculum theory] views the teacher" (Reid, 2006, p. 93) and by this he means that students might be seen as objects of the effects of curriculum [deliberative] or victims of the system [radical]. In many educational settings, students have unquestioningly been subordinate to teachers in terms of curricular experiences. Reid calls for a deliberative approach to curriculum theory in which students are viewed as "sources of curricular experience" (p. 98) who, just like teachers, are included as enthusiastic and knowledgeable participants in curriculum-making. Such curriculum issues are an important consideration of science education and curriculum reform.

The connection between teacher and student is established by the process of learning and a prominent place in contemporary research is devoted to inquiries into the characteristics that teachers develop or hold which might contribute to that learning process. One such exploration is Sandra Abell's review (2007) of how science teachers develop knowledge about science and how they learn to teach science. In her review, Abell (2007) states that, although the general term *teacher knowledge* is evident in the research for several decades, the focus on teachers' *formal knowledge* about teaching (Abell, 2007 citing Fenstermacher, 1994) did not shift until the 1980's when four research programs inquired into teachers' practical knowledge that was "derived from teachers participating in teaching" (Abell, 2007, p. 1106). Fenstermacher (1994) reviews four approaches to teacher knowledge shown in Table 1.4.

Table 2.4 : Models of Teacher Knowledge
(adapted from Abell, 2007 citing Fenstermacher (1994)

Researcher(s)	Program / Model
Clandinin and Connelly (1996)	Personal practical knowledge through teacher narrative
Schön (1983, 1987)	Reflective practice for professional development
Cochran-Smith & Lytle (1993, 1999)	Teacher Researcher Movement
Shulman (1986)	Teacher Knowledge Types

With the exception of Shulman, the studies shared similar views about how knowledge is produced and held by teachers. Shulman's work with teacher knowledge types looked at the knowledge that teachers need to have in order to teach one subject versus another subject: for example, the knowledge teachers need to have in order to teach science as opposed to English (Abell, 2007). Eventually, Shulman and his colleagues used his theoretical model to coin the term *pedagogical content knowledge* (PCK) which is defined as "the knowledge that is developed by teachers to help others learn" (Abell, 2007, p. 1107 citing Hashweh, 1985; Grossman, 1990; Shulman, 1986, 1987; Wilson, Schulman, & Richert, 1987) and as "the transformation of subject-matter knowledge into forms accessible to the students being taught" (Abell, 2007 citing Geddis, 1993, p. 675). PCK continues to be developed as a concept and as a methodology (Abell, 2007), but important questions remain about the connections between teacher knowledge, teacher practice and student learning.

Another example of the characteristics that teachers develop or hold which might contribute to that learning process is Tom Russell and Andrea Martin's review that states: "science teacher educators continue to be reluctant to practice in their own teaching what their research suggests that new and experienced teachers should do" (Russell & Martin, 2007, p. 1174). Their conclusions call for careful attention to:

> how we think about teaching science….[and] how we think about learning to teach science. Progress demands that perspectives that move us forward in teaching science be extended to the context of learning to teach science. Science education research has produced compelling insights that must be developed coherently as those learning to teach science move through their initial teaching experiences (2007, p. 1175).

There is a compelling reason for teachers to have opportunities to synthesize the findings of science education research, either during teacher developments programs such as BEd (Bachelor of Education), or during professional practice, as PD (professional development).

In terms of students, the literature is equally expansive and there are several things known. First, the majority of K-12 students are not going to become scientists (Roberts, 2007b). Second, the number of students entering post-secondary programs, BSc. and engineering programs is decreasing (Sjoberg, 2000). Third, there is an increasing public and, by implication, student distrust of scientists. It is important to make connections between teaching and learning science at school science with students' everyday world (Erickson, 2007). One way this might be accomplished is to move curriculum from experiments in the school laboratories, to the street, home, countryside, and industry, following Schön's (1987) lead in search of relevance that has for too long been missing in contemporary programs that focus specifically on rigor.

In conclusion, this section has presented contemporary issues in science education that are related to curriculum, including the tensions around how science curriculum has been exacted in schools; how school science is impacted by social factors such as identity, politics, and culture; and how teachers might connect with students through the learning process. In terms of science curricula, the formerly dominant Vision I curriculum represents a sub-culture of the scientific enterprise, but the value of learning science can be lost on students who do not intend to pursue careers as professional scientists. Speaking to the practicalities of teaching and learning, there is a need to balance science subject matter as disciplinary connections to everyday situations or human affairs in which science plays a role. When such affairs involve humanity and science, the curriculum cannot ignore the political, social, and cultural aspects. Vision II and Vision III have been developed as pluralist, context-driven attempts to help all students understand and connect science with their everyday world. Issues related to how students make these connections are taken up further in Border Crossing theory (see Chapter 5) and in the Discussion (see Chapter 7).

The final part of this section about contemporary research issues provides a brief but concise overview of how and why science programs and curriculum are evaluated at the institutional, national and international levels.

B) Assessment

Since the 1960's, school science programs have been connected to and in some cases, integrated with political agendas that fund public (and to some degree, private) education. Some examples of large scale, international assessments include: Trends in International Mathematics and Science Study (TIMSS) (Trends, 2009); Programme for International Student Achievement (PISA) (Programme, 2000) ; and Relevance of Science Education (ROSE) (Relevance, 2009).

TIMSS is sponsored by the International Association for the Evaluation of Educational Achievement (IEA) and has been conducted in 40 countries since 1994/1995 with subsequent surveys in 1999 and 2003. TIMSS was administered to students in grades 3,4,7,8, and the final year of secondary school with an aim to assess academic achievement. Information was gathered about processes of teaching and learning in mathematics and science from teachers, school principals, and documentation, such as curriculum guides, textbooks and other curriculum-related materials (Guo, 2007).

PISA was developed by the Organisation for Economic Co-operation and Development (OCED) as a triennial survey, first administered in 2000 to students age 15, in industrialized countries and other countries around the world. The aim is to assess knowledge, skills, and related academic characteristics of 15-year old students with a focus on literacy in reading, mathematics and science (OECD, 2009). Although some aspects of PISA assess students' attitudes and approaches to learning, these are not considered the primary aim of the survey (Guo, 2007).

Findings from TIMSS and PISA indicate that most countries surveyed have a major concern about students' (low) achievement in science (Guo, 2007). Of particular note are gender related issues, where boys score significantly higher than girls especially in physics, earth science, chemistry, environmental science, as well as gaps between intended, implemented, and attained curriculum. Findings of both surveys indicate that current states of science learning processes are inadequate in most countries. Context is assigned a high level of importance where the physical environment and social-cultural conditions at home, in the classroom, and at school are factors that impact these results.

Projects such as PISA and TIMSS assess academic achievement and understanding with aims to establish benchmarks and universal standards; however, these assessments lack the means to adequately capture how young people feel about science (Sjoberg 2007). Svein Sjoberg (University of Oslo) attempted to assess this affective domain of learning through an assessment project, called *Science and Scientist* (SAS) (Sjoberg, 2000), by investigating the interests , experiences, and perceptions relevant to the learning of science by children (age 13). The project involved 30 researchers in 21 countries assessing 9300 children's interests in attitudinal and motivation perspectives about science education and led Sjoberg to consider the critical importance of the affective domain on learning science and eventually develop a comparative survey entitled, Relevance of Science Education (ROSE). ROSE focuses on learners' perceptions about learning science and technology, a rationale that relates to the earlier discussion of Vision I, II and III curricula.

Given that Vision I curriculum still dominates school systems in many countries, the *intended* curriculum of a traditional Vision I school science program is structured around scientific content as facts, concepts, theories, and laws of nature. Embedded in the curriculum are hidden, implicit messages about how science is related to society, how scientific work is conducted, the various roles of scientists in scientific organizations and occupations, the nature of science, the status of scientific knowledge, and philosophical aspects about nature of science. Sjoberg notes that despite these cognitive complexities and intriguing aspects of science, the majority of students pursue careers outside of science due to the fact that much of the science curriculum is not relevant to the student audience. He even goes so far as to state that lack of relevance is "the greatest barrier for good learning as well as for interest in the subject" (2007, p. 103).

To date, approximately 40 countries have been involved with ROSE and administered the survey to students completing high school (average of 15 years of age). The premise of the survey is that several factors influence attitudes toward and motivation to learn science / technology, including the following:

- Experiences students have outside of school, related to science and technology
- Different contexts
- Students' prior experiences with school science
- Views that students have developed about school science
- Students' attitudes to the scientific enterprise (science and scientists in society)
- Hopes, priorities, and aspirations for the future
- Feelings about environmental and global challenges (Sjoberg 2007, p. 103)

Unlike TIMSS and PISA, ROSE reveals the attitudinal perspective of the learner, rather than their cognitive insights expressed at the institutional level or at the level of an overseeing body, such as The Ministry of Education (in Canada). In this way, ROSE reveals another important voice in the debate about how we assess the success, or otherwise, of science curriculum.

Large scale assessments such as TIMSS, PISA, and ROSE focus on student performance and student attitudes and as such, present only certain aspects of evaluating of science education programs. Recently, Lawrenz (2007) published a comprehensive review of the broad approaches to assessment and their underlying philosophies, as well as different models used to evaluate science education programs, in terms of the strengths, limitations, and different methodological approaches within each model.

Table 2.5: Examples of Models for Science Education Program Evaluations
(generated from Lawrenz, 2007, p. 953)

Theme	Model	Science Education Example
Accountability Oriented	Decision/ accountability	Science teacher development program – analyze strengths and weakness – make appropriate decisions for the upcoming year
Social Agenda / Advocacy Focus	Deliberative/ democratic	Science teachers in a school district – debate and vote on instrument questions and interpretation of results
Methods Oriented	Case Study	School Board – in-depth description and analysis of particular setting such as an Advanced Placement chemistry class

These models focus on teacher development and practicing teachers using three general themes: accountability (improvement) oriented; social agenda/advocacy focused; and methods oriented (Stufflebeam 2001) as shown in Table 1.5 above. Lawrenz's comments indicate that much of the published literature is theoretical, with a focus on descriptions of approaches, procedures, and when they can be used. She claims that the literature lacks information about which approach can/should be used in a particular setting or situation (2007). Lawrenz proposes several suggestions for future contributions to the field of science education program assessment, listed in Table 2.6, all of which relate to extending the approach to assessment, considering the stakeholders, and expanding educating programs for developing Evaluators.

Table 2.6: Filling Gaps in the Study of Assessment
(generated from Lawrenz, 2007)

CRITERIA	ACADEMIC LEVEL
Comparing strengths and weaknesses of different evaluation approaches and methods	○ Different grade levels ○ Different content areas ○ Different types of students
Determining the value of a science program evaluation approach in terms of needs and opinions of different stakeholders	○ Consideration of evaluation of the results of similar programs obtained through different methods ○ similar to an idea proposed by NRC (National Research Committee) to assess standards-based reform
Identifying competencies required to conduct assessments of science education programs, and expanding educational programs in order to provide qualified EVALUATORS	○ Graduate level programs ○ Short courses and intensive workshops ○ (it is important to note that currently there is no clear indication of the skills needed to perform these evaluations)

In summary, whether considering assessment of science education from a global perspective or from a local perspective, it is obvious that many *old* problems, such as declining enrollment and students' lack of interest in science, exist alongside *new* challenges, such as preparing scientifically literate citizens for life in the 21st century. Assessment instruments and practices reflect the values and cultures of the science classroom, especially those of the teacher (Lawrenz, 2007) and for this reason, it is important for science education researchers to consider the development of teachers' attitudes and conceptions about learning and teaching science.

2.3 FUTURE DIRECTIONS OF SCIENCE EDUCATION RESEARCH

According to Abell and Lederman (2007), research programs in science education must consider its ultimate purpose, draw on new theoretical and methodological frameworks and strategies, be grounded in the real world of the classroom and society, and, finally, in a form that can be translated for teachers (2007). They caution that if the ultimate purpose of researching science education is to improve the teaching and learning of science throughout the world, then good care must be taken to maintain rigor in designing, conducting and reporting work. In the current reality of competing for research funds, building numbers of publications for tenure and promotion, and presenting conference papers for university-funded travel, science researcher/educators must "take care that the proximate cause for the research…does not derail us from achieving the ultimate purpose" (p. xiii). As an applied field, science education research has to make sense in the real world of student, teachers, the school system, and society. Conversations about the gap between research and practice exist throughout the education literature, and science education research is no exception. Questions and concerns of the teachers, who come from or intend to inhabit that world, merit the attention of researchers who must attempt to address the issues and formulate answers that are understandable for practitioners, policy-makers, and other stakeholders who make decisions about the practical value of the research findings (2007).

Erickson shares this view of science education research as an applied field, His comments focus on the world of the science classroom and its connection with everyday life when presenting thoughts and ideas about future work (2007). He mentions the importance of pedagogical structures that teachers can use in the classroom, for example, the Learning Study approach (Linder, Fraser & Pang, 2006; Pang & Marton, 2003). There is also a need to bring teachers, students, and researchers together to collaborate rather than isolate, particularly when curriculum processes (development, review, revision, modification) are involved. At the post-secondary level, university science departments also have an interest in improving science education. For example, at UBC, the science faculty have promoted several initiatives including: Science One where the integrated approach to disciplinary learning is used; Skylight 2002, a centre to promote teaching and learning of science; and in 2007, the Carl Weiman Science Education Initiative (CWSEI) with a focus on improving teaching and learning science at the post-secondary level. Erickson wonders how these particular courses and initiatives will affect teaching and learning science at K-12 levels, but recognizes that teaching and learning can be improved by starting with programs at the tertiary level (post-secondary) and eventually moving to research projects with aims to improve curriculum and other educational concerns at the K-12 level.

Atkins and Black share their views about the future aims of science education in which the rationale for future work addresses the fact that all societies in our growing global community are influenced by science and technology. The science education community has a responsibility to enable all citizens, not only those who intend to become future scientists, to learn, live and work in a scientific and technological culture (2007). There is a need to focus on social awareness and “recast love of nature” to ensure a healthy environment for future generations.

Important questions and issues for researchers will be related to how the disciplines of science advance, how teachers can keep up with those advances, and how teacher education programs will address the growing need for teachers with adequate knowledge and understanding of science, and an appreciation of what they do in their classroom will have a significant impact on how science is taken up and enacted upon by all students.

Even though some have predicted the end of science (Horgan, 1994), scientists continue to generate new knowledge and understanding about the natural world. As a discipline, science education is much younger than the natural sciences, yet the approach to research programs and the body of knowledge that has been generated from such programs is fruitful, complex, and substantial. It is unlikely that science education and science will come to an end as current answers generate new questions:

> The highway from ignorance to knowledge runs both ways: As knowledge accumulates, diminishing the ignorance of the past, new questions arise, expanding the areas of ignorance to explore (Siegfried, 2005, p. 77).

Such expansion is the exploration of what is meant by the term *science* and how one's perspective can affect understanding, or misunderstanding of the term. The next chapter introduces the reader to some ideas about *science as a construct of education.*

Chapter 3: What science and for whom?

> ꕥ
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> Our definitions of ourselves as science teachers (and learners) are bound to our belief systems, epistemologies, prior experiences, motivation, knowledge, and skills. These factors are all linked to each other with reciprocal influence and are embedded in the larger sociocultural environment. Only through further research that can take a systems view of attitudes and beliefs can we truly understand how attitudes and beliefs shape instructional practice and use this knowledge to achieve reform.
>
> (Jones & Carter (200), p. 1096)

The question "What is science?" may appear simple to some at first, but when a philosopher asks what science is, the question becomes much more complicated. When the question expands to become: "What is science as a component of education?" then the level of complication moves beyond a simple list of scientific topics and laboratory experiments. Rather, the question becomes which aspects of the philosophy of science have an impact on science education.

Philosophical debates about the meaning of *Nature of Science* (NOS) occur in an arena of complex, ongoing discussions and arguments. Science education researchers and educators have many concerns that extend beyond the philosophical debates and into the science classroom, as evidenced by a plethora of published research studies over the past 60 years. A recent comprehensive review (Lederman, 2007) highlights the perspectives, findings, and implications of these studies about NOS in order to: explore contemporary science educators' and students' conceptions about the nature of science; assess and validate some of these conceptions; and articulate the impact of some alternative conceptions about NOS on science teaching and learning. Prior to continuing the discussion, it is important to understand how the terms *science, natural sciences,* and *nature of science* are used in this dissertation.

Several fields of study use the label ***science***, for example, social science, political science, library science, complexity science, and even creation science. Any discussion about NOS must be preceded by a clearly framed and situated reference to the term *science.* Many prominent authors have attempted to arrive at a clear and concise definition. Abell and Lederman define science as "1) a body of knowledge, 2) a method, and 3) a way of knowing, or the values and beliefs inherent to scientific knowledge and its development" (2007, p. 833). Aikenhead offers two pluralist definitions of science as "a rational-empirically based way of knowing nature that yields in part, descriptions and explanations of nature; where the term *rational* does not signify universalist rationality, but a rationality founded within the cultural context of use (Aikenhead, 2007, p. 67, citing Elkana, 1971) and a second version in which science is "a process that produces knowledge that proposes explanations about the natural world"(Aikenhead 2007,p. 67, citing OECD, 2006). Following Aikenhead, the discussion in this dissertation will consider science as a body of knowledge, a method, and a rational-empirically based way of knowing about the natural world that produces values, beliefs, descriptions, and explanations about this natural world within a cultural context of use.

N***atural sciences*** refers to the disciplines of science, including *physical sciences* (physics, chemistry, geology), *life sciences* (biology, genetics, environmental sciences), and *applied sciences* (health sciences, including nursing, medicine, pharmacology, and engineering, including chemical, mechanical, biomedical, electrical, and others). In this context, the natural sciences represent distinct and different disciplines[8] from the social sciences, such as sociology, political science, education, and psychology. Creation science is not considered part of the natural sciences.

Nature of science is a construct applied to science education (including school, undergraduate, and graduate science programs) that is considered to be "the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development" (Lederman, 1992). Similarly, Chalmers presents his epistemological perspective, stating:

> Science aims at true statements about what there is in the world and how it behaves, at all levels, not just at the level of observation….we cannot know that our current theories are true, but they are truer than earlier theories, and will retain at least approximate truth when they are replaced by something more accurate in the future (1999, p. 238).

He echoes Kuhn's Structure of Scientific Revolutions (1970) in which he discusses the nature of "normal" science in terms of "a promise of success [of a paradigm] discoverable in selected and still incomplete examples" (p. 23) wherein the "actualization of that promise….achieved by extending the knowledge of those facts that the paradigm displays as particularly revealing , by increasing the extent of the match between those facts and the paradigm's predictions, and by further articulation of the paradigm itself" (p. 24). Chalmers writes that Kuhn's theories of paradigm shifts, or *disciplinary matrices*[9]*,* emphasizes the revolutionary characteristic of science where a new theoretical structure replaces an existing (inadequate) theoretical structure (1999). Chalmers borrows from Kuhn's view that, in its simplest form, there is no co-existence

[8] The notion that different disciplines of the natural sciences involve different approaches to teaching and learning is explored in-depth in Chapter 1: Introduction to Science Education

[9] According to Chalmers, Kuhn later used the term *disciplinary matrix* when referring to paradigm in a general sense. End Notes, Ch. 8, p. 254

of multiple paradigms or in other words, “a mature science is governed by a single paradigm” (Chalmers, 1999, p. 108).

In science education, Canadian and United States (US) government documents include NOS in reports from the Science Council of Canada (Nadeau & Desautels, 1984), and the National Research Council’s National Science Standards (1996). One interpretation of the placement of NOS in these documents could be an indication that the scientific community has arrived at consensus about NOS as a construct. Even though some researchers present arguments that consensus has not yet been achieved (Alters, 1997), other authors in the literature suggest that there is “more consensus than disagreement” about NOS (Smith & Scharmann, 1999; Smith et al., 1997). Lederman clarifies the position of science education within the debate by pointing out that school science (K-12) is not a function of the ongoing debates and defends this position stating: “disagreements about the definition or meaning of NOS that continue to exist among philosophers, historians, and science educators are irrelevant to K-12 instruction” (2007, p. 832) because at the most basic level of knowing about science, there is:

> an acceptable level of generality regarding NOS that is acceptable to K-12 students and relevant to their everyday lives….[such as the characteristics including:]…scientific knowledge is tentative (subject to change), empirically based (based on and /or derived from observations of the natural world), and subjective (involves personal background, biases, and /or is theory-laden);…involves human inference, imagination, and creativity (involves the invention of explanations); and is socially and culturally embedded (2007, p. 833).

This characteristic of generality related to school science is supported and accepted by many researchers (Smith et al., 1997; Lederman, 1998; Smith & Scharmann, 1999; Elby & Hammer, 2001; Rudolph, 2003).

In this dissertation, **NOS refers to beliefs, values, and ways of knowing and articulating scientific theories/ideas about the natural world**. In addition, NOS is distinguished from scientific inquiry, the processes of science, and/or the resulting body of knowledge. Scientific inquiry, such as making an observation, is considered an experience on which ideas about NOS are built. Lederman notes that the "conflation of NOS and scientific inquiry has plagued research on NOS from the beginning and, perhaps, could have been avoided by using the phrase 'nature of scientific knowledge' as opposed to NOS." (author's emphasis, 2007, p. 835). A significant portion of the aforementioned philosophical debate revolves around ideas and conceptions about scientific inquiry.

It is important to clarify that even though many of the philosophical arguments about NOS stem from the canonical operations and practices of the scientific enterprise where philosophers, historians, and educators debate NOS mirroring the debate about science itself, the breadth and depth of this pool of conversations greatly exceeds the purpose of this paper. Therefore, this discussion will focus on aspects about NOS that are relevant to science education enacted in schools.

3.1 PERSPECTIVES ON NOS

The body of literature about NOS has been extensive since its inclusion in one of Ernst Mach's Popular Scientific Lectures in 1886, entitled "On instruction in the classics and the sciences". Twenty-eight years later, Dewey (1914) published "Science as subject-matter and as method"; thereby, initiating a wealth of published articles, books and lectures about the nature of science. Subsequent to these early questions about the nature of science, the literature has grown, especially in the mid-to-late 20th century. A sampling of references is presented in Table 3.1, not as an exhaustive list, but simply as a *pre-1980*[10] *snapshot,* examining and questioning science as a way of knowing for those interested in the traditional roots of the conversations about NOS.

Table 3.1: Conversations in the Literature: Traditional Perspective

(generated from Bell, Abd-El –Khalick, Lederman, McComas & Matthews, 2001)

1953	Campbell	What is Science?
1953	Toulmin	The Philosophy of Science
1954	Wilson	A Study of Opinions Related to the NOS and its Purpose in Society
1958	Stice	Facts About Science Test
1957	Frank	Philosophy of Science, the Link Between Science and Philosophy
1957	Mead & Metraux	Image of the Scientist Among High school Students
1961	Cooley & Klopfer	Test on Understanding Science
1961	Behnke	Reactions of Scientists & Sci Teachers to Statements Bearing on Certain Aspects of Sci and Sci Teaching
1963	Gruber	Science as Doctrine or Thought? A Critical Study of 9 Academic Yr Institutes
1963	Popper	Conjectures and Refutations: The Growth of Scientific Knowledge
1962	Processes of Sci	Biological Sciences Curriculum Study:1962 - Test
1965	Bronowski	Science and Human Values
1956	Kleinman	Teachers' Questions and Student Understanding of Science
1964	Schwab	The Teaching of Science as Enquiry
1965	Shoresman	A Technique to Clarify the Nature of Theories
1967	Kimball	Understanding the NOS: A Comparison of Scientists and Science Teachers
1968	Carey	An Analysis of the Understanding of NOS by Prospective Second. Sci. Teachers
1968	Popper	The Logic of Scientific Discovery
1969	Herron	Nature of Science: Panacea or Pandora's Box
1969	Olstad	The Effect of Science Teaching Methods on the Understanding of Science
1969	Robinson	Philosophy of Science: Implications for Teacher Education
1970	Carey	An Analysis of Experienced Science Teachers' Understanding of NOS
1970	Elkana	Science, Philosophy of Science, and Science Teaching
1970	Lakatos	Criticism and the Growth of Knowledge
1971	Mackay	Development of Understanding About the NOS
1972	Martin	Concepts in Science Education: A Philosophical Analysis
1972	Popper	Objective Knowledge
1974	Connelly	Significant Connections Between Philosophy of Science and Science Education
1975	Billeh & Hasan	Factors affecting teachers' gain in understanding the NOS
1975	Smolica & Nunan	The Philosophical and Sociological Fndns of Science Education: The Demythologizing of School Science
1976	Munby	Some Implications of Language in Science Education
1977	Laudan	Progress and Its Problems
1977	Mendelsohn	The Social Production of Scientific Knowledge
1978	Feyerabend	Against Method
1978	Horner & Rubba	The Myth of Absolute Truth
1978	Schwab	The Nature of Scientific Knowledge, as Related to Liberal Education
1978	Bronowski	The Common Sense of Science
1978	Cawthron & Rowell	Epistemology and Science Education
1979	Glen Aikenhead	Science: A Way of Knowing
1979	Ennis	Research in Philosophy of Science Bearing on Science Education
1979	Forge	A Role for the Philosophy of Science in the Teaching of Science

[10] There was no grand rationale for selecting 1980. It is simply the halfway point in the body of research that is being highlighted in this section.

This *snapshot* highlights a rich, long history and the changing face of NOS research. Contributions from prominent science educators[11] such as, Schwab, Elkana, and Aikenhead, are presented alongside several noteworthy philosophers[12], such as Popper, Feyerabend, Lakatos, and Laudan, to demonstrate that both philosophers and science education researchers have contributed to the complicated conversations about NOS and science education.

Much of this early research involved interrogating beliefs, values and ways of knowing the natural world rather than how science and the NOS was taught to students in schools; however, there is a general undercurrent acknowledging that teachers and students did not have a good grasp or adequate understanding about NOS. These traditional views are part of the "intense philosophical and historical debate about the nature of science itself, culminating in the much-publicized "Science Wars" of recent time" (authors' emphasis, Bell et al., 2001) but do not attempt to present any solutions to the problems related to teaching science in schools. In response to this diverse view of the recent research about NOS, Lederman characterizes our perceptions about NOS as a "moving target":

> If one considers the differences among the works of Popper (1959), Kuhn (1962), Lakatos (1970), Feyerabend (1975), Laudan (1977), and Giere (1988), it becomes quite clear that perceptions of NOS are as tentative , if not more so, than scientific knowledge itself. In short, NOS is analogous to scientific knowledge ….The recognition that our views of NOS have changed and will continue to change is not a justification for ceasing our research until total agreement is reached, or for avoiding recommendations or identifying what we think students should know (2007, p. 835).

The significance of this quote is an acknowledgement of the changing landscape of our understanding about NOS, science education, and even the scientific enterprise itself. It is accepted that the philosophers and science education researchers will continue to argue about the nature of scientific thought, the nature of instruction, the nature of knowing about science.

[11] For citations, see Table 3.1
[12] For citations, see Table 3.1

One question from Alters (1997) and Smith, Lederman, Bell, McComas, and Clough (1997) is “Whose Nature of Science?”. Alters surveyed philosophers of science in an effort to demonstrate agreement or disagreement about the nature of science. He claims there is a difference between tenets for NOS as held by philosophers of science and as held by science educators, leading to a conclusion in which “the tenets that are advocated as basic criteria for science education’s ‘the nature of science’ must be reconsidered so that more accurate criteria may be developed for future nature of science research” (author’s emphasis, 1995, p. 39). Smith et al. (1997) counter that while acknowledging the ongoing debates about the philosophy of science, such as empiricism versus realism: “too much is being made of disagreements concerning the NOS that involve tenets that are esoteric, inaccessible, and probably inappropriate for most K-12 instruction” (1997, p. 1102). From this researcher’s perspective, this proposition could be extended from K-12 to include science education at the post-secondary level (at least to non-science majors in BA and BEd programs who intend to become elementary teachers). Smith et al. conclude their argument by stating: “It appears that [Alters’] study was designed and the data interpreted in such as way as to create the false impression that there is a great disagreement about the NOS tenets relevant to K-12 instruction” (1997,p. 1103).

In another example highlighting false impressions of disagreement, the differences in the responses of philosophers (of science) and science education researchers (some of whom might also call themselves philosophers of science) is evident in a debate about the nature of scientific thought[13]. Suchting (1995) presents his search for a single definition of the nature of scientific thought. Lederman claims that Suchting's conclusion about the absence of a "final 'ultimate' answer to the question of the nature of scientific thought" (p. 371), along with his support of the idea that because subject matter in science is constantly changing then scientific reasoning must also changing, is problematic to science education, because the implication that "the current generic and universal approach to scientific thinking and process skills may be unfounded at best and contrary to the nature of scientific thought at worst" (1995, p. 372). Lederman concludes his argument by stating that Suchting's conclusions are not consistent with current aims and goals for science education and curricula. Suchting's (1996) response to Lederman seems to focus on the philosophical aspects rather than connections to science education. For example, Suchting focuses on conceptions of the word *nature* in the phrase *nature of science*, and although he clearly rejects the idea of multiple conceptions about the word nature, there is little elaboration about the ideas he does hold. In a self professed state of confusion and apprehension, Suchting's arguments spin and revolve around Lederman's interpretations of what he (Suchting) intended to convey; however, with this concentration on philosophical issues, any response to Lederman's significant points about connections to science education are lacking.

From this researcher's perspective, there is a need to attend more carefully to what Lederman has said about how the debates on the deeper philosophical aspects of NOS are irrelevant to K-12 instruction and extend this thought to include instruction to post-secondary non-science majors students as well.

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[13] Referring to a meta-theoretical view about the operations of professional science (the scientific enterprise) rather than NOS, a construct of science education about the scientific enterprise.

Returning to the objectives of research programs in science education, since the early 1990's, the focus of many contemporary articles is on questions related to how teachers' and students' understandings and conceptions about NOS can be affected, impacted, or explained. Table 3.2 highlights more recent research programs, after 1980, providing an overview of titles indicating the dynamic nature of the science education research.

Table 3.2: Conversations in the Literature: Contemporary Perspective

(adapted from Bell, Abd-El –Khalick, Lederman, McComas & Matthews, 2001)

1980	Baddelley	Teaching the Philosophy of Science through Nuffield Schemes
1984	Aicken	The Nature of Science
1984	Nadeau & Desautels	Epistemology and the Teaching of Science (Science Council of Canada)
1986	Hodson	The Nature of Scientific Observation
1986	Lederman	Students and Teachers' Understanding about NOS: A Reassessment
1987	Aikenhead	Science: A Way of Knowing
1987	Aikenhead, Fleming & Ryan	High school Graduates Beliefs About Science-Technology-Society: Methods and Issues in Monitoring Student Views
1988	Hodson	Toward a Philosophically More Valid Science Curriculum
1989	Brickhouse	The Teaching of the Philosophy of Science in Secondary Classrooms: Case Studies of Teachers' Personal Theories
1989	Zeidler & Lederman	The Effects of Teachers' Language in Students' Conceptions of NOS
1990	Brickhouse	Teachers' Beliefs About the Nature of Science and Their Relationship to Classroom Practice
1990	Chalmers	Science and Its Fabrication
1990	Cleminson	Establishing an Epistemological Base for Science Teaching in the Light of Contemporary Notions of the NOS and of How Children Learn Science
1990	Lemke	Talking Science: Language, Learning, and Values
1991	Burbules	Science Education and Philosophy of Science: Congruence or Contradiction?
1991	Hodson	The Role of Philosophy in Science Teaching
1992	Meichtry	Influencing Student Understanding of NOS: Data from a Case of Curriculum Development
1992	Ryan & Aikenhead	Students' Preconceptions About the Epistemology of Science
1992	Suchting	Constructivism Deconstructed
1993	Carey & Smith	On Understanding the Nature of Scientific Knowledge
1993	Edmundson & Novak	The Interplay of Scientific Epistemological Views, Learning Strategies, and Attitudes of College Students
1993	Hoyningen-Huene	Reconstructing Scientific Revolutions: Kuhn's Philosophy of Science
1994	Driver, Asoko, Leach, Mortimere & Scott	Constructing Scientific Knowledge in the Classroom
1994	Duschl	Research on the History and Philosophy of Science
1994	Lakin & Wellington	Who Will Teach the NOS? Teachers Views of Science and Their Implications for Science Education
1995	Boujaoude	Demonstrating the Nature of Science
1995	Rankin	A Challenge to the Theory View of Students' Understanding Natural Phenomena
1995	Suchting	The Nature of Scientific Thought
1996	Jenkins	The NOS as a Curriculum Component
1996	Kuhn	The Structure of Scientific Revolutions
1996	Solomon, Scott & Duveen	Large Scale Explorations of Pupils' Understanding of NOS
1996	Suchting	More on the Nature of Scientific Thought: Responses to Professors Lederman and Ohlsson
1997	Alters	Whose Nature of Science?
1997	Clough	Strategies and Activities for Initiating and Maintaining Pressure on Students' Naïve Views Concerning NOS
1997	Eichinger, Abell & Dagher	Developing a Graduate Level Science Education Course on the NOS
1997	Loving	From the Summit to Truth to Its Slippery Slopes: Science Education's Journey Through Positivist-Postmodern Territory

1997	Roth & Lucas	From “Truth” to “Invented Reality”: A Discourse Analysis of High school Physics Students’ Talk About Scientific Knowledge
1997	Smith, Lederman, Bell, McComas and Clough	How Great Is the Disagreement About NOS? A Response to Alters
1997	Tobin & McRobbie	Beliefs About NOS and Enacted Science Curriculum
1998	Abd-El-Khalick, Bell & Lederman	The Nature of Science and Instructional Practice
1998	Abell & Eichinger	Examining the Epistemological and Ontological Underpinnings in Science Ed
1998	Bell, Abd-El-Khalick, & Ledermanm	Implicit versus Explicit Nature of Science Instruction: An Explicit Response to Palmquist and Finley
1998	Clough	Integrating the NOS with Student Teaching: Rationales and Strategies
1998	Jansen & Voogt	Learning by Designing: A Case of Heuristic Theory Development in Sci Teaching
1998	Lederman & Abd-El-Khalick	Avoiding De-natured Science; Activities that Promote Understandings of NOS
1998	Matthews	In Defense of Modest Goals When Teaching About NOS
1998	McComas, Clough, Almazroa	The Role and Character of NOS in the Science Classroom
1998	National Academy of Science	Teaching About Evolution and the NOS
1998	Roth & McGinn	Knowing, Researching, and Reporting Science Education: Lessons From Science and Technology Studies
1999	Cobern, Gibson & Underwood	Conceptualizations of Nature: An Interpretive Study of 16 Ninth Graders Everyday Thinking
1999	Lederman	Teachers’ Understandings of the NOS and Classroom Practice Factors That Facilitate or Impede the Relationship
1999	Ryder, Leach & Driver	Undergraduate Science Students’ Images of Science
2000	Cobern	The NOS and the Role of Knowledge and Belief
2000	Lederman, Abd-El-Khalick & Bell	If We Want to Talk the Talk We Must Also Walk the Walk: NOS, Professional Development, and Educational Reform
2001	Abell	“That’s what scientists have to do’: Preservice elementary teachers’ conceptions of the nature of science during a moon investigation.

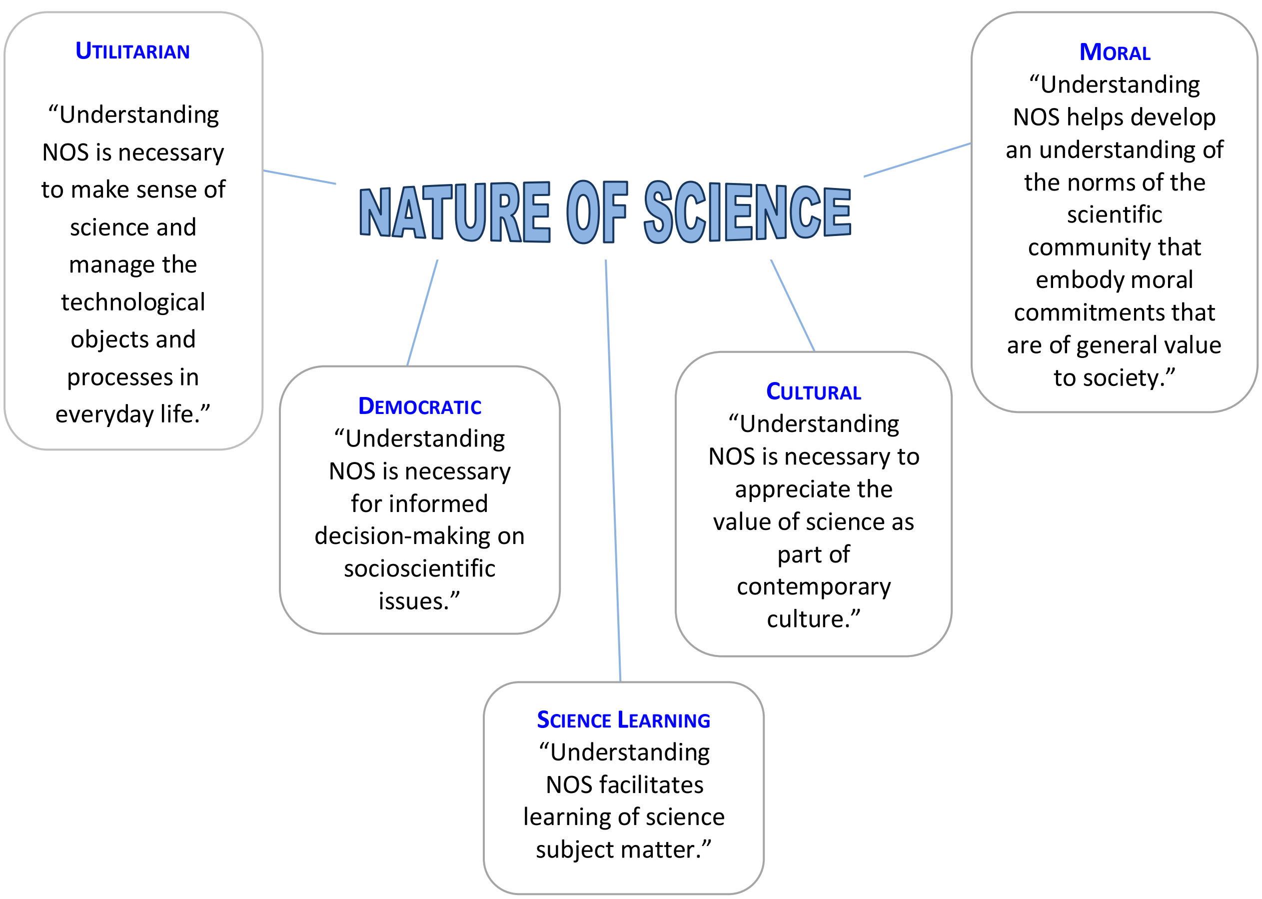
One prominent example of recent research study that demonstrates a more contemporary approach to NOS is Sandra Abell’s work with pre-service elementary teachers, which claim “students valued the social dimensions of learning [about phases of the moon], but were unable to apply them to the activity of scientists” (2001, p. 1095). In other words, even though the students were able to demonstrate their learning about the moon, they did not connect this *scientific knowledge* with aspects of NOS where science has empirical, subjective, and socio-cultural elements[14]. Abell points out that despite her efforts to model the activities of professional scientists, the students openly express their beliefs about the value of social aspects of learning but do not make connections of these beliefs with the activities of scientists. The paper concludes with recommendations about how to make NOS more explicit in future classroom activities to enhance students’ understandings about NOS:

[14] These elements of NOS are the focus of Table 3.3

> We will also ask students to reflect more about their evolving NOS conceptions. At the start of the moon investigation, students draw a scientist and explain their ideas about what science is. We plan to revisit their responses to these tasks periodically so they can examine if their ideas about NOS are changing. At the end of the study, students write a final reflection on their learning. We will require that they also discuss how they think the moon investigation relates to NOS (Abell, 2001, p. 1107).

Similarly, Driver et al. propose five arguments for the importance of including NOS in science curricula, as shown in Figure 3.1.

Figure 3.1: Arguments for the Importance of Nature of Science
(generated from Driver, Leach, Millar, and Scott, 1996, p.7)



From these five arguments, Driver et al. raises two significant points: first, are the reasons why NOS should be included in the school science curriculum; and the second is about whether including NOS makes a difference to student learning when it is included in the school science curriculum. Lederman criticizes their arguments as “primarily intuitive, with little empirical support” (2007, p. 832) because his view is that in order for educators and researchers to know that what is being assumed is actually being achieved will depend on assessing teachers’ and students’ conceptions about NOS and noting how and why teaching and learning is being affected.

Debates in the literature are fueled by differences between traditional views of science, everyday views of science, and non-Western views of science. The latter is explored by Sutherland and Dennick in their work with First Nations’ People (Cree) about the cultural impact on science learning in which they hypothesize that the different worldviews held by Cree and Euro-Canadian students will influence their perceptions of science. The findings of their study related to science teaching, indicate that “the standard process of presenting the nature of science to students, which assumes the ideas are equally accessible to all students, may not be a valid assumption…..[and] may be due to the epistemological differences between Cree and Euro-Canadian students” (2002, p. 21). The researchers call for further investigation into how students and teachers understand the epistemological differences associated with Western and non-Western science knowledge and how that knowledge is constructed: in other words, NOS in different cultural contexts.

Other findings relate to a space for science education as anti-racist and multicultural education. Despite Matthew’s (1994) proposal that conversations about cultural differences within science classrooms is a “conspiracy of relativist science education to discredit Western science” (Sutherland & Dennick, 2002, p. 22), such conversations about different world views could be seen as a positive direction for science education in terms of helping students to understand the traditional views they hold in conjunction with the Western scientific world view and promote a broader more meaningful conversation about NOS.

Sutherland and Dennick refer to Aikenhead (1997) in their concluding remarks about science teachers acting as “cultural brokers between everyday and traditional notions and scientific [notions]” as long as these teachers realize that “culture and language influence the perceptions students have about scientific phenomena” (2002, p. 22).

The final example of recent thinking about NOS is the noticeable shift in thinking about the beliefs, values, and ways of knowing science by integrating scientific views of the natural world with socio-cultural, creative and subjective aspects in ways beyond the considerations offered by the traditional views of the 60’s and 70’s:

> The tentativeness of scientific knowledge stems from the creation of that knowledge through empirical observation and inference. Each of these acts is influenced by the culture and society in which the science is practiced as well as by the theoretical framework and personal subjectivity of the scientist. As new data are considered and existing data reconsidered, inferences (again, made within a particular context) may lead to changes in existing scientific language. (Schwartz, Lederman, & Crawford, 2004, p. 613).

The view on science has evolved from an objective, culturally-neutral practice in search of absolute truth to a subjective, creative human endeavor seeking knowledge of the natural world. This is not to say that individual components, such as empiricism, observation, and inference, are *new* in any way. What is *new* is Schwartz et al.’s ideas about the interdependence of these aspects, not as separate, isolated parts, but rather as an integrated whole embedded in the value and belief systems of those *doing* the science (the scientific enterprise), shown in Figure 3.2 and Table 3.3, alongside text descriptions demonstrating integration of science with socio-cultural concerns.

Figure 3.2: Interdependent Aspects of NOS
(generated from Schwartz, Lederman, and Crawford, 2004)

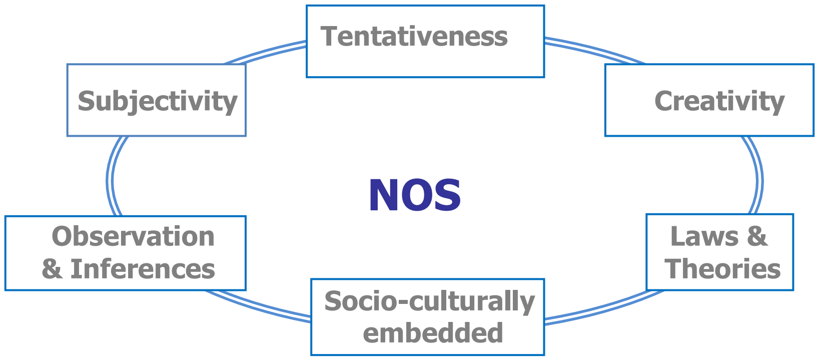


Table 3.3: Contemporary Views of NOS
(adapted from Schwartz et al., 2004, p. 613)

ASPECT	DESCRIPTION
Tentativeness	**Scientific knowledge is subject to change with new observations and with the re- interpretation of existing observations. All other aspects of NOS provide rationale for the tentativeness of scientific knowledge.**
Empirical basis	**Scientific knowledge is based on and /or derived from observations of the natural world.**
Subjectivity	**Science is influenced and driven by the presently accepted scientific theories and laws. The development of questions, investigations, and interpretations of data are filtered through the lens of current theory. This is an unavoidable subjectivity that allows science to progress and remains consistent, yet also contributes to change in science when previous evidence is examined from the perspective of new knowledge. Personal subjectivity is also unavoidable. Personal values, agendas, and prior experiences dictate what and how scientists conduct their work.**
Creativity	**Scientific knowledge is created from human imaginations and logical reasoning. This creation is based on observations and inferences of the natural world.**
Socio-culturally embedded	**Science is a human endeavor and is influenced by the society and culture in which it is practiced. The values of the culture determine what and how science is conducted, interpreted, accepted, and utilized.**
Observation and Inference	**Science is based on both observations and inference. Observations are gathered through human senses or extensions of those senses. Inferences are interpretations of those observations. Perspectives of current science and the scientist guide both observations and inferences. Multiple perspectives contribute to valid multiple interpretations of observations.**
Laws and Theories	**Theories and laws are different kinds of scientific knowledge. Laws describe relationships, observed or perceived, of phenomena in nature. Theories are inferred explanations for natural phenomena and mechanisms for relationships among natural phenomena. Hypotheses in science may lead to either theories or laws with the accumulation of substantial supporting evidence and acceptance in the scientific community. Theories and laws so not progress into one another, in the hierarchical sense, for they are distinctly and functionally different types of knowledge.**

Given these revolutions and evolutions about our conceptions of NOS, what is the impact on school science? In other words, it is important to *know* about the conceptions held by students and teachers. If alternative conceptions emerge, then what can be done in order to expand, change, or modify those conceptions to enable a better reflection of current *understanding* about NOS?

This chapter has synthesized and highlighted the debates within the science education movement with regard to trends and views of NOS. The next section highlights some of the instruments used to evaluate these views.

3.2 ASSESSING VIEWS OF NOS

A wide variety of instruments have been used to assess students and teachers' conceptions of NOS, as shown in Table 3.4 on the next page. The findings continue to point to the conclusion that students and teachers have inadequate views of NOS. Despite questions from the critics, including Hukins (1963) about the validity and reliability of some of these instruments, Lederman (2007) characterizes the consistency of the conclusions as significant. The instruments are indicators of the nature of the questions about NOS, as applied to science education. Over the past 60 years, many instruments have been developed to assess understanding about NOS.

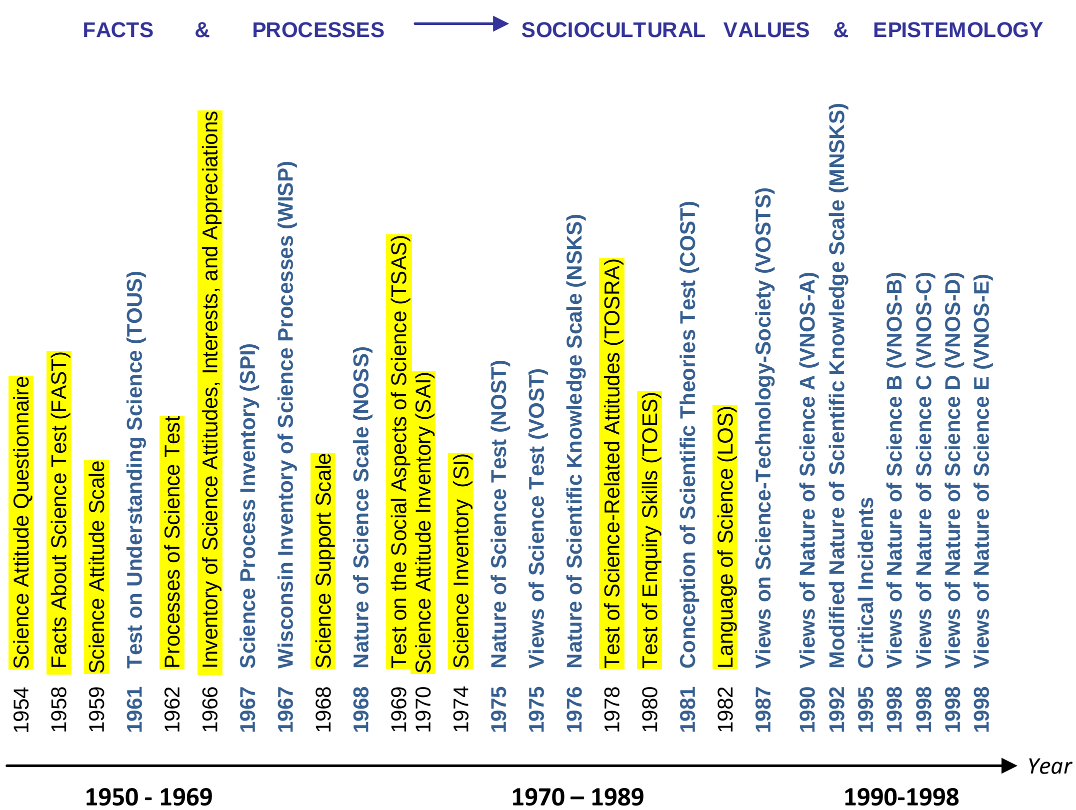
Assessment instruments used in the early years paid more attention to inquiries into science as facts and processes rather than an assessment of the epistemological aspects of science learning and knowledge. In the 1960's and well into the '70's, the assessment process mirrors the majority of educational research programs of that era, using measurements and numbers to quantitate understanding and knowledge.

Table 3.4: Instruments Used to Assess Understanding of Nature of Science
(generated from Abell & Lederman, 2007)

Decade	Instrument	Author(s)
1950's	• Science Attitude Questionnaire • Facts About Science Test (FAST) • Science Attitude Scale	Wilson Stice Allen
1960's	• Test on Understanding Science (TOUS) • Processes of Science Test • Inventory of Science Attitudes, Interests, and Appreciations • Science Process Inventory (SPI) • Wisconsin Inventory of Science Processes (WISP)	Cooley & Klopfer BSCS Swan Welch Scientific Literacy Research Centre
1970's	• Science Attitude Inventory (SAI) • Science Inventory (SI) • Nature of Science Test (NOST) • Views of Science Test (VOST) • Nature of Scientific Knowledge Scale (NSKS) • Test of Science-Related Attitudes (TOSRA)	Moore & Sutman Hungerford & Walding Billeh & Hasan Hillis Rubba Fraser
1980's	• Test of Enquiry Skills (TOES) • Conception of Scientific Theories Test (COST) • Language of Science (LOS) • Views on Science-Technology-Society (VOSTS)	Fraser Cotham & Smith Ogunniyi Aikenhead, Fleming, & Ryan
1990's	• Views of Nature of Science A (VNOS) • Modified Nature of Scientific Knowledge Scale (MNSKS) • Critical Incidents • Views of Nature of Science B (VNOS-B) • Views of Nature of Science C (VNOS-C) • Views of Nature of Science D (VNOS-D)	Lederman & O'Malley Meichtry Nott & Wellington Abd-El-Khalick, Bell & Lederman Abd-El-Khalick & Lederman Lederman & Khishfe

In the 1980s and 1990s, there is a significant shift from facts and attitudes about scientific facts and processes, prevalent in the 50's and 60's, to epistemological and socio-cultural concerns about science [NOS], as shown in Table 3.5.

Table 3.5: Evolution of Approaches to Assessing Nature of Science
(format modified from Table 3.4)



Lederman, Wade, and Bell (1998) published a critical assessment of these instruments, claiming that the validity of some instruments (highlighted in yellow) is questionable because the focus is extended to areas that extend beyond the nature of science (Lederman, 2007, p. 863).

Many of these standardized instruments are designed for large scale assessments, using forced-choice questions, such as agree/disagree, Likert scales, or multiple choice questions. Other critics of NOS assessment instruments, such as Cotham and Smith (1981), challenge the validity of instruments that are based on an assumption that the developers' view [of science] is the *correct* view. The problem becomes how the results are interpreted by those scoring the tests with an underlying assumption that students who take the test will perceive and interpret the questions in the same (or similar) manner as the instrument developers (Gall, Borg, & Gall, 1996). In the end, these instruments are quite limited in the way they label respondents' views about NOS as either *adequate* or *inadequate* because there is no opportunity offered to respondents to elaborate or clarify their views. These criticisms speak to the larger philosophical conversation and entangling debates described previously, where a shared agreement about a definitive description of NOS has not yet been reached, thereby returning full circle to Lederman's thoughts about how the debates about NOS affect educational concerns of K-12 students. He reminds us that in school science, NOS is represented with "an acceptable level of generality" in order to help students see which aspects of science (as NOS) are "relevant to their everyday lives" (2007, p. 833).

In order to make meaningful conclusions about students' views about NOS, the instruments must assess "the meaningfulness and importance of any gains in understanding NOS achieved by learners as a result of various instructional strategies" (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002, p. 503). Referring to Table 5, the instruments that are not highlighted (blue, bold text in Table 5), focus on at least one idea about NOS, and are reported in the literature as valid and reliable (Lederman 2007), satisfying the perspective about importance and meaning outlined above.

Extensive descriptions of the aims, methods, and criticisms of the most popular instruments including TOUS, SPI, WISP, NOSS, NOST, VOST, COST, VOSTS, MNSKS, and VNOS (a-e) are included in Lederman's review (2007). The limited space of this paper does not allow a detailed description of every instrument; however, certain elements from VNOS-C are presented in Table 3.6 that link with the doctoral study undertaken in this dissertation.

VNOS-C (Views on Nature of Science - version C) (Lederman et al, 2002) was modified from VNOS-B by Abd-El-Khalick with an aim to assess respondents' views about the *universality* of the Scientific Method and the socio-cultural aspects of science. Rather than using a pencil-and-paper test, this test uses an interview format to pose up to 10 open-ended questions to college undergraduate and graduates and BEd students (pre-service teachers in elementary teaching programs and secondary teaching programs). Some typical questions from this instrument are shown in Table 3.6 on the following page. Posing these questions in an interview format (as opposed to a paper and pencil test) allows the investigator to check in with the participant to ensure the question is understood and that the answer is correctly interpreted by the researcher. This approach:

> aims to elucidate learners' NOS views and generate profiles of the meanings they ascribe to various NOS aspects for the purpose of informing the teaching and learning of NOS rather than for labeling learners' views as adequate or inadequate or sum their NOS understanding into numerical scores (Lederman et al, 2002, p. 517).

Some of the questions posed by the VNOS-C instrument to spark participants' thinking about NOS are included to familiarize readers with the forms of questions in this instrument. Sample Questions #1 and #3 will be referred to in the final section of this chapter, illustrating how this approach is taken up in practice to spark participants' thinking about NOS in their personal journals that are used in the doctoral study undertaken in this dissertation.

Table 3.6: VNOS-C Sample Questions
(adapted from Lederman et al, 2002, p. 509)

Sample Question #1	What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (such as religion or philosophy)?
Sample Question #2	What is an experiment?
Sample Question #3	Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced. • If you believe that science reflects social and cultural values, explain why. Defend your answer with examples. • If you believe that science is universal, explain why. Defend your answer with examples.
Sample Question #4	Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence **do you think** scientists used to determine what the atom looks like? (authors' emphasis)

3.3 NOS IN THE SCIENCE CLASSROOM

Over 25 years ago, the National Science Teachers Association (NSTA, 1982) stated that NOS is a key element of science literacy; however, current research indicates that K-12 teachers do not hold adequate conceptions about NOS. Despite a wealth of fruitful research programs and the related progress that is being made in science education research, there remains a persistent lack of teachers' and students' understanding about the nature of science. More scientists have been trained, more citizens have been educated (about science), yet how is the research about NOS being enacted in science classrooms? Research questions have become more complex, for example, when NOS is included in the science curriculum, will students make better decisions, for example, about their contribution to global warming? If so, then how will researchers know that inclusion of NOS affects student learning about science?

Lederman's review reveals aspects about NOS that are important to science education, based on claims about what the nature of science IS and what the nature of science IS NOT (2007). He lists six aspects about NOS aimed at school science: 1) the differences between observation and inference; 2) the differences between scientific laws and scientific theories; 3) how science involves creativity and imagination; 4) why science is subjective; 5) how science has a cultural context; and 6) why scientific knowledge is often considered tentative.

As an educator, I have often experienced, first-hand, the importance of understanding the difference between all of these aspects. Science students often memorize definitions of terms such as observation and inference, expecting that moving from one to another is a simple mechanical event revealing their naïve and superficial understanding about science. As a construct of education, NOS clarifies the distinction between an ***Observation*** as an *a priori* empirical happening that we do and reflect upon, and an ***Inference*** as an application of other knowledge that we know, transcending the mere description of a phenomenon or event, to make justified claims about what is being observed. In order to make an inference, a person must have in their possession (and be able to draw on) a great deal of prior learning that might take the form of background knowledge of many, many observations or a deep understanding of relevant scientific principles. An inference is an explanation that demonstrates a deeper understanding of abstract and universal processes (see the example of Bubonic Plague later in this section).

If one moves from observation to inference by combining a certain number of observations with prior learning to draw a conclusion about how understanding is achieved, then in science, drawing inferences from observations are ways of theorizing based on one's knowledge of how nature works. In this way understanding is built about the workings of the natural world, for example, how things function or why certain organisms cause disease, draws on a larger body of knowledge that includes scientific principles and concepts of physics, chemistry, and biology. This larger body of background knowledge is much like a *horizon of scientific concepts and categories* that professional scientists reply on to draw inferences competently and offer full scientific explanations. To defend science as a meaningful enterprise is to suggest that what gives it rigor is the immense background that is over the horizon. It is not enough for a practicing scientist to take for granted that even the most obvious thing is true. Any inference they publish or share would be justified by rigorous, scholarly research on a topic. In this dissertation about future teachers' experiences learning and teaching science, this researchers concern is that even though a scientist is unlikely to take the obvious for granted, a science teacher who lacks the vision of the horizon, or who might hold inadequate conceptions of NOS might indeed take for granted that because something is obvious, it must also be true. One of the most problematic ways that science is depicted in schools is that it is merely an exercise of bantering around obvious facts. Science teachers and their students often take observations at face value, drawing conclusions about things that seem to be obvious, while in fact, some of the most important scientific discoveries have been about what is NOT obvious. One example of this point is the different names people gave to diseases before they learned that certain microorganisms are pathogenic[15].

Historically, people put names on things, such as diseases, in order to explain them in ways that were simple but inadequate. Names such as "Black Death", "Great Pestilence", or "The Great Plague" were used in Medieval Europe (Bennett & Hollister, 2006, p. 326) to describe what we now call Bubonic Plague [16]. Prior to invention of the microscope, the world of bacteria was not **obvious** and people drew the innocent but completely wrong inference that dogs and cats were the cause of the disease. We now know that Bubonic Plague is caused by a bacterium, *Yersinia pestis* that inhabits the gut of fleas. When fleas feed on rodents (such as rats) they regurgitate the contents of their gut and transfer the bacteria to the rat and by doing so, the rats become infected with the bacteria (AVMA, 2006). The great irony of the medieval inference about controlling the disease by killing off dogs and cats is that by doing so, they killed off the very beasts that controlled the rodent populations that hosted the microbe.

Science is about drawing the best explanation from the observation, and if people had not become scientifically minded in the 18th and 19th centuries, there is no way they would have ever discovered that "The Black Death" was not caused by dogs or cats or other erroneous explanations, such as ill humors in the air, but rather than a microorganism called *Yersinia pestis*. This supports the point about the horizon of concepts and categories or meticulous and careful study and rigorous application of logic and even more importantly the rigorous

[15] Disease-causing
[16] from the term *buboes* referring to infection of lymph nodes

application of deep skepticism that goes behind the practices of thescientific enterprise in order to avoid making the wrong inference.

Just as NOS points out the distinction between observation and inference, there is also a distinction between a ***scientific law***, as a universal statement or equation that describes how certain phenomena are related to each other (e.g., Newton's Laws of Motion), and a ***scientific theory*** as an inferred explanation of the phenomenon (e.g., Einstein's Theory of Special Relativity where Newton's Laws of Motion no longer apply to objects travelling at, or close to, the speed of light). Acquiring adequate conceptions of NOS involves moving beyond the false idea of progressing in a mechanical fashion from observations to inferences to theory to law; however, Lederman's review states that students and teachers do not have adequate conceptions of this knowledge (2007).

3.4 REVIEW OF RESEARCH

NOS researchers claim that is not common for students to view science as a creative, tentative, subjective, or cultural (Lederman, 2007). In fact, many students mistakenly view science as an objective, culturally-neutral enterprise lacking subjectivity and creativity, with a complete exclusion of any consideration of social constructs, power, politics, and religion (Aikenhead, 2007, Roberts, 2007). To correct these general perceptions, many agree that NOS must be embedded into the curriculum of school science (Hodson, 1988, 1991; Brickhouse, 1990; Ryan & Aikenhead, 1992; Solomon, Scott & Duveen, 1996; Roth & Lucas, 1997; Abd-El-Khalick, Bell & Lederman, 1998; McComas, Clough, & Almazroa, 1998; Ryder, Leach & Driver, 1999) and post-secondary programs (Edmundson and Novak, 1993; Eichinger, Abell & Dagher,

1997) although it should be noted that some researchers call for a more modest approach (Matthews, 1998).

In his extensive 2007 review of research studies, Lederman makes several summative generalizations about the current findings from research studies about NOS at the end of his 2007 review, as follows:

- *K-12 students do not typically possess "adequate" conceptions of NOS.*
- *K-12 teachers do not typically possess "adequate" conceptions of NOS.*
- *Conceptions of NOS are best learned through explicit, reflective instruction as opposed to implicitly through experiences with simply "doing" science.*
- *Teachers' conceptions of NOS are not automatically and necessarily translated into classroom practice.*
- *Teachers do not regard NOS as an instructional outcome of equal status with that of "traditional" subject matter outcomes.*

(author's emphasis, 2007, p. 869)

These generalizations are drawn from a great number of research studies about the students' conceptions of NOS and teachers' conceptions about NOS. The majority of studies are conducted in secondary school with some attention to science teaching and learning at the elementary level. Studies at the post-secondary level are mostly focused on pre-service teachers who are learning to teach science in BEd programs. A summary of the most compelling findings are presented below, not as an exhaustive synopsis of all research in this area, but simply research studies located in the following areas: students' conceptions of scientific phenomena; students' perceptions of science; pre-service teacher knowledge (PCK); and pre-service teachers' views of NOS.

First, regarding **students' conceptions about NOS**, students view scientific knowledge as something that is absolute, and learning science as a process that involves uncovering laws and truths about the natural world (Wilson, 1954; Mead & Metraux, 1957). In 1977, Rubba's findings indicate students view scientific research as something that reveals incontrovertible and necessary absolute truths (Rubba, 1977). Similarly, students' views of science and NOS are simplistic and naively absolutist/empiricist (Bady, 1979; Kang, Sharmann and Noh, 2004). More recently, Sutherland and Dennick (2002) found that students with different world views hold similar, yet still inadequate views about NOS. In general, students appear to have insufficient knowledge of the role of creativity in science; function of scientific models; roles of scientific theories and their relation to research; distinction among hypotheses, laws and theories; relationship between experimentation, models, theories, and absolute truth; fact that science is not solely concerned with collection and classification of facts; what constitutes a scientific explanation; interrelationships among and interdependence of the different branches of science (Korth, 1969; Broadhurst, 1970; Mackay, 1971; Aikenhead, 1972, 1973; Zeidler, Walker, Ackett & Simmons, 2002) as cited by (Lederman, 2007, p. 837). Lederman states that findings were the same across different grade levels and for different nationalities (2007).

Second, regarding **teachers' conceptions about NOS**, Lederman's review (2007) of research studies over the past 60 years are as follows: teachers hold "serious misconceptions" (p. 839) about the scientific method (Anderson, 1950); over 50% of science teachers felt scientific results are not tentative (Behnke, 1961); secondary teachers' understandings of science are less than that of their students and most teachers do not understand science well enough to teach the subject (Miller, 1963; and Schmidt, 1967); teachers conceptions of NOS are not related to their other academic experience (for example, grades, math credits) or years of teaching experience (Carey & Stauss, 1968, 1970); teachers valued the scientific method but viewed the procedures involved as contextually-situated (Koulaidis & Ogborn, 1989); teaching of science is greatly affected by teachers' lack of background in the history and philosophy of science (King, 1991); there is some evidence for a connection between teachers views of NOS and their conceptions of teaching and learning (Aguirre, Haggerty, and Linder, 1990); and the anthropocentric nature of teachers' beliefs influences their conceptions of science, specifically the theory of evolution (Bloom, 1989).

Despite the wealth of published research about students' and teachers' views of NOS in a variety of settings and contexts, the literature seems to lack studies which focus on future teachers' views of NOS in the BA science curriculum; NSMs' conceptions of scientific phenomena; and conceptions of NOS held by applicants and candidates for BEd programs.

Given that many teachers hold inadequate conceptions about NOS and do not see a place for NOS as an outcome of their work, then as a science educator and researcher, it does not seem unreasonable to wonder about what is going on in the classroom. What is the impact of teachers AND students' inadequate conceptions about NOS on science teaching and learning? What is important for educators, researchers, and students to know about NOS? This line of questioning relates to the deeper conversation about Science Education and scientific literacy discussed in Chapter 2; however, there are certain aspects that are relevant at this point., one of which includes how researchers assess students' and teachers' views about NOS.

Lederman poses a series of ten questions for future research involving teachers, students and the nature of NOS at the end of his review (2007). If teachers' and students' conceptions are "inadequate", then how will their conceptions change from "naïve" to "adequate" over time? What interventions can be used to change their conceptions and how will the effectiveness of our intervention(s) be assessed? He suggests it would be interesting to compare lessons that link NOS with science content to lessons that focus solely on science content. In addition, he questions the relationship between science content knowledge, pedagogy, and NOS with a focus on teacher-as-learner. Even though there is abundant literature about pedagogical content knowledge (PCK) related to science content, there seems to be a lack of literature linking PCK with aspects of NOS. Two areas Lederman does not specifically address are the following: first, if and how NOS is included in teacher education programs, and second, how students on career paths to becoming teachers (in the researcher's case, elementary) are impacted by NOS in terms of their own experiences learning NOS. Further, Lederman wonders if students learn science (content) better when they have a good foundation about NOS. He also asks how a person's worldview affects their conceptions about NOS, especially when different cultures are studying "western" science.

Considering the shifting nature of our understanding of NOS, future research must address the assumption that NOS is generic across all disciplines of the natural sciences. Lederman asks if NOS and scientific inquiry are the same for all science disciplines or if understandings are a function of the discipline. For example, is NOS the same for a geologist and an immunologist? One would expect there to be differences given that: 1) understandings about NOS mirror understandings in science education; 2) teaching and learning is a function of different disciplines of the natural sciences; and 3) there are discipline-specific and discipline-dependent differences in scientific knowledge and practices at the professional level of the scientific enterprise. This line of thinking might lead to the hypothesis that NOS is influenced by and is a function of disciplinary perspectives. In other words, understanding NOS in geology is different from understanding NOS for immunology. As is often the case in the natural sciences, exploring this hypothesis raises many research questions for science education research programs.

Some of these issues are being tackled in this doctoral study exploring future teachers' experiences in Bachelor of Arts science elective courses, by exploring students' perspectives on teaching and learning science with an aim of investigating students' conceptions about science as a way of knowing and the values and beliefs they hold about scientific knowledge and how it is developed. More specifically, addressing how students' experiences integrate (implicitly or explicitly) their understanding of NOS with their career plans to become teachers who will one day be teaching science in an elementary school classroom. The participants in this study were encouraged to think deeply about the socio-cultural, moral, political, utilitarian aspects of the scientific enterprise and share their views about what science IS, from their perspective.

In conclusion, many philosophical debates turn on how we understand science and scientific knowledge. Prominent science education researchers claim that many of the disagreements about our knowledge and understanding about NOS might be highly relevant to philosophers and historians but is not pertinent in the K-12 science classroom. There is agreement to acknowledge the importance of including the generalized conceptions of NOS where science is viewed as a tentative, creative, subjective, and sociocultural pursuit alongside science content, so that teachers and students will have adequate conceptions about the nature of science. Researchers continue to improve instruments, such as VNOS-C, to assess students' and teachers' conceptions about NOS. In elementary education, NOS tries to help students know that there IS a difference between observation and inference, but not necessarily the deeper meanings behind that difference. The problem is that despite the numerous studies conducted in this field, there is very little research conducted with NSMs in undergraduate science courses, in particular those NSMs who intend to become teachers.

If students must have adequate conceptions about NOS, then how do we develop elementary teachers' conceptions about NOS, especially those who are non-science majors who lack a vision of the horizon of scientific knowledge? Throughout subsequent chapters of this dissertation, participants' conceptions about NOS become a central focus and key theme. Before presenting the data and findings leading to claims about NOS, the next chapter presents the methodological framework that was used to inquire and interrogate how the conceptions of NOS are held by students in career tracks to elementary teaching.

Chapter 4: Methodological Framework

> Experience does not go on simply inside a person. It does go on there, for it influences the formation of attitudes of desire and purpose. But this is not the whole of the story. Every genuine experience has an active side which changes in some degree the objective condition under which experiences are had.
>
> John Dewey, 1938, p. 39)

The study employed a phenomenological framework, borrowing primarily from Amadeo Giorgi (1985) to interrogate, examine, and understand students' experiences in a BA science elective course, based on the assumption that "being human is a unique way of being, in that human experiences and actions follow from their self-interpretation" (Benner, 1994, p. ix). A phenomenon, such as non-science majors' undergraduate experience in a science elective course, can be explored and explicated using an applied phenomenological approach (Giorgi, 1985, van Manen 2006). The focus of this inquiry was on the experience as "lived" by the participants wherein the researcher suspended her *apriori* knowledge, assumptions, and beliefs to view the phenomenon from all aspects, moving beyond subject-object dualism to a unified view of consciousness and experience (Giorgi, 1989, 1994).

At the roots of phenomenology is the intention of returning "to the concrete" as captured by Husserl's dictum: "Back to the things themselves!'" (Husserl, 1970/1900, p.252). From these roots, phenomenology has branched out to many areas including transcendental, hermeneutic, existential, linguistical, and applied. The latter branch of *Applied Phenomenology* is often used to research human experience in education. The discussion in this chapter opens with a general exploration of some key philosophical aspects of phenomenology that underpin an in-depth conversation about phenomenology as a suitable methodological framework for studying students' experiences in post-secondary level science education.

This researcher does not propose that phenomenology is a panacea or as the only method to study students' experiences in education; however, this chapter shows how a phenomenological inquiry can be used to understand students' experiences in science courses *as lived,* without conceptualizing or categorizing, to gain insights into their lifeworld or to make explicit meanings that might have otherwise been taken for granted or forgotten.

4.1 PHENOMENOLOGY AS A PHILOSOPHY

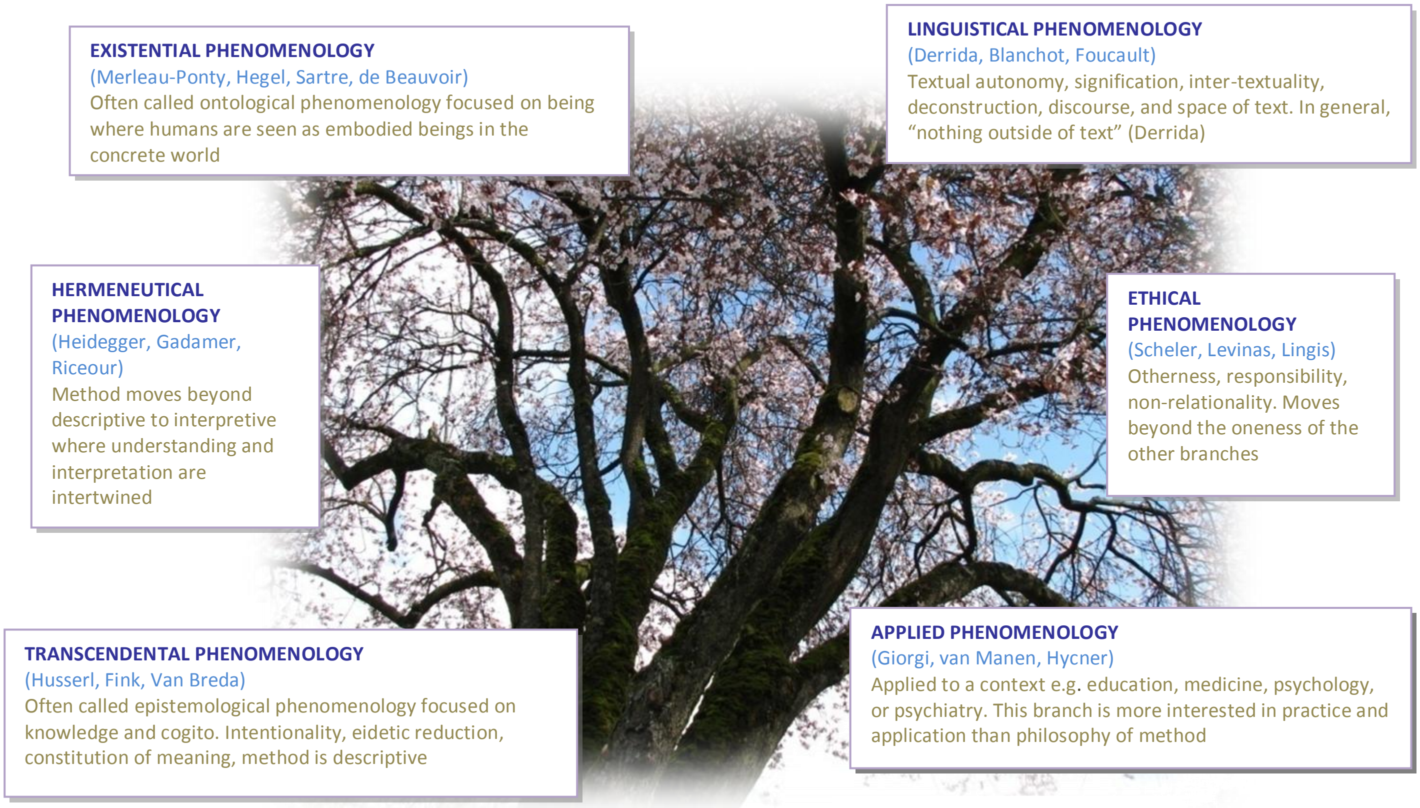
The etymological roots of the word phenomenology stem from the Greek origins: "phainomenon" (an appearance) and "logos" (reason or word), leading to a definition of phenomenology as a "reasoned inquiry which discovers the inherent essences of appearances" (Stewart & Mickunas, 1990 p. 3). For the sake of clarity, it is important to articulate what is meant by *appearances* and *essences.* Appearances refer to "anything of which one is conscious…[or]…a manifestation of the essence of that which it is the appearance" (Stewart & Mickunas, 1990, p.3), noting that phenomenologists do not consider consciousness as a separate "unextended [thinking] substance", such as that described by Descartes (1596-1650) (Solomon, 2008. p. 32), which can be investigated and quantitated by empirical methods, but rather the elimination of body-mind dualism where "minds and objects both occur within experience" (Laverty, 2003, p.5). Consciousness is seen as a "co-constituted dialogue between a person and the world" (Laverty, 2003, p. 5 citing Valle, King, & Halling, 1989). Essences refer to the ultimate structures of consciousness, arising from the process of focusing on and describing a specific reality (Edie, 1987).

The philosophical roots of phenomenology stem from the work of Husserl (1859-1938), who is often referred to as the father of phenomenology (Cohen & Omery, 1994; Koch, 1996; Polkinghorne, 1983; Laverty, 2003), and other thinkers including Husserl's student Heidegger (1927/1962), Merleau-Ponty (1964), Gadamer (1989), Derrida (1978), Foucault (1980), van Manen (1990), and Giorgi (2005). Because phenomenology has branched into several different philosophical areas, one would be more accurate describing phenomenology as a *movement* rather than a "rigid school or uniform philosophic discipline" (Spiegelberg, 1975; Stewart & Mickunas, 1990 p.4). Giorgi confirms the point by noting that a "consensual, univocal interpretation of phenomenology is hard to find' (1985, p24).

The phenomenological movement evolved into many different branches as other philosophers challenged and argued Husserl's epistemological and ontological positions. Spiegelberg (1982) even goes so far as to say there are as many branches of phenomenology as there are phenomenologists (Dowling, 2007). This topic is too vast to cover exhaustively in this dissertation, but it is interesting to note the diverse and divergent evolutionary nature of the phenomenological movement. Six branches of phenomenology are shown below in Figure 3.1 with brief descriptors showing a snapshot of adherents who align with that branch. Due to space limitations, only a few adherents are listed for each branch, with an understanding that there are many more others who have contributed to the field.

Figure 4.1: Branches of Phenomenology

(generated from van Manen, 2006)



(Photo credit: Bergere, 2007)

Despite this philosophically diverse nature of the phenomenological movement, one unifying theme of the branches is a shared belief that a phenomenological inquiry highlights the world as it is lived by a person (Valle, King, and Halling, 1989), a significantly different perspective than other paradigms, such as logicopositivism, which consider the world as something distinct and separate from the person. A phenomenological inquiry delves into the meaning of the experience, as it is lived in the everyday world, or as it unfolds, by asking:

> What is this experience like? Polkinghorne (1983) identified this focus as trying to understand or comprehend meanings of human experiences as it is lived. The 'life-world' is understood as what we experience pre-reflectively, without resorting to categorization or conceptualization, and quite often includes what is taken for granted or those things that are common sense (Husserl,1970/1900). The study of these phenomena intends to return and re-examine these taken for granted experiences and perhaps uncover new and/or forgotten meanings (Laverty, 2003, p. 4).

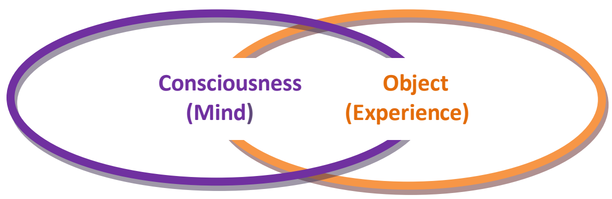
The belief that human experience is "a unique way of being, in that human experiences and actions follow from their self-interpretation" (Benner, 1994, p. ix), is common to most branches of the movement. Another unifying theme is that phenomenology returns to the traditional roots of philosophy. Husserl's work (1970/1900) was conducted in post-World War I Europe, at a time when the entire continent was in a shambles, with the natural sciences dominating the philosophical search for truth and wisdom. Eagleton paints a graphic picture where:

> The social order of European capitalism had been shaken to its roots by the carnage of the war and its turbulent aftermath. The ideologies on which that order had customarily depended, the cultural values by which it ruled, were also in deep turmoil. Science seemed to have dwindled to a sterile positivism, a myopic obsession with the categorizing of facts; philosophy appeared torn between such a positivism on the one hand, and an indefensible subjectivism on the other; forms of relativism and irrationalism were rampant, and art reflected this bewildering loss of bearings (Groenwald, 2004, p. 3, citing Eagleton, 1983, p. 54).

At this time, the positivists believed that anything "meaningful" could be investigated using empirical, quantitative methodologies. Anything that could not be verified empirically or by definition as *analytically true*, such as ethics, metaphysics, religion, consciousness, was considered meaningless. In these turbulent times and with the imperatives outlined above, Husserl built on Franz Brentano's earlier work about ***intentionality of consciousness*** and developed phenomenology as a new approach that "would lend absolute certainty to a disintegrating civilization" (Groenwald, 2004, p. 3 citing Eagleton, 1983, p. 54), based on the belief that phenomenology can be used to question true knowledge of conscious human experience.

A phenomenologist believes that when one thinks consciously, one is thinking about something in particular. Brentano's characterization of consciousness as *intentional* means that consciousness is related to external objects by a causal relationship where “psychic of mental phenomena [are] distinguish[ed] from non-mental phenomena” (Stewart & Mickunas, 1990, p.8). As Brentano’s student, Husserl advanced this idea and conceived intentionality as an “indissolvable unity between the conscious mind and that of which it is conscious” (Stewart & Mickunas, 1990, p. 9) as shown in Figure 4.2.

Figure 4.2: Representation of Husserl’s Unity of Consciousness and Experience



Husserl (1970/1900) claims about this unity of *thinking* with *the object the thinking is aimed at* moving beyond Cartesian dualism where consciousness and object are viewed as separate and distinct from each other. Descartes’ claims that reality can be divided up into discrete categories such as mind/body or object/subject (Cottingham, 1992) led some philosophers to question the reality of physical objects or to focus solely on one of the terms. For example, idealists explain reality in terms of the mind, and naturalists “account for mental reality in non-mental forms” (Stewart & Mickunas, 1990, p.9). Husserl claims that the unity of mind and experience as intentionality assumes “consciousness is never empty and abstract but concrete and tied to the world of experience…[and] shifts the emphasis from the question of reality of the world to the meaning of that which appears to be consciousness” (Stewart & Mickunas, 1990, p. 9) This refusal of the subject-object dichotomy reduces the separation between the *thinker* and the *something* being thought about. Intentionality of consciousness, as described above, is meaningful to a researcher conducting a phenomenological study where the thinker is a student and the something is human experience in a science course.

Another cornerstone of a phenomenological approach is the concept of ***phenomenological reduction****.* In her 2005 review of phenomenological approaches, Dowling refers to phenomenological reduction as a "key epistemological strategy of phenomenology" (2007, p. 132). The aim is for a researcher to encounter, describe and understand a phenomenon in a manner that is as "free and as unprejudiced as possible" (p. 132). In a literal sense, reduction means reducing "the world as it is considered in the natural attitude to a world of pure phenomena or, more poetically, to a purely phenomenological realm" (Dowling, 2007, citing Valle, King, and Halling, 1989, p. 11). Similarly, Parse (2001) refers to phenomenological reduction as "the process of coming to know the phenomenon as it shows itself as described by the participants" (p. 79, cited in Dowling, 2007). Giorgi's view on phenomenological reduction draws on Merleau Ponty (1964) and applies to the process of data analysis (explication) in two ways. First, any thoughts that a participant has about a prior particular situation (as lived) are reduced when it is being studied at some later point in time: "The very fact that a concrete situation that was lived through prior to any thought about being studied or analyzed can later be taken *as an example* of learning already indicates a reduction" (1985, p. 69). Second, is that an individual's testimony about their experience is a description of the meaning attached to their recollection rather than truth about what in fact happened "What is being referred to is not taken as objective real truth but only as the correlate of what the subjects believed happened – that is, what the situation meant to them, not what it really was" (1985, p. 70).

In a research study, phenomenological reduction can be enacted in various ways. One example is the *phenomenological nod,* described in a lecture by Buytendijk (1962) as one "way of indicating that a good phenomenological description is something that we can nod to, recognizing it as an experience that we have had or could have had" (van Manen, 1990, p. 27). In this way, the description validates the experience. Spiegelberg (1982) speaks of enacting phenomenological reduction as an *intentional analysis* in which the researcher describes the essence of the experience, then focuses on the experience and describes how it is constructed.

The various branches of phenomenology are unified by the thinking about exploring experience *as lived*, intentionality of consciousness, and phenomenological reduction. The remainder of the space in this paper is devoted to the philosophical stance and methodological frameworks of the branch of phenomenology called Applied Phenomenology.

4.2 APPLIED PHENOMENOLOGY

Chapter 2 of this dissertation offered an overview of science education as an applied field in which research programs make sense in the real world of student, teachers, the school system, and society. The branch of phenomenology called Applied Phenomenology as described by Giorgi, van Manen, Benner, Hycner and others, often appears in the literature under other labels, such as *phenomenology of practice*, *experiential phenomenology* or *lifeworld phenomenology* (van Manen, 2006). Many research programs in psychology, nursing, and education use this branch of phenomenology to explore and understand human experience.

The distinguishing feature of applied phenomenology is the application to a specific context, such as, education, when a researcher's primary focus is on practices and applications, rather than the philosophical underpinnings and arguments of method. From an applied phenomenological point of view, human experience is an "individual's perceptions of his or her presence in the world at the moment when things, truths, or values are constituted" (Richards & Morse, 2007 p. 49, citing van Manen, 1990), such as a student's perception of their own presence experiencing lessons in a classroom. Two widely published researchers in this area are Amadeo Giorgi (psychology) and Max van Manen (education). Noting Giorgi's close attention to the scientific aspects of psychology and van Manen's attention to pedagogy and educational practices, it makes good sense for a researcher exploring student experiences in science education to draw on the teachings and publications of these authors.

Max van Manen (1990), out of the Utrecht School, maintains a strong connection to hermeneutic phenomenology stemming from the work of Husserl's student, Martin Heidegger (1889-1976). van Manen adapts this hermeneutic stance to applied phenomenology, as a method used for studies in education, assigning priority to ***interpretation*** and issues of ***being***. van Manen's approach characterizes phenomenological research as the human scientific study of the nature of a phenomenon (the essence) that begins in the lifeworld. He claims phenomenology is a retrospective recollection of a phenomenon where parts are re-integrated into a whole by explicating meaning *as lived* in the everyday existence of this lifeworld. Somewhat contentiously, he continues by stating that a phenomenological inquiry has no claim to ethnography (culture), sociology (social groups), history (historical period), psychology (mental types), or to biography (an individual's personal history). Where other social sciences focus on the frequency or occurrence of particular behaviours, prevalent social opinions, or statistical relationships among variables, van Manen focuses on a deep and rich description (as a type of interpretation) of the meaning of a person's life, as lived by that person.

van Manen refers to phenomenology as a human science or *Geisteswissenschaften* and to the natural sciences (biology, chemistry, physics, etc) as *Naturwissenschaften (*van Manen, 1985*)* , distinguishing characteristics, methods, and understandings to clarify the meaning of each form. In the natural sciences, a phenomenon is typically categorized/ taxonomized, or derived from a causal relationships, or explained as a function of probability (citing Wilhelm Dilthey, 1987); however, in the human sciences, the meaning of a phenomenon is explicated through study of the lifeworld in an attempt to understand the "structures of meanings" (van Manen p. 1990, p. 3).

Typical methods of a natural science study involve quantitative, controlled, experiments where the researcher is considered a detached observer studying things, events of nature, and the behavior of the subject/sample of the study. People in such a study are often referred to as *individuals*, a biological term of classifying one member of a species, rather than one unique being. Conversely, the human sciences consider a person in terms of values, mind, consciousness, thoughts, feelings, purpose, action who "act purposefully in and on the world by creating objects of *meaning* that are *expressions* of how human beings exist in the world" (van Manen, 1990 p. 4) where the objectifications are found in beliefs, arts, languages and institutions. Unlike the natural sciences where people are viewed as *subjects*, the human sciences view people as unique, irreplaceable *beings*.

Despite these vast differences between the human and natural sciences, van Manen claims the natural sciences and phenomenology share some common ground. In a broad context of studying lived experience as subject matter, a phenomenological study is systematic, explicit, self-critical, and inter-subjective (practices derived from the scientific method) by:

- using specific modes of questioning, reflection and focus (systematic);
- attempting to articulate structures of meaning embedded in lived experience (explicit) as opposed to poetry where meaning is implicit);
- continually examining it goals & methods, strengths & shortcomings (self-critical); and
- needing the *other* to validate the phenomenon; i.e. inter-subjective (van Manen, 1990, p. 11).

Despite understanding where van Manen is coming from in terms of his views about phenomenology as a human science that shares certain characteristics with the natural sciences, this researcher is not convinced that his hermeneutic stance, rejection of culture, and methodological approach are appropriate for exploring students' experiences in science education for reasons that are discussed and elaborated below.

Amadeo Giorgi (1985) out of the Duquesne School, maintains a strong connection to existential phenomenology stemming from the work of Merleau-Ponty (1964) which aligns closely with Husserl's priority to "careful description"[17] (2007). Giorgi characterizes phenomenology as a *human science* rather than a mere imitation of the natural sciences that is often the case in clinical psychology (2005). The history of the term *human sciences* has been traced back to the ancients (Gusdorf, 1967) and is not unique to Giorgi or van Manen; however, Giorgi makes important distinctions between the philosophical underpinnings where phenomenology, as a human science, is "a knowledge acquiring, non-reductionistic enterprise that uses an approach and method that is faithful to the unique qualities of human beings"

[17] The Husserlian approach characterizes interpretation as an "articulation of the given object that was relevant to the experience but not limited to the strictly given (Giorgi, 2007, p. 1)

(2005, p. 78). This view frames “knowledge and understanding about human consciousness and subjectivity using anthropological and philosophical criteria rather than the logico-empirical criteria of the natural sciences” (Giorgi, 2007, p. 11).

Even though many of Giorgi’s thoughts about phenomenology overlap with van Manen, in a recent paper about variations in phenomenology, Giorgi (2006) presents several arguments challenging van Manen’s phenomenological approach, as articulated in this quote:

> Hermeneutic phenomenology tries to be attentive to both terms of its methodology: it is descriptive (phenomenological) methodology because it wants to be attentive to how things appear, it wants to let things speak for themselves; it is interpretive (hermeneutic) methodology because it claims that there are no such things as uninterpreted phenomena. The implied contradiction may be resolved if one acknowledges that the (phenomenological) “facts” of lived experience are always already meaningfully (hermeneutically) experienced. Moreover, even the “facts” of lived experience need to be captured in language (the human science text) and this is inevitably an interpretive process (van Manen, 1990, p. 180).

First, acknowledging that description itself is an interpretive act, Giorgi concludes that this tension between description and interpretation is only resolved by eliminating the descriptive alternative. Second, if there are “no such things as uninterpreted phenomena”, then how is it possible for a methodology to “let things speak for themselves”? Third, Giorgi believes that if phenomenology is to be considered a human science, then a sense of method is required. Giorgi criticizes van Manen’s desire to use a systematic approach (van Manen, 1990, p. 168) while simultaneously stating “there is no research design or blueprint to follow” (van Manen, 1990, p. 167). Giorgi completes the argument by saying “a blueprint is one thing, but a logical sequence of steps is quite another” (2006, p. 316).

Even though some aspects of van Manen’s work in education are relevant to this study, because of the close connections of the natural sciences with psychology and Giorgi’s stance on van Manen, the study presented in this dissertation is situated within the framework characterized by Giorgi's approach, exploring students' experiences *as lived* in a university science course. The meaning of their experiences would emerge as the phenomena are lived, or as they unfold (Laverty, 2003). Another justification of selecting Giorgi is the issue of culture. van Manen's views of phenomenology have no claim to ethnography; however, culture and cultural differences constitute a major theme in the study. One of Giorgi's latest works (2007) is a view of "framing knowledge and understanding about human consciousness and subjectivity using anthropological and philosophical criteria rather than the logico-empirical criteria of the natural sciences" (p. 11) which is a stance that is better suited to this study.

The intentions of such a phenomenological study do not include making claims representing universal truths about science education; however, when multiple participants are involved in a study such as this, claims can be made about both the individual and collective experiences at one institution. A phenomenological study does not ask: *How do BA students learn science?* Instead, a phenomenological study asks: *What is the essence of BA students' experiences of learning science?*

4.3 PHENOMENOLOGY AS A METHODOLOGICAL FRAMEWORK

A phenomenological approach goes "back to the things themselves" (Husserl, 1970./1900 p. 252) as the researcher goes back to participants' common everyday experiences in their day-to-day lives and interprets those experiences within the framework of the inquiry by enacting epoché, applying phenomenological reduction, and using imaginative variation (Giorgi,2007). In doing so, a researcher is able to: "access life's living dimensions while hoping that the meanings we bring to the surface from the depths of life's oceans have not entirely lost some of the natural quiver of their undisturbed existence" (van Manen, 2006).

A) Connections to a Theoretical Framework

A theory of knowledge, or epistemology, will certainly influence the decision about how a phenomenon, such as students' experiences, will be studied (Creswell, 1994; Holloway, 1997; Mason, 1996); however, theory is not seen as the first step of a phenomenological study: "practice (or life) always comes first and theory comes later as a result of reflection"(van Manen,1990, p. 15). This is not meant to infer that a phenomenological inquiry avoids theory, but rather to follow the qualitative researcher's tendency to work outward from the data towards developing theoretical propositions. The theoretical framework used to situate and frame this study is Aikenhead's border crossing perspective[18] (1996), following this methodological tradition of how a theory emerges as a result of refection on the descriptions of the participants.

A phenomenological inquiry is a retrospective view involving recollections of or reflections on an experience that has already happened or been lived through. This lens is based on a philosophy without presuppositions in which the researcher challenges assumptions about the nature of an activity or investigation. The researcher should be informed of the philosophical underpinnings of the framework, not as a professional philosopher, but "enough to articulate the epistemological and theoretical implications of doing phenomenology" (van Manen, 1990, p. 8).

[18] Border Crossing is discussed at length in Chapter 5

B) Epoché and Bracketing

The phenomenological study presented in this dissertation involved collecting data through interviews, observations, language, and/or fictional accounts (for example, stories, poems, artwork, etc). Key aspects of data collection are discussed in greater depth in Chapter 6, section 6.1. This section highlights how the methodological framework considers the highly controversial issue of epoché or bracketing.

Giorgi (1985) refers to epoché or bracketing as the process in which a researcher, as an interpreter aiming to get back to the everyday experiences, must consciously bracket the meanings of a discipline such as science or education, as well as any of their *a priori* expectations for outcomes of a research study where, "Conventional understandings of both phenomenology and science must be bracketed in order to allow for the possibility of the more radical understandings to emerge" (p. 25). Some critics question the philosophical underpinnings of phenomenological reduction and epoché in its entirety, while others accept the philosophical aspects of epoché but argue when epoché should be enacted in the research process. Referring to the latter category, Lytle and Hutchinson (2004) conducted epoché before, during, and after data collection in a phenomenological study of physical education academics (as cited by Dowling, 2007, p. 136). Graber and Mitcham (2004) refer to their use of bracketing interviews with academics from anthropology, ethics, and divinity. Similarly, Rolls, and Relf (2004) take the idea of epoché one step further to identify and eventually put aside the principal researcher's prior assumptions (Dowling, 2004, p. 136). While supporting epoché as an overarching component of the phenomenological methodology, he believes epoché should not be used during data collection, especially interviews, because bracketing in that phase could impact the emergence of radical understandings. His argument is that “bracketing is properly done in the analysis phase of the research and is not appropriate while interviewing, when closeness with the other takes priority”(Dowling, 2004, p. 136 citing Drew, 2004).

Phenomenological reduction and epoché are regarded as some of the most widely contested areas of phenomenology since the early days of Husserl. In education, unlike Giorgi, van Manen critiques Husserl’s views on epoché: “if we simply try to forget or ignore what we already “know”, we might find that the presupposition persistently creep back into our reflections” (Dowling, 2007, p. 138, citing van Manen, 1990, p. 47). Similarly, in nursing, Donalek (2004) states: “research is not truly phenomenological unless the researcher’s belief’s are incorporated into the data analysis” (p. 516, cited by Dowling, 2004, p. 136.). Given that her study focuses on the practical aspects of nursing (as method) with minimal focus on the philosophy aspects, her views have been criticized by Giorgi (2000, cited by Dowling, 2007) and Thomas (2005) who re-emphasize the importance of research studies with a strong theoretical foundation.

C) Methods

This study utilizes various empirical methods, such as: **Describing**, which refers to focusing on a particular situation or event without providing further explanation; **Gathering**, which involves inviting individuals to write plausible accounts of their experiences; **Observing**, which means entering a person’s world by participating in it, being careful to invoke epoché as much as possible; **Interviewing,** which means exploring and gathering experiential, narrative, stories and anecdotes; **Fictional**, which refers to using vicarious sources of experience such as stories and poems; and, **Imaginal**, in which artistic media provide the form for an experience (van Manen, 2006).

The phenomenon of human experience in a science class dictated the use of phenomenological framework, a stance validated by Hycner who states that "the phenomenon dictates the method (not vice-versa) including even the participants" (1999, p. 156). Similarly, Groenwald (2004) describes the use of qualitative interviews in his phenomenological study, when the interviewer's questions are "directed to the participants' experiences, feelings, beliefs, and convictions about the theme in question" (Welman & Kruger, 1999, p. 196). The unstructured, phenomenological interview is a method to "understand the world from a subject's point of view, to unfold meaning of peoples' experiences (Kvale, 1996, p. 1-2) and in this way, Groenwald's study focuses on "how the participants 'think and feel in the most direct ways" (Bentz & Shapiro, 1998, p. 96) by paying particular attention to "what goes on within" the participants with an "intent to understand the phenomena in their own terms – to provide a description of human experience as it is experienced by the person herself" (Bentz & Shapiro, 1998, p. 96).

This inquiry stays true to the view that a phenomenological study does not typically involve collecting data from group activities such as focus groups, community meetings or classroom activities because the focus is on the individual experience rather than the collective experience of a group, class, etc.; however, the researcher does acknowledge that the literature reports phenomenological research studies that have utilized group interviews when appropriate to a particular study (Spiegelberg, 1982; Benner, 1984, Racher, 2003). Similarly, this study does not involve a situation where the researcher conducts classroom observations of a group of students or observations of other experiences such as laboratory sessions, study processes, etc. and then describes the experiences (of the *other)* from this researcher's perspective. Such a process is contrary to the phenomenological approach where participants give testimony as descriptions about their own experiences, as lived *by them* and <u>not</u> as descriptions of their experiences as observed by the researcher.

This line of thought introduces the idea that observation is theory laden and thus interpretive. For a phenomenologist, the question becomes about *who* is doing the observing. If, a phenomenological approach involves a person observing and interpreting their own experience as lived, then the researcher's role is not to be an observer, but rather to be the translator, organizer, and synthesizer. A phenomenological approach does not involve another person (such as a researcher) interpreting a participant's experience, although it is possible that a researcher might actually enter the participant's world and by participating in that world, the researcher becomes part of the study; however, in this situation, the arguments around the researcher's ability to invoke epoché become even more compelling. Any inquiry of this sort would benefit from heeding the advice of Kensit (2000) and Bentz and Shapiro (1998) who caution an enthusiastic researcher to allow the data to emerge and to interpret the findings not necessarily as *answers to pre-determined questions* or *solutions to defined problems*, but rather as rich descriptions of the phenomenon *as lived* by the participant(s) of the study.

D) Analyzing Data

Doing good research involves much more than generating data. Good research moves "beyond the data to develop ideas" (Coffey & Atkinson, 1996, p. 139). Ideas are developed by analyzing, or for a phenomenological study, explicating the data. In this study, the term *data analysis* with *data explication* because analysis usually means a "breaking into parts and therefore often means a loss of the whole phenomenon...[whereas explication implies an] investigation of the constituents of a phenomenon while keeping the context of a whole" (Hycner, 1999, p. 161).

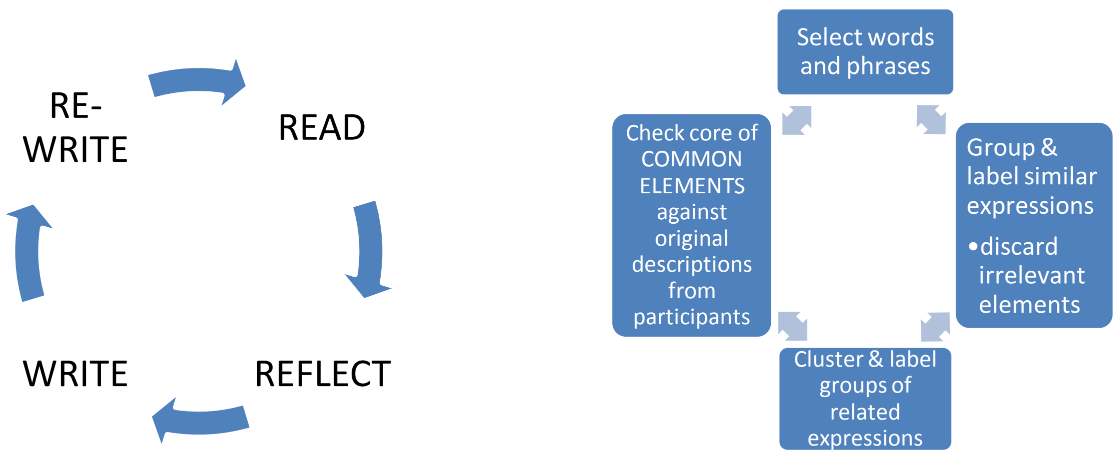
The literature of applied phenomenology cites various models for coding, categorizing, theme-izing and theorizing the data, including the work of van Manen (1997), Hycner (1999), and Giorgi (1997). The next section presents descriptions and comparisons of these models that are commonly used for data explication, not as exhaustive explanations each process, but as highlights of the key points that differentiate and distinguish one model from another. For each model, a visual representation accompanies the text description to clarify how the explication processes might be tackled[19]. Even though some of the models use steps and arrows, this is not to say that the nature of the process is necessarily linear or sequential, but simply to show a progression of thinking toward a concrete description of the experience. Following presentation of the different models is a series of arguments and comments about why Giorgi's model is taken up for this study.

[19] *Visual representations of the four models designed Bergere, T. (2008) using SmartArt, Microsoft Word 2007.*

(i) Model #1: van MANEN

van Manen's (1990) model is rooted in hermeneutic philosophy and applied to the field of education. He describes an iterative process (see Figure 4.3) of reading, reflecting, writing, and re-writing to record and communicate the essence of experience into a text based account.

Figure 4.3: Phenomenological Methodology - van Manen's Model
(generated from van Manen 1990, 1997, 2002, 2006, Richards & Morse, 2007)



(a) General Phases of the Process **(b) Specific Phases of the Process**

This model involves tracing etymological sources of selected words and phrases, searches idiomatic phrases, groups these phrases into themes (eliminating aspects that are not relevant), uses interviews and stories as experiential descriptions, for example, interviews and personal stories, then observes/reflects and shares the essence of the experience with the scholarly community.

Van Manen's hermeneutic approach emphasizes the fact that this form of inquiry demonstrates a heavy reliance on the process of writing. Data explication is much more than simply recording the findings as the final step of preparing the study for publication. The very nature of the explication process of research and reflection is practiced through writing and reading:

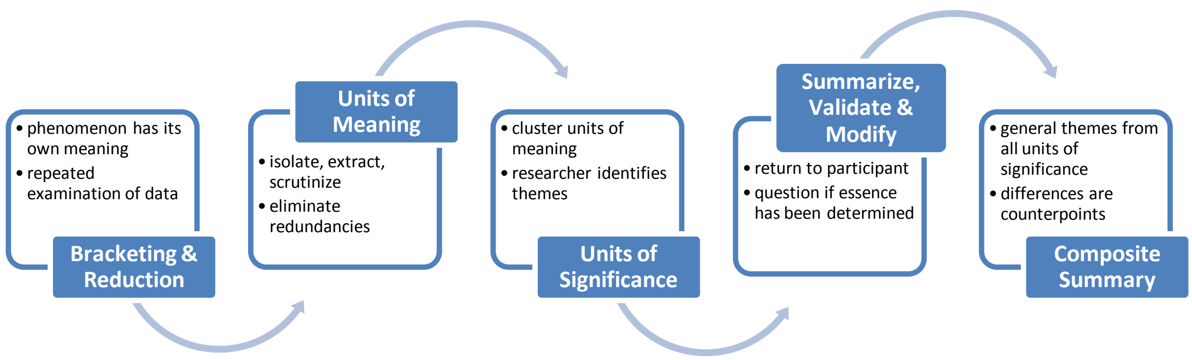
> Something does happen in the act of phenomenological writing. Phenomenological writing is the very act of making contact with the things of our world. It is in this sense that we can say that to do research is to write and that the insights achieved depend on the right words and phrases, on styles and traditions, on metaphor and figures of speech, on argument and poetic image. And even then, writing can mean both insight and illusion. And these are values that cannot be decided, fixed, or settled since the one always implies, hints at, or complicates the other. (van Manen, 2006)

Through the solitary and isolated dimension of the writing process, a phenomenologist seeks meaning about a question by entering the spaces created in the text. Once inside that space, the writer attempts to "bring things into presence through artistic evocation" by traversing the space of the text, "where there reigns the ultimate incomprehensiblity of things, that we may sense the unfathomable infiniteness of their being, that we may hear the uncanny rumble of existence itself" (van Manen, 2006). By using words to draw in the reader, an author creates a "linguistic image" so that the reader (even reluctant ones) can be in touch with something. In the end, the author in her/his search for meaning about the phenomenon is able to touch something about the "lived" experience with words, and in this way, the reader is brought in touch with this "phenomenological nod" or perspective on the phenomenon. One final and important note about van Manen's approach is that he views epoché as ignoring what is already known and feels that presuppositions will naturally percolate into the reflection process.

(ii) Model #2: HYCNER

This 5-phase process (Figure 4.4) involves bracketing and phenomenological reduction, delineating units of meaning, clustering units of meaning to form themes, summarizing, validating, and modifying (if necessary) each interview, and extracting general and unique themes from all the interviews to form a composite summary of the experience.

Figure 4.4: Phenomenological Methodology - Hycner's Model
(generated from Hycner 1999; Groenwald 2004; Richards & Morse, 2007)

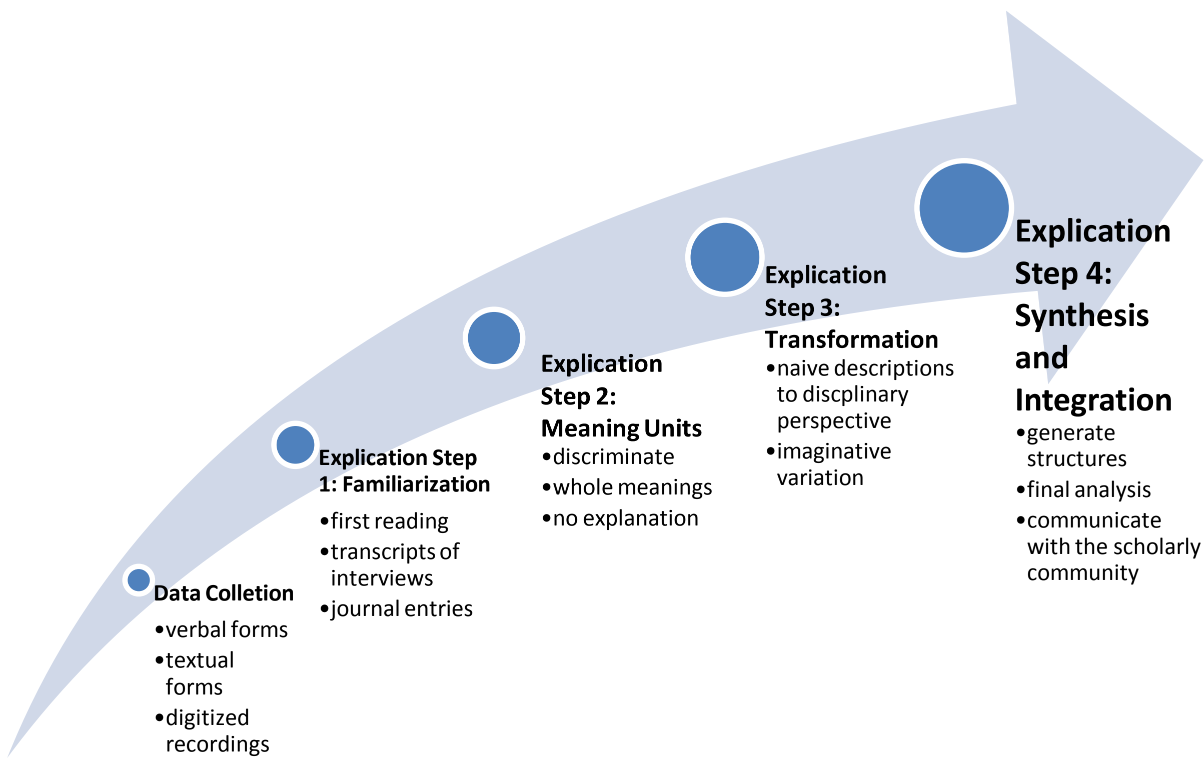


Researchers using this model conduct epoché as much as possible to ensure their views and preconceptions about the phenomenon do not enter the world of the study and that the phenomenon acquires its own meaning. The figure uses arrows to show a progressive directional nature of the process; however, it is understood that a researcher will often repeatedly examine and re-examine the data to gain a holistic sense of the phenomenon. For each individual participant, units of meaning are organized by the researcher as s/he isolates, extracts, and scrutinizes statements from the participant, paying close attention to the literal content, the number of times something is stated, and the manner in which it was stated, including non-verbal or paralinguistic communication. Anything that is redundant is eliminated at this second phase. The third phase involves clustering units of meaning into themes or units of significance (Sadala & Adorno, 2002) which sheds more light on the deeper meanings of the phenomenon. Next is the validity checkpoint. In this phase, the researcher returns to the participants to verify whether the essence of the experience (phenomenon) has been determined in a way that is valid and authentic. After doing so, the final stage involves the researcher's consideration about themes that are common to ALL of the participants, noting differences. The variation(s), due to different individual experiences, serve as important counterpoints for the phenomenon. At this point, the researchers summarizes the findings and "transforms the participants' everyday expressions" into a form that is "appropriate to the scientific discourse supporting the research" (Sadala & Adorno, 2002, p. 289).

(iii) Model #3: GIORGI

Similar to Hycner's model, the arrow gives the impression of a directional pathway to the process, but a researcher employing Giorgi's model will repeatedly examine and re-examine the data to gain a holistic sense of the phenomenon (See Figure 4.5). The dimensions of the arrow increase as the essence of the phenomenon becomes substantiated by moving through the explication process. Giorgi's views support the use of epoché in the explication phase of a study in which researchers bracket their assumptions, expectations, and prior knowledge, and view the phenomenon "from all aspects" (Giorgi, 1997, p. 237). When researchers prepare concrete descriptions of phenomena by breaking the data into parts, organizing and synthesizing ideas, they will (as much as possible) suspend their own views, prejudices, and pre-suppositions about what the experience *might be like* for the other.

Figure 4.5: Phenomenological Methodology - Giorgi's Model
(generated from Giorgi,1989, 1994, 1997, 2006; Richards & Morse, 2007)



Giorgi refers to data explication as a spontaneous and pre-reflective activity involving simple descriptions of experiences "as they present themselves and precisely as meanings for us without taking the further step of stating that they are what they present themselves to be, or that they are what they mean to us" and in this way, bracketing ensures our "theoretical prejudices in terms of analytic or explanatory categories do not enter our initial descriptions" (Giorgi, 1985, p. 43).

Data are collected about experience of the participant (as the experiencer) in various forms including verbal communications, digitized recordings of interviews, text from interview transcripts or personal journals. Data collection provides the descriptions, accounts, or recollections of the experiencer's experience, as they understand it to be.

The **first step** in Giorgi's data explication process involves reading through these descriptions. During this step, the researcher becomes more familiar with the language that participants are using to communicate their experience as a whole, where "the general sense grasped after the reading of the text is not interrogated nor made explicit in any way. Primarily, it serves as a ground for the next step." (Giorgi, 1985,p. 11, cited in De Castro, 2003).

The **second step** in explication organizes the descriptions into *Meaning Units* where each unit holds a particular meaning that makes it distinct from other units in some way. Giorgi notes the importance of being careful to not de-contextualize the description because "the context contained within a description is highly important for determining meanings" (Giorgi, 2006, p. 308). A researcher is able to accomplish this by paying close attention to words, terms, language and related descriptions of the experience, and in doing do, s/he is beginning to interpret the expressions or descriptions provided by the experiencer. It is noteworthy to point out that Giorgi draws on the phenomenological idea of *whole* versus *parts* to deal with the interpretive act: "grasping the whole meaning of the experience, instead of dividing it into parts without understanding the basic meaning structure, which gives sense to the whole experience" (De Castro, 2003, p, 47). In this way, the researchers' initial abstractions remain focused on the experiencer rather than becoming an interpretation of the meaning of another's experience based that researcher's own perspective. In this step it is important that the researcher is not so diligent in organizing that meanings are introduced that are not being described by the experiencer because such units would once again, be an interpretation of the researcher rather than the experiencer.

Transformation is the **third step** of Giorgi's model where the meaning is expressed in language of the discipline, such as, psychology for Giorgi, or science education for this dissertation. For each Meaning Unit, the researcher draws on the naïve language of the experiencer's descriptions to draft a statement about the meaning of the description in the language of the discipline, and then interrogates the meaning against the topic, problem, or research question being posed in the study. In doing so, this step of Giorgi's model begins to approach the *essence* of the phenomenon by utilizing imaginative variation, a concept that De Castro (2003) describes as a key aspect of Husserlian philosophy, clarified by Polkinghorne's statement:

> Imaginative variation is a type or mental experimentation in which the researcher intentionally alters, through imagination, various aspects of the experience, either subtracting from or adding to the proposed transformation. The point of free variation is to imaginatively stretch the proposed transformation to the edges until it no longer describes the experience underlying the subject's naïve description. The use of these processes is to enable the researcher to produce meaning transformations on which there is consistent intersubjective agreement (1989, p. 55).

In his self-critique, Giorgi (2006) explains his use of imaginative variation stating "essences and meanings are 'seen', intuited, brought into the presence of the researcher's consciousness. There is a certain 'giveness' that guides the formulation of meanings."(p. 308) and in this way the Husserlian stance is maintained because the meaning is being guided by the data rather than moving beyond the data to something that is beyond the experiencer's experience.

After familiarizing themselves with the data, generating meaning units and transforming those units into the language of the discipline, a researcher following Giorgi's model will undertake the **final step** in explication process which involves synthesis and integration of their ideas and insights about the phenomenon. In his review, De Castro (2003) explains Giorgi's use of specific descriptions (called situated structures) that "focus on the concreteness of the situation in which the phenomenon takes place" (p. 54) and general descriptions (called general structure) that "focus on attending the aspects of the protocol that transcend a specific situation in order to find a general or universal validity" (p. 54). Insights about the situated structure are gained by "synthesiz[ing] the meaning units of each description or protocol in order to make descriptive statements of the particular and specific characteristics of every subject". Then "transsituational" insight(s) are gained from the general structure when the researcher "tries to reach and show the most general and essential meaning of the phenomenon under study" (p. 54). The distinction between the two structures is that universal claims about meaning are only made after the particulars have been described in Step 2, transformed in Step 3, and synthesized in the early phase of Step 4. When the situated and general structures are in place, the researcher will conduct a final analysis and make claims about the *essence* of the phenomenon by going "Back to the things themselves!'" (Husserl, E.,1970/1900, p.252)

Recently, Giorgi reviewed variations of how phenomenological methods were being applied (2006) and in that paper, he argued against certain aspects of van Manen and Hycner's approaches. Giorgi's arguments against van Manen were expressed earlier in this paper (see pages 81 & 82). Similarly, Giorgi raises several criticisms of Hycner's (1985) perspective. First, that Hycner's description of phenomenological reduction is incomplete. Giorgi acknowledges that although Hycner is correct about bracketing, he fails to acknowledge that the "given" is only understood to be the way it is present to the consciousness of the experiencer and not assumed to exist the way the experiencer perceives it. In other words, the phenomenal status of what is experienced is not at all mentioned by Hycner" (Giorgi, 2006, p. 309).

Second, Giorgi criticizes Hycner's final step where final results are returned to the participant for approval or validation. Giorgi notes that even though other researchers (Colaizzi, 1978) agree with Hycner and that this validation step is appearing in more and more dissertations, he (Giorgi) argues against the validation process step. First, is the inconsistency between the testimony of the experiencer (which is lodged in their lifeworld), and the phenomenological perspective that is used to interpret that testimony. Second, Giorgi follows Merleau-Ponty's argument (1964) that "the experiencer is not necessarily the best judge of the meaning of his or her experience" (Giorgi, 2006, p. 311). Third, Giorgi's practical concern is that the lengthy second order analysis may not be necessary if it is the first order testimony of the experiencer that researchers are after.

To summarize the discussion on methodological framework, phenomenology has been presented as a philosophically-rich, qualitative, methodology utilizing empirical methods for data collection and explication. van Manen clearly captures this phenomenological stance in these words:

> ….we are not primarily interested in the subjective experiences of our so-called subjects or informants, for the sake of being able to report on how something is seen from their particular point of view, perspective, or vantage point. Rather, the aim is to collect examples of possible experiences in order to reflect on the meanings that may adhere to them (van Manen, 2006).

This approach is often used to study human experience in education settings and offers a suitable methodological framework for studying students' experiences in science education. As such, phenomenology can be used to interrogate, examine and understand how university students experience science elective courses, specifically in terms of their a) perspectives on being non-science majors learning science; b) conceptions about NOS; and c) visions of how they see themselves apply classroom experiences to their future careers as elementary teachers. Such a study would not ask: How do BA students learn science? Instead, a phenomenological study would ask: "What is the essence of BA students' experience of learning science?" with the intention of understanding what this learning experience is like for a non-science major student in a BA program.

4.4 STUDYING UNIVERSITY STUDENTS' EXPERIENCES WITH SCIENCE

Applied phenomenology can be used to examine, interrogate, and understand students' experiences, by drawing on the work of Giorgi to explore experiences *as lived* in undergraduate science courses. The remainder of this dissertation is devoted to the study introduced at the start of this dissertation. The stance this researcher takes assumes that the participant, as the *experiencer*, is the agent of his/her own experience, involving primacy of the individual over the group, gender, or historical period. The aim of the study is to understand individual student's points of view about their *lived experiences* as viewed through her/his eyes. My aim is <u>not</u> to generate claims representing universal truths about learning and teaching science; however, certain claims could be made about common experiences when multiple participants are involved in a study. The next section articulates the position of the researcher in the study, along with the nature, source, and validity of the knowledge being claimed. The purpose for doing so is to ensure the credibility, academic rigor, and scholarly excellence.

4.5 STANCES ON KNOWLEDGE AND TRUTH

As the researcher, I came to the study as an interested, but not innocent, observer with the intention of looking at something that is problematic. I have a *masters-level* background in the natural sciences (biochemistry) that dovetails with *doctoral-level* interests in curriculum and pedagogy in science education. This background merges the expertise of a practicing scientist and post-secondary science educator with the intellectual curiosity of a researcher focusing on the human experience in a science classroom. I am not the teacher/instructor of the participants, although I have a close collegial affiliation with the participants' instructors as the Science Faculty Team leader. At present, the Team comprises 5 faculty members who have been teaching in the program, in various capacities, from 2 to 7 years. I have worked closely with all of these members as long as they have been with the department. Even though I assume no position of classroom privilege, authority, or power, the participants might have their own perceptions of the power of my position (as researcher) as a one who could potentially influence their instructor. This point is re-visited in greater detail in Section 4.7.

In this study, knowledge is the way students (who aspire to become teachers) experience and live through a science elective course in the earliest phase of their post-secondary learning about science. A phenomenological approach is used to transform and synthesize meaning from the *data corpus,* as the researcher stands apart from that as much as possible in order to construct an authentic rendering of participants' experiences.

Data are collected from personal journals and unstructured interviews that focus on: descriptions of a particular situation or event without explanations; plausible accounts of individual's experiences; exploring and gathering experiential, narrative, stories and anecdotes. During the interviews, participants are invited to consider other methods that might assist in giving an account of their experience, including: novels, stories, poems, and/or artistic media, such as a drawing. Text-based data from journal entries and verbal data from interview transcripts is collected, recorded, digitized, reviewed, scrutinized, organized, synthesized and summarized, with repeated re-examination of the data, to gain a holistic sense of the essence of students' experiences.

Aikenhead's border-crossing perspective (1996) of science as culture is used to situate and to frame the phenomenological exploration of science education where the participant, as the *experiencer,* is the source of knowledge about the way they live and interpret their experience in science classes. When taking this stance and understanding that knowledge is personally constructed, socially medicated, and inherently situated, it is clear that knowledge is not separate from, nor resident in me.

This position begs other questions. For example, how does one know this knowledge is trustworthy and valid? In other words, how can a researcher know that claims about an experience are generated from a participant's truthful descriptions? Even though any discussion about discovering truth about one's reality might easily become philosophically problematic and distract the reader's attention away from the important point about *knowledge in this study* into an entangled conversation with its arguments and debates about truth and "Truth", it is nonetheless important to take a position on truth and knowledge in this study.

For the purposes of this work, the trustworthiness of knowledge does not align with views of truth such as Foucault's "Regimes of Truth" in which truth is a function of power structures and therefore as something dynamic and changing with history (1996); or the Correspondence Theory of Truth in which "a belief (statement, sentence, proposition, etc) is true provided there exists a fact corresponding to it" (Cambridge Dictionary, 1995). In other words, the correspondence between the appearance of things and the reality of things where much of what one perceives with one's sense corresponds to an external reality outside of one's own body that can be verified through experimentation. Or alternatively, Hegel's stance where truth is externalized to the extent of becoming an object fully and completely separated from thought in which he regards "Truth is its own self-movement within itself" (1979).

In this study the truthfulness of knowledge about participants experience is considered a subjective truth, a view that borrows from Kierkegaard's existential view in which all knowing is related to existing and experiencing. Kierkegaard claims that one's truth is not separated from one's existence (Watts, 2003):

> All essential knowing pertains to existence, or only the knowing whose relation to existence is essentially knowing….all essential knowing is therefore essentially related to existence and to existing (CUP (E), VII, p. 166 as cited in Watts, 2003, p. 81).

and he argues against an objective, detached, or observed truth which "completely ignores the *essence* of living things" (Watts, 2003, p. 80). This position on truth as a subjective way of knowing reality is clearly much more than a belief that something is true just because someone believes it to be true. Kierkegaard's claims:

> the subjective experience of being, or living, within truth – of immersing oneself in the subjective, inward activity of experientially exploring and discovering truth of one's own self in the process of existing, which is the process of becoming, a direct personal involvement in the living moment-by-moment process of unfolding reality (Watts, 2003, p. 82).

Participant in this study shares *his/her truth* about *their own experiences* as subjective, inward, and dynamic recollections coming from their own values, morals, and beliefs. The researcher's position about the truthfulness and validity of participants' recollections about their experience in the science course borrows from Kierkegaard's view of a subjective truth that is:

> about our *way of being*. For who we *are, our way of being* and the *significance* our existence has for us can only be understood within the context of the unfolding process of our life in terms of our values and that determines the choices and decisions we make (Author's emphasis. Watts, 2003. p. 83).

In other words, the idea of taking people as authentic engaged selves and the moral implications of when they try to testify to their experiences that they will be honest because they <u>are</u> engaged selves.

With this view, Kierkegaard moves away from the views of others (Foucault, Hegel, etc.) because of his view that what an individual takes to be true is a function of their experience. Here he draws a connection, not just from knowing to existing (Correspondence Theory) but from knowing to experiencing. In order to know anything, one must be an active agent and active participant in their own life and by and through that participation, one comes to know, not just because something is believed to be so, but because as a participant and agent in this activity, that is what was gleamed from that participation.

This stance on truth pre-supposes two things. First, that no matter how wildly variant the experiences might be, different people will draw different beliefs and conceptions about *what their truth is,* from the same experience. To say that truth is subjective to one's experience also means that it is relative to one's own experience. In other words, there is no meta-truth or “Truth” to use as the standard for measuring one’s truth. This does not mean that one cannot draw reasonable inferences from what people say. It simply means that a researcher’s role is to translate, organize, and synthesize what they say, according to the explication steps described previously. Second, this stance pre-supposes rather optimistically that people will be truthful in their testimony about their experiences with an underlying assumption of authenticity that has to be accepted as a *professional hazard* that exists in this kind of qualitative study.

As the researcher in this study, my stance borrowing from Kierkegaard only partially explains how I know and trust that participants are being truthful. I acknowledge a gap that remains between Kierkegaard’s view of knowledge as something to be gleaned through experience that each of us as agents absorb constantly just through the act of living, and then explaining that to someone else. Some things will always remain inexplicable and intangible and untranslatable into words. I must also acknowledge the possibility that the participants’ recollections, descriptions and testimonies are related in a form that a participant would consider to be *pleasing to me*, a point that is taken up in the Discussion (Chapter 6).

This section about knowledge and truthfulness is also about accepting a certain level of uncertainty because I know of no way to absolutely verify whether someone is being truthful or not. I take people at their word because I presume there are certain values imbued in being an active agent. Whether or not they are able to translate their experiences into statements about their truth or their experience is another matter that is a function of the methodology. As researcher, I interrogate their experience to find Transformed Meaning Units from which Structures, or Claims, are synthesized.

As a phenomenological researcher, I too must interrogate how I am being truthful. Again, borrowing from Kierkegaard, I am putting forth my best efforts in this situation at this time in my life and the work being produced is an expression of my existential reality at this point. My role is to ensure that even though I am presuming participants are being authentic and are committed to their own truth, I still have an obligation to check for inconsistencies, contradictions and counterpoints when attempting to interrogate the truthfulness of their testimony. This is one way to be sure that the data I use is in some way 'useful', being much more than just telling me what they think I want to know.

The preceding section on truth leads into issues of how confidentiality, risk, and consent are dealt with in the study.

4 .6 ETHICAL CONSIDERATIONS

This final section of this chapter provides an overview of how ethical issues are handled in the study, including the following: identification of participants, confidentiality, risks and harm to participants, informed consent, data storage, benefits for participating, and finally, compensation. Documentation and approvals related to ethics are included in Appendix A.

Participants in this study are adults over the of age 18 who were registered students in first year science electives in a Bachelor of Arts (BA) program at one Canadian University. All were informed that participation was voluntary. Students who did not intend to apply for BEd programs, as well as students in my own classes, were excluded from participating in the study.

During an informal information meeting and during the interviews, participants were reminded that all activities related to the study were considered confidential and that information would not be shared with their instructor before the course has been completed and official grades submitted to the Registrar. The study does not involve collection of personal photographs or video data. All potential participants were assured that they would be treated in a professional manner, as outlined in the institutional policies, whether or not they participated in the study. Every effort was extended to provide accommodations for students with disabilities.

The study was introduced to students who attended an informal information session. At that time, I explained confidentiality, documentation, methodology, benefits, and compensation. Those who became participants in the study were offered an opportunity to be contacted by the researcher with instructions for accessing any published results, including the dissertation.

In terms of risks or harms of this research, because I am the science faculty team leader in the program and a colleague of the participants' instructors, there was a possibility that a student might feel obligated to participate in the study or perform according to certain pre-determined expectations. To reduce any feelings of pressure that might possibly be felt by the students, they were assured that confidentiality, as noted above, would be maintained.

Potential benefits for participation were explained as a function of the value individual participants placed on the process of their own learning. Participants were also informed that when they explored their own attitudes and conceptions about learning and teaching science they might become more suitable candidates for BEd programs and better K-8 teachers.

All participants in the study received an individual letter acknowledging their role in the study and thanking them for volunteering their time, presented on official letterhead of the

Department of Curriculum and Pedagogy at UBC and signed by the Principal Investigator, Anthony Clarke and myself. A $50 honourarium accompanied the letter. Each participant was advised to note the study on their *Curriculum Vitae* and to include the letter in their academic portfolio.

Various means were used to store and secure participants' testimony and the related study materials. Text-based data will be stored for a period of five years in a secure, locked cabinet that can only be accessed, retrieved, and returned to the cabinet by me. Computerized data submissions are stored as password-protected files. Hard copies of digital files, such as CD's are stored in the cabinet with the text-based files. Only myself and the Principal Investigator have access to the data files; however, participants could book an appointment to access to their individual files. The data will not be available to persons or agencies outside the university. Data will be destroyed by shredding (text files) or by erasing (digital files) in the spring of 2016.

4 .7 LIMITATIONS OF THE STUDY

There were four limitations to this study: (1) remaining true to the methodological framework by paying close attention to epoché during the data collection process; (2) monitoring the development of my own skills and ability as an interviewer; (3) potential presence of the Hawthorne Effect; and (4) influence of the phenomenological explication process on my research question.

First, as much as possible, I remained true to Giorgi's methodology of ***not invoking epoché during the data collection***, particularly when conducting the interviews with participants. There were several instances in the transcripts where I turned off the recorder to address some issues that were beyond the study, especially with Sammy. At the time, due to the highly sensitive nature of some issues that were raised, I felt ethically bound to deal with them immediately, off the record. Consequently, I intentionally changed my role, mid-interview, from *doctoral student interviewer* to *professional faculty member*, and turned off the audio recorder accordingly. Sammy and I spent several minutes discussing the problem off the record, not necessarily to find a grand solution, but to open up a space for Sammy to articulate her concerns and gain a sense of being heard. Shortly afterwards, I turned on the recorder and we resumed the interview, picking up where we left off. In this example, I was conscious about fully suspending epoché in order to help a student with something that was particularly troubling at the time. My sense was that even if the off-record discussion had some unknown or unintentional effect on the rest of the interview, I attributed that to becoming a part of Sammy's experience, *as she was living it*. Even more importantly, as researchers who make an ethical promise to "do no harm", we must not get so caught up in our own research 'agenda' that we minimize or ignore the impact that emerging issues might have on the participants.

Another example of not invoking epoché involves the language I selected for the interview questions (see Appendix 2), which to some degree, served to prompt the participant without going to the extreme of leading them to a pre-determined explanation. For example: one question stated: *"now I have a couple of questions for you about the course itself and not in terms of what [the professor] did or what happened in the classroom, but really how you were in the course and what your experience was like" (Terry, p. 5*). Typically, the intent of a phenomenological question is not to prompt or lead to a certain explanation, but for this study I felt it was important to provide a certain amount of structure to certain questions (not all) to help participants focus on their own experiences, rather than talk about larger classroom issues such as what the professor did in the class that day or how other students reacted to a class activity. I learned from informal, pre-interview talks with the participants, that students, especially those fresh from High school have an easier time sharing more generalities about class (e.g., *the Professor did…, or all of the students said…),* rather than particulars about their own experience (e.g., *when the professor did…I felt…*). I wanted to know more about the latter (so that I could uphold Giorgi's principles of phenomenology as a method) and framed the questions accordingly, appreciating that epoché is one of the most important concepts of phenomenology. In my mind, this form of question is appropriate for a phenomenological interview because students often provide superficial or naïve descriptions about their experience. By not invoking epoché in the interview, I am free to lead them in a certain direction, while maintaining the phenomenological approach.

The third point regarding epoché or bracketing one's presuppositions begs the question: How can one interpret without interpreting? Building on the previous examples of how epoché was intentionally NOT enacted during the data collection phase, I invited the participants to respond to *Journal Joules (JJ)* in their journal descriptions. JJ is a play on words, where the word *jewel* (meaning a precious stone or gem) is replaced with *joule* (a unit of energy, studied in physics). My aim was to use wordplay in a humorous way to link the personal journaling process (of the study) with a physics concept (energy) from science class. Further, participants appreciated that the abstract concept of measuring energy in Joules could correspond to measuring intellectual energy (needed to write in their journals). In other words, participants related an abstract topic from class (physics) to a personal experience of using brain energy to write responses to the Journal Joules[20]. One example of a JJ is taken from VNOS-C[21] which asks: *"What in your view is science?* Close attention was paid to how the language used for each JJ is framed so the participant are not being prompted or led to pre-determined expectations, implying an *intentionality* about the use of language, and my attempts in enact epoché by bracketing my own expectations. The language asks for abstraction and conceptualization rather than simple directed reflections about a pre-determined expectation.

Participants are <u>not</u> required to reflect on their experience with particular classroom tasks, such as a test, exam, or assignment. Instead, the participants' experiences were allowed to emerge naturally, in a context that was meaningful for *them*. A phenomenological study is about *THEIR* experiences and I do not *TELL* them what to reflect on. Instead, I used JJ as an invitation to think about their experience, so they could then bring a deeper view about their experiences to their descriptions. This seemed necessary for those who might need some help beginning the journaling process, especially for those participants who had never kept a journal before. The JJ also provided a means to compare descriptive elements from one participant to another, not to universalize the findings, but simply to see what is similar and different when all participants were asked to reflect on the same question.

One might ask: "what makes the JJ phenomenological OR different from any other question?" The difference lies in the *thoughtfulness* and *intentionality* of the process, (see Chapter 3). Husserl conceived intentionality as an "indissolvable unity between the conscious mind and that of which it is conscious" (Stewart & Mickunas, 1990, p. 9) (see Figure 3.2) and

[20] See Appendix C for specific Journal Joules used in this study.
[21] See Table 3.6, VNOS-C Sample Questions in Chapter 3

claims a unity of *thinking* with *the object the thinking is aimed at* moving beyond Cartesian dualism. Husserl's claims of intentionality as unity of mind and experience assumes "consciousness is never empty and abstract but concrete and tied to the world of experience……[and] shifts the emphasis from the question of reality of the world to the meaning of that which appears to be consciousness." (Stewart & Mickunas, p. 9). By using JJ in the ways described above, the JJ became the something (e.g., participants' views about the nature of science) tied to participants' experiences because their minds became conscious of their responses. The JJ, interview questions and activities were all framed with this phenomenological view of intentionality in mind.

A second limitation of the study involved several entries in my own research journal where I ***questioned my interview skill and abilities***, asking myself if the participants felt pressured by my technique, or put *on the spot* when I probed for a deeper response. Was I asking them to *perform* for me in a certain way during the interview? Retrospectively, when I reviewed the transcripts, I noted several entries where Sammy states she is particularly uncomfortable doing the activities. Even though I politely acknowledged her discomfort, I proceeded with the activity anyway, missing the opportunity to explore the reasons for her discomfort more deeply. Upon reading the transcript, I became aware of the missed opportunity and asked myself why I did not pay closer attention to her statement. My presumption is that in sticking to my timeline for the interview I was not thinking about the responses. Consequently, through this critical self-reflection (Goodnough, 2001), I have identified my attentiveness to responses as an area for self improvement (e.g. improving my interview skills). This is different from the previous example relating to ethics which was about my attention to the impact of the interview process on her experience, rather than this example regarding my attention to self-improvement.

Third, there were points in the interview process when I wondered if the participants were saying and writing things that they thought would *please me* and fulfill what they saw as the purpose of the research being conducted, instead of saying and writing what they were actually experiencing. Was it a power issue? Was I perceived as someone in a position of influence in their science course or BA program? In my attempts to address these questions, I draw on Diaper's research on the ***Hawthorne Effect*** (1990) about how participant's behaviours might change when they become engaged in a research study. In short, participants do what they believe they are expected to do when participating in a research study. A causal basis has not been firmly established from studies that produce and control the effect and "no one knows precisely what it is"(Diaper, 1990, p. 265 citing Adair, 1984), but there a great deal of convincing anecdotal evidence is presented in Diaper's work. The Hawthorn Effect might be one plausible explanation for my questions in this regard, but the data corpus does not support any claim about whether this is actually occurring in this study. In future studies, I will keep in mind the potential for such possibilities as the Hawthorn Effect.

The Hawthorn Effect may also have been present in participants' journals. Do the participants view writing in their personal journals as performing a TASK for me or for what they think the research is about? This might be an area of potential weakness in the study. My intention was that a personal journal is a means for participants to record and interrogate their experiences so that during the interview they were able to easily recall particulars about their experiences. In retrospect, I question how my intention was made explicit to the participants.

Also, the journals did not (at first) seem useful to me as adding to the data corpus, but as I became more familiar with the descriptions (Giorgi's explication Step 1), it seemed that the journal might have been very useful to some participants, because writing in the journal seemed to spark ideas for them during the interview. For some participants, it was obvious that keeping a very detailed journal is simply another task and as the researcher, I am pressuring them think about their experience in another way. Their purpose for keeping a journal is not to be introspective or reflective or thoughtful. Their purpose is to keep a journal for me, for the study, to fulfill what they consider to be certain expectations. The problem is that when the journaling process is seen in this way, as another TASK, then there is a shift from THEM (focus on their experience) to ME (collecting information). My sense is that this was true for Kelly and Terry, who appeared to consider the journal to be a task that was completed for me and submitted as a requirement for the study. The writing style and language is brief, clipped, uninventive, non-specific, and repetitive (to the interview). On the other hand, for Sammy, it seems that the opposite was true. Early in the study she admitted her thoughts about the journal being a task that she agreed to do (for me), but later, her writing reveals that her journal was very much about her thoughts on her experiences in the science courses. She identifies several instances of what she calls venting, which I took as an important expression of her frustrations with people and experiences such as "group work". Woven through her journal is a richness of deeply personal stories and recollections about her time at school at work and at home. The tone of her writing was conversational, at times contradictory and argumentative (with herself), and much deeper descriptions of her thoughts, emotions, and challenges that she alluded to in the face-to-face interview. For Sammy, the journal seemed to be a safe place where she could write freely and openly, without judgment, except from herself. For the remaining participant, Chris, it was not as easy to acquire a sense of her motivation for using the journal. Factors such as: her status as a mature learner; someone who has faced a life-threatening disease; or, an adult with a recently-diagnosed learning disability influence my desire to dig more deeply on this issue of journal as tool or task, likely in person, with her before jumping to any conclusion about her use of the journal.

In future work, I will use pay more attention to using journals as learning tools, rather than tasks, shifting the perspective from *ME* to *THEM*, with the aim of helping participants to focus/reflect/clarify. In this way *my research interests* will shift to *their descriptions of their experiences, as lived*.

Finally, as stated earlier in this chapter, the data *emerges* in a phenomenological study, but not necessarily as an answer to a question. During explication, there was a time that my original research question did not fit with the data coming out of the study. In fact, the data was revealing much <u>more</u> than what was being asked in the research question. By questioning and modifying my original research question during and after the explication phase, my work moves "beyond the data to develop ideas" (Coffee & Atkinson, 1996) and in doing so this study stays true to the phenomenological perspective.

Despite these challenges related to phenomenology as a methodological framework, my own developing skills as a researcher, and the possibility of the Hawthorne Effect, I did manage to successfully navigate most issues and move ahead in the study to collect and explicate data that was both rich and comprehensive.

In summary, this chapter has **situated** phenomenology as a philosophy and as a methodological framework with specific methods for data collections and explication. I have also presented the stances I take as a phenomenological researcher, including my position in the doctoral study, and my views about how knowledge is being used in the study, as truthfully as possible at this time. Ethical considerations related to confidentiality, risks, harm, and informed consent were reported and explained in detail.

Chapter 5: Theoretical Framework

> Can we (or anyone) really know the way the world is? Of course, if we had no ideas about the true nature of the world, then we would have no reason for doubting. We would assume that our world simply was what it seemed to be. But with reflective awareness, we become capable not only of speculating about what is beyond our immediate experience but also of questioning our ability to know what is beyond our immediate experience.
>
> Robert C. Solomon, 2008, p. 51

This phenomenological study of science education did not begin with particular theoretical frames in mind. The intention was to allow for different frames that might be brought to bear when constructing and making sense of the study. After the data had been collected and stories about the participants began to emerge, it seemed that Aikenhead's Border Crossing (BC) perspective (1996) was particularly well suited to this study. The term border crossing *perspective* is used in place of border crossing *theory because* BC uses the metaphor as an interpretive frame to describe the scenario of learning sciences and to understand the struggles the students experience. This chapter presents how BC was used as a powerful lens to interpret, re/interpret, and understand students' lived experiences in university science courses.

BC emerged while thinking and writing the contribution of one participant. *Sammy's Story*[22] cried out for a theoretical framework that could do justice to her experiences as a First Nations person learning science. As culturally compelling as Sammy's story is and even

[22] Sammy's Story is presented in Chapter 6, section 6.2 (ii)

though "there has been a historical marginalization of Aboriginal people that must be disrupted" (Aikenhead, 2006, p. 110), if a researcher intends to make meaningful claims about future teachers' experiences in a university science elective course, then the experiences of all participants in this study warrant consideration. This chapter opens with a clarification of how the term *culture* was used in this study, leading into a deeper discussion about how border-crossing has been used for research studies in science education.

5.1 CULTURES AND SUB-CULTURES

Aikenhead's Border-crossing perspective rests on three foundational elements: first, a generalized view on culture and sub-cultures; second, that professional science is a sub-culture of the dominant Western culture; and third, school science is a sub-culture of the Western culture as well.

The first foundational element of culture and related sub-cultures can be defined in a variety of ways. While acknowledging that many researchers draw a variety of meanings for the term ***culture*** (Banks, 1988; Bullivant, 1981; Ingle & Turner, 1981; Jordan, 1985; Samovar, Porter & Jain, 1981), in this study I draw on the definition provided by Phelan, Davidson and Cao where culture includes "norms, values, beliefs, expectations, and conventional actions of a group" (1991, as cited by Aikenhead, 1996, p. 8). Borrowing from Aikenhead's (1996) and Costa's (1995) justification for this choice, the definition is broad enough to include the values, skills and knowledge that are involved in science classroom environments, and coherent enough to include ***sub-cultures,*** such as race, language, ethnicity, gender, social class, occupation, religious view, where one person might belong to several of these subgroups. For example, a female, First Nations, middle-class, elementary school teacher. Members of a certain sub-cultures share norms, values, beliefs, expectations, and conventional actions that are unique to that sub-culture. Aikenhead speaks of using clusters of these sub-cultures to "provide the generic framework for my analysis of border crossings by students in science classrooms" (1996, p. 9)[23].

The second foundational element of border crossing theory rests on the element of ***science as a sub-culture***. In this context, the reference is to a professional enterprise of the Western culture, a term that is considered synonymous with Euro-American (or Euro-Canadian) culture (Baker & Taylor, 1995: Cobern, 1991; Dart 1972; Jegede, 1994; Maddock, 1981; Ogawa, 1986; Pomeroy, 1994, Aikenhead, 1996). Members of this science sub-culture generally share similar norms, values, beliefs, expectations, and conventional actions of the group in terms of the symbols, method, knowledge, skills, and language used for communications and advancement of the scientific enterprise within communities involving human social interactions. Aikenhead states that although these values and norms might vary from one scientist to another (e.g. a physicist versus a biochemist), or by the setting (e.g. a university research lab versus an industrial manufacturing plant), the literature characterizes science sub-culture (of Western culture) as: "mechanistic, materialistic, masculine, reductionistic, mathematically idealized, pragmatic, empirical, exploitive, elitist, ideological, inquisitive, objective, impersonal, rational, universal, decontextualized, communal, violent, value-free, embracing, disinterestedness, suspension of belief, and parsimony (Fourez, 1988; Gauld, 1982; Harding, 1986; Kelly Carlsen & Cunningham, 1993;

[23] Later in this chapter, I sketch an outline of how Aikenhead uses border crossing theory in his studies on science education.

Rose, 1994; Savon, 1988; Simonelli, 1994; Smolicz & Nunan, 1975; Snow, 1987; Stanley & Brickhouse, 1994.)" (cited in Aikenhead, 1996, p. 10). The sub-culture of science is a community of professional practice engaged in the *scientific enterprise or* practicing *canonical science*.

The third foundational element of border crossing is that ***school science is a sub-culture of Western culture***. Aikenhead offers a perspective that moves away from traditional school science curricula based on the tendency of school science to present negative or false images of science and scientists as "socially sterile, authoritarian, non-humanistic, positivistic" seekers of absolute truth (1996, p. 11), to contemporary curricula where the subcultures of professional science and school science become more "closely aligned" (1996, p. 11).

Traditional school science has perpetuated inaccurate views of how professional science is presented by the school science curriculum (Cobern, 1991; Duschl, 1988; Gaskell, 1992, Millar, 1989, Nadeau & Desautels, 1984, Ryan & Aikenhead, 1992; Smolicz & Nunan, 1975, cited in Aikenhead, 1996). Aikenhead posits these inaccurate views may result from the enactment of a *hidden curriculum* rather than an *intended curriculum* (2006).

Contemporary approaches to school science, such as Aikenhead's BC perspective, are moving toward a school science subculture that is set apart from, but remaining adjacent to, science sub-culture by incorporating social, political, ethical, and cultural perspectives into school science curricula. An example of this movement is Robert's Vision III curriculum (2007) presented in Chapter 2.

This cultural aspect of school science warrants serious consideration for students and especially for future science teachers who are from cultures within and outside of Western, Eurocentric culture. Even students who are from the Western culture, but from different sub-cultures that are outside of science or school science, such as peer groups, family, media and other parts of the school (Furnham, 1992; Phelan 1991), may be affected by cultural differences when studying science in school. In fact, "most students view orthodox science content as having little or no relevance to their life-world subcultures: (Aikenhead, 1996, p. 13) as do "non-masculine students…humanities-oriented non Cartesian thinking students…. [and] students who are not clones of university science professors" (Haste, 1994, Seymour, 1992, Tobias, 1990, cited by Aikenhead, 1996, p. 15.). The term *life-world,* in this context, refers to an individual's own personal culture, details of which are discussed later in this section. From this personal lifeworld perspective, the sub-culture of science is often viewed as "foreign" by students from non-Western and Western cultures because their ideas about science, which some call pre-conceptions, do not make sense and might even clash with their worldview (their personal sub-culture), Consequently, such students often face equally difficult challenges when they encounter Western science (Ogawa, 1995; Kawagley, 1990).

Cobern's worldview or *life-world* model (1991, 1993, 1994, 1996b) outlines how a student makes sense of their world using categories (self, other, causality, classification, relationship, time and space) where one's mind is organized in ways that are a function of one's culture, so that an individual holds "culturally validated presuppositions about the natural world" (Aikenhead, 1996, p. 4). When students are in the classroom, lab or other settings learning science, many are learning about a new culture. This new culture might be incorporated, or as often is the case, may only be partially or not at all incorporated into their life-world or worldview. The idea of cultural acquisition is linked to constructivist theory (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Solomon, Duveen, & Scot, 1994; and Lawrenz & Gray, 1995) and Solomon's 'life-world knowing' versus 'science-world knowing' (1983).

School science is a subject area that can sometimes intentionally be a cultural and political force that separates students belonging to marginalized social groups from students in privileged, higher social position and power groups (Anyon, 1980; Fensham, 1992; Giroux, 1992; Jegede, 1995; Posner, 1992; as cited by Aikenhead, 1996, p. 13). This is particularly prevalent in science courses in the physical sciences (physics). Fensham claims this forced separation in terms of groups with particular interests, including: political interest (people who can advance into scientific careers); economic interest (people in business and labour who need access to a pool of skilled labourers); and the scientific community (people who have an interest in maintaining a certain status quo within the scientific enterprise) (1992).

One reason why this marginalization occurs is because students arrive in science classrooms with a personal life-world perspective of family, friends, and peers (Cobern, 1994) that is a function of their culture. Some students have Western Eurocentric worldviews, while others may be Indigenous People who hold non-Western worldviews that differ significantly from Western culture. Groups in this non-Western, Indigenous Peoples' category include the following: First Nations Peoples (Canada); Native Americans (USA);

Indian Nations (South America); Saami (Europe); Indigenous People (Africa); Aboriginal Families (Australia); Ainu (Japan); and the Polynesian Nations (Pacific) including Maori (New Zealand) and First People (Hawaii) (Aikenhead, 2006).

Students who study science at the primary level (elementary) and secondary level (high school) navigate between their personal culture (of family, peers, and friends) and the sub-culture of science (Aikenhead, 1996), in some cases with a wide discrepancy between the two. I would also add that in my experience teaching science at the college and university level in Canada, these navigations extend beyond primary and secondary levels to the post-secondary level of college and university because many adult students continue to hold personal worldviews that differ substantially from those held within the sub-culture of science.

The border crossing perspective, as applied to science education in this study, rests on a metaphor of distinct, different, and adjoining *territories* of Western culture, non-Western cultures, and school science sub-culture. Table 5.1 outlines Aikenhead’s explanation of the development of these different territories from a historical, developmental perspective. The subcultures of the *scientific enterprise* and traditional *school science* curriculum (that prepares future generations of scientists) both stem from a Western, Eurocentric, colonializing culture of what Quinn (1992) calls *Takers*, rather than *civilized*. The underlying assumptions associated with the term *Takers* is that humans are placed above nature in a world that is in place to support humans. This culture diverged and evolved separately from Indigenous cultures, the *Leavers*, after a cultural revolution in Asia

Minor that occurred more than ten millennia ago. Quinn's view of *Leaver* cultures place humans equal to or below nature, giving back to and living in harmony with nature .

Table 5.1: Overview of Anthropological Development of Cultures and Sub-Cultures
(generated from Aikenhead, 2006, p. 7-13)

	CULTURAL REVOLUTION ASIA MINOR – 10,000 YEARS AGO	
Society	Egyptians, Greeks, Babylonians	Other societies and non-societies
Eurocentric label	Civilized	Primitive
Contemporary Label (Quinn, 1992)	TAKERS	LEAVERS
Placement of Humans	above nature take FROM nature	equal to/below nature give back TO nature
Sense of the world	To support human life	Nature and humans in harmony
Stories	Written traditions, held in books, letters for literate people	Oral tradition, often held by elders
Culture	Western/Eurocentric	Non-Western
21st century science	evolved from ancient philosophy, then natural philosophy (BAAS, 1831 in UK and AAAS, 1848 in USA)	Evolved from Aboriginal/Indigenous peoples' cultural traditions
Values	Universal abstractions	Self identity/survival
Knowledge structures	Systematic, empirical, rational to serve the sub-culture of Western science	Systematic, empirical, rational to serve the sub-culture of Indigenous science
Traditional View of School Science	**VISION 1 CURRICULUM** • pre-professional training of future scientists • Eurocentric worldview about science and culture • Students are enculturated, assimilated, marginalized	
Contemporary Views of School Science	**VISION II and VISION III CURRICULA** • prepare future scientists & scientifically informed citizenry • consider and respect Western and non-Western cultures • link science with society, politics, and culture	

Even though values, norms, and beliefs differ between Western and Indigenous cultures and the sub-cultures that stem from them, it is important to note that in terms of knowledge structures about science and the natural world, the similarities cannot be ignored.

One major difference in the two cultures is how knowledge is used or applied, a factor that is closely linked to cultural values and beliefs. Consider the bark of the willow tree which is known to have pain reliving effects in humans. For generations, First Nations People have gathered small pieces of the bark and boil them in water, in essence brewing a tea which when consumed orally, would act as a pain reliever or analgesic. This *Leaver* culture views humans living in harmony with nature, drawing on what is necessary for a remedy from the willow that improves health and ensures survival, but the tree itself is left to grow for the benefit of future generations.

The Western science approach is to harvest the trees, separate the bark from other parts of the tree, isolate and concentrate the active ingredient ASA (acetylsalicylic acid) into a small pill that is easy to swallow. Pills are packaged and marketed by pharmaceutical suppliers. Even today, the corporate giant Bayer manufactures and distributes Aspirin (brand name) to millions of consumers, generating corporate profits for their shareholders. This *Taker* culture views humans as above nature, taking from nature to support and improve the quality of human life, but often neglecting or dismissing cumulative destruction of nature that arises in the context of large-scale commercial Western enterprises.

Considering the sub-culture of school science, there is a slow but noticeable shift from a traditional curriculum (Vision I) that serves as a *pipeline* (Aikenhead, 2006) for pre-professional training of future scientists and engineers, to contemporary curricula (Vision II and III), as alternatives to the pipeline, which incorporate a broader social, political, cultural perspective into school science curricula with an aim to educate a scientifically literate citizenry. These concepts are discussed in detail in Chapter 2. Any suggestion that school science as a sub-culture could or should bridge the gap between the Taker and Leaver cultures' views about the natural world may be the subject of ongoing debate; however mounting evidence from the literature supports the need to explore how students from different cultures and sub-cultures engage with science in effective and meaningful ways. Aikenhead's border crossing perspective (1996) is one way to think about such explorations.

5.2 BORDER CROSSING AS AN ADDITIONAL FRAME FOR ANALYZING DATA

The roots of the border crossing perspective have grown from several researchers, but Aikenhead's framework stems predominantly from Henry Giroux's (1992) early work examining modern versus post-modern views in education that connect classroom practice and teachers' practical knowledge with anthropological educational research (Aikenhead, 1996; Aikenhead and Jegede, 1999; Jegede and Aikenhead, 1999; and Pomeroy, 1994) – as cited by Aikenhead, 2006, p., 119). Giroux's work contrasts the *modern* view, in which borders are established between locations of differing social and political power, with the *post-modern* view of a world in which people hold multiple identities and can navigate to and from a variety of different cultural locales by crossing borders. Aikenhead's views are also informed by Costa (1995), Maddock (1981), Pomeroy (1994), and others, extending our thinking about the process students undergo when transitioning between their personal lifeworld culture to the culture of school science by crossing metaphorical borders between cultures and sub-cultures. Aikenhead also draws on several theoretical assumptions of "boundary crossing" (Erickson, 2004) about one's capacity to:

- *think differently in various cultures (for example, in the culture of Western science);*
- *talk about those differences (metacognition not normally prevalent in elementary students);*
- *feel at ease in a less familiar cultural context; and*
- *resolve conflicting beliefs. (2006, p. 119-120)*

If and when transitions are made, the result is **enculturation, assimilation,** or **acculturation,** and in this way, teaching science is viewed as ***culture transmission,*** and learning science is viewed as ***culture acquisition (***Aikenhead, 2006).

Students view their science teachers in various roles: as border brokers who reduce hazards to help students cross; or as assimilators who want to indoctrinate students into the culture of school science; or as border guards who can make the crossing difficult, painful, or sometimes impossible. Given that students arrive in our classrooms with a life-worldview linked to their culture, including Western Eurocentric views and non-Western views, all students who study science at all levels of education in Canada navigate between their personal culture (family and friends) to the sub-culture of science (school, work, etc). Some students, whom Aikenhead (drawing from Costa, 1995) categorizes as "Potential Scientists", are able to demonstrate academic success in science classes, and for them, the border is unproblematic and their crossing is smooth, almost as if there was no border. These individuals are already well indoctrinated into the culture of science due to the influence of family members and/or prominent friends who are themselves part of the scientific enterprise. Conversely, when the sub-culture of school science differs from a student's personal culture, then a cultural clash emerges, and these students may find the border crossing process to be hazardous or even impossible (Aikenhead, 1997, Battiste & Barman, 1995; Cajete, 1999; Chinn, 1999; Ezeife, 2003; George, 1999; Jegede & Okebukola, 1991; Kawagley, 1990; McKinley et al, 1992; Sutherland & Dennick, 2002; Cobern 1996a; Kawasaki, 1996, 2002; Lee, 1997; Ogawa, 1995; Tsai, 2001; Koul, 2003 as cited by Aikenhead, 2006,p. 108).

Many Euro-Western and non-Euro-western students who experience struggles crossing the border develop strategies to help them cope with a process they see as assimilation by unconsciously using Fatima's Rules or other strategies, memorizing class content but not actually engaging with that content on an intellectual level. These students may appear to be "making the grade", but they do not achieve the learning outcomes of the course (Aikenhead & Ogawa, 2000). Jegede describes ways students handle the transition between cultures on a continuum of what he calls *collateral learning*. At one end of the continuum, students maintain the two cultures in separate compartments with no overlap of one with the other. At the other end, students eliminate any conflict between school science and their lifeworld using various strategies, such as playing Fatima's Rules (explanation follows). Such strategies are a form of **cognitive apartheid** (Cobern, 1994), referring to the way that students, in their minds, segregate science content that is learned at school from life-world learning from their personal worldview culture. This segregation can vary considerably. Jegede's thoughts about **collateral learning** (1995, 1997) indicate how students hold science culture as completely segregated from personal culture but often remaining accessible to various degrees. Some students, typically from Indigenous cultures, who do well in their school science classes construct a schema of scientific concepts that are held adjacent to, but not epistemologically integrated with, a parallel schema aligning with their personal culture. This is particularly typical with students from Indigenous cultures but also those from the mainstream Western culture. Knowledge is held in different ways with the scientific knowledge being accessible in a person's long term memory, and retrievable when needed, but compartmentalized and kept separate from their personal culturally situated knowledge about the same topic (Aikenhead & Jegede, 1999).

Many students play Fatima's Rules (a term coined by Larson, 1995), at the other end of the continuum, when they feel they are being indoctrinated into a science culture that clashes with their personal culture. These students appear to be working hard at their studies and are even able to pass their tests, but learning is only a temporary, rote memorization of science content, rather than acquiring a deep understanding about the culture of science (Aikenhead & Jegede, 1999). Generally, due to this superficial level of engagement in their science studies, these students do not have a deep understanding of science but a sufficient knowledge for 'passing the test', suggesting the problematic role the assessment of school science plays in this context. Consequently, students who demonstrate collateral learning, such as playing Fatima's Rules, progress through their required science courses and earning course credits, while continuing to view science as being minimal or not at all relevant to their everyday lives (Aikenhead, 1996), nor connected to the ways in which they make sense of the world.

Teachers and future teachers, must recognize these traits in students with culturally diverse backgrounds because the typical mix of students in their classroom is not homogenous. Only a minority of their students will one day become part of the scientific enterprise. Some students will want to do well in their science studies but will not continue studying science any longer than required by the school; whereas, other members of the class will experience great difficulty learning science. Aikenhead's cultural border crossing theory is one way to explore and interrogate this heterogeneous nature of students who collectively make up a school science classroom. The next section provides several models, which map the evolution of the theory used for this phenomenological study.

5.3 MODELS OF STUDENTS' CULTURAL HETEROGENEITY

One of the earliest studies of cultural heterogeneity in science education was conducted by Phelan, Davidson, and Cao (1991) investigating a physics class and exploring the similarities and differences between the cultures of school science and students lifeworlds. He classified the heterogeneity of the students using four categories (Table 5.2) and related their transitions across cultural borders to each category. For students whose personal lifeworlds aligned closely with school science, the process of crossing borders was smooth and easy; whereas, other students found it impossible to cross the cultural borders between their personal lifeworld and the sub-culture of science.

Table 5.2 Phelan's Classification Model

Alignment of Personal and Science Cultures	Ease of Transition
Congruent	Smooth
Different	Managed
Diverse	Hazardous
Highly Discordant	Impossible

Building on Phelan's work, Costa (1995) researched students' transitions from personal culture to high school chemistry classes by also considering how they to made transitions to school in a general sense. She identified five different categories of students, noting their transition process from one culture to another, as shown in Table 5.3.

Table 5.3 Costa's Classification Model

Categories of Student Heterogeneity	Ease of Transition
Potential Scientists	Smooth
Other Smart Kids	Manageable
'I Don't Know' students	Hazardous
Outsiders	Impossible
Insider Outsiders	Difficult/Impossible

Using the descriptors of Potential Scientist, Other Smart Kids, 'I Don't Know' students, Outsiders and Inside-Outsiders, Costa addresses heterogeneity of science learners and relates the characteristics of each category to the process of crossing the cultural border between students' personal lifeworlds and school science.

Aikenhead (1996) builds on Costa's work adding three key aspects to the border crossing theory: relevance of school science (to students); students' self-esteem; and student's images of themselves. To adequately capture this expanded view of heterogeneity, Aikenhead adds the ***'I Want to Know' students***, a category that fits between *Potential Scientists* and *Other Smart Kids*. In doing so, Aikenhead expands the framework to include a broader classification of science learner heterogeneity and captures aspects of students' self image and self-esteem alongside various degrees of the relevance of school science. Key elements of Aikenhead's border crossing framework are summarized and integrated in Table 5.4, providing an overview of the six categories of students in terms of their transitions between personal lifeworld/school science situated within the larger context of science curriculum and science education as described in Chapter 2.

Aikenhead's early work (1996; 1997) refers to processes involved in border crossing as acculturation, assimilation, or enculturation. **Acculturation** is a process in which students replace or modify their old ideas (often called misconceptions in the literature) because there is some inherent value to them (e.g., an institutional requirement to complete a university program). These students borrow from the cannon of scientific knowledge but often continue to incorporate thinking from their everyday world to some extent.

Table 5.4 Aikenhead's Classification Model

(generated from Aikenhead, 1999; Aikenhead, 2006; Costa, 1995; and Aikenhead & Jegede, 1999)

Descriptors for Heterogeneity	Potential Scientists	'I Want to Know' students	Other Smart Kids	'I Don't Know' students	Outsiders	Insider Outsiders
Ease of Cultural Transition	Smooth and natural	Hazardous but worth the risk	Manageable	Hazardous but able to cope	Not possible	Difficult/Impossible
Characteristics of border	Invisible	Visible	Visible	visible	Highly visible High risk	Highly visible risky but possible
Worlds of science, school, family & peers	highly congruent	Congruent	Personal and school are congruent but personal and science are not	Worlds are only congruent when playing the game (grades)	School AND science are discordant with personal worldview	School and personal are irreconcilable but <u>potential</u> for congruence with science
Implication of transition	enculturation	enculturation	assimilation (reject enculturation)	assimilation	No transition	assimilation
Relevant Points	• Pipeline for future scientists and engineers • Many Euro-American males • Enjoy challenge of school science • Disregard bad experiences with science teachers	• Lifestyle resonates with science • Challenged by Western science as something that is intelligible, plausible, and fruitful	• Accept cultural norms of science but preference is creative activities • Rarely choose science at U. • might play Fatima's Rules to pass science	• play Fatima's Rules • no deep learning about science • defer to media and to scientists as experts • grades are important so they want to do well in science	• only a few discover Fatima's Rules • science <u>and</u> <u>school</u> are foreign • school is very difficult • students are problematic for teachers • View scientists as dull, boring experts	• lives are unconventional • tend to not trust teachers or administrators
Interest level in science	High for career and personal interest	Relatively high interest	High for career but (not for personal use)	Non-committal attitude	Reject all notions of science	Interested in science and bright but often no support from family/peers
Curriculum Issues	Satisfies canonical. political, and economic interests of the discipline See little value in a curriculum for society (subjective, epistemological, cultural etc.)	Hold modest but effective understanding about science Low grades in science impact their self-esteem	Build academic bridges: Autonomous acculturation (students invited to add to/modify personal worldview) OR anthropological acculturation (engagement without acceptance)	Possibly alternative, cross cultural curriculum where teacher serves as travel agent and/or *tour guide*	Often created by a "hidden" curriculum and must be dealt with by teachers one-on-one	
Metaphor	Students as fully independent travelers	Students benefit from teacher as tour guide	Students as travelers in unfamiliar culture	Students as tourists who need the help of a travel agent (teacher)	Students do not travel anywhere	Students as potential sightseers

Assimilation is a process in which students' personal worldviews are fully replaced by ideas about canonical science or held alongside the cannon, but only on the periphery of their understanding, with canonical science placed in a dominant position of their thinking. **Enculturation** is a process in which students fully integrate their personal worldview with the cannon of science. Their thinking about everyday things is seen through the lens of the science.

According to Aikenhead's recent review (2006), the literature indicates that students' cultural heterogeneity is also important for developing and practicing teachers because "most science teachers are unaware of the cultural nature of this school science they teach (Aikenhead & Huntley, 1999; Aikenhead & Otsuji, 2000; Haidar, 2002; McKinley, 2005)" (p. 120), and hence, equally unaware of their role as tour guide, cultural broker, travel agent, border guard. This framework sheds some light on the issues of why "so few students respond favorably to traditional science content" (Aikenhead, 2006, p. 116), directly linking to the research question in this study about how students experience a university science elective course, in terms of the organic interactions between the phenomena of students' experience and the science classroom.

One aspect of the uniqueness of this study is the expanding the view of Aikenhead's six categories about the perspectives of **students as learners of science** (who make transitions across cultural borders) to **students as future teachers of science**, who will one day, consciously or unconsciously, act as *border brokers* or *cultural assimilators* or *border guards* in *their* science classrooms with *their* science students who will experience science class as an interaction between sub-cultures. This aspect will be discussed in greater detail in the Discussion section in Chapter 7.

5.4 THEORETICAL ASSUMPTIONS AND IMPLICATIONS

The border crossing theoretical framework is based on several assumptions: first is that "every individual is a dynamic and unique hybrid of many ongoing life experiences and genetic predispositions" (Aikenhead, 2006, p. 110) and I would add that a person's genetics are also affected by environmental modifications that are a direct result of their life experiences, for example, their food, drugs, air, water, radiation.

Aikenhead states that "the field of cultural studies in science education ultimately applies to all students who experience school sciences as a cross-cultural event. This excludes of course, the privileged elite who find science pipeline highly comfortable as it is" (2006, p. 109). Much like Glen Aikenhead, I was a person belonging to that group of people who found studying biochemistry at the Master's level to be comfortable; it was challenging. At the time, I did not feel I occupied a privileged or elite position. Consequently, I asked myself, what makes these folks elite?

Research studies on border crossing are typically conducted with students between the ages of 11 and 16 because of the assumption that students in this age bracket have developed the following capacities:

- to think <u>differently</u> in various cultures (for example, culture of Western science);
- to talk about these differences (metacognition);
- to feel at ease in a less familiar cultural context (for example, school science); and
- to resolve conflicting beliefs (for example, collateral learning) (Aikenhead, 2006, p. 119)

and I would add that these capacities would also apply to most adult learners, over age 16, including non-science majors from Western and non-Western cultures, learning science in university programs.

Border crossing brings a relatively new cultural perspective to science education compared to other analytical perspectives, such as constructivism, and is important for science education research for several reasons. First, the border crossing perspective involves the approaches of Vision II and III science curricula and conceptions about NOS (explained in Chapters 2 and 3, respectively) where science is a human endeavor. Aikenhead's *humanistic* approach refers to "values, the nature of science, the social aspects of science, the culture of science, and the human character of science revealed through its sociology, history, and philosophy" (Aikenhead, 2006, p. 2). Second, the research "promises insightful descriptions and explorations to benefit policy makers, teacher educators, and classroom teachers" (Aikenhead, 2006, p. 2) and this researcher might add curricular considerations for development of pre-service teachers as well. Third, research using border crossing's anthropological, humanistic framework, grounded in the science classroom of teachers and students, "offers new avenues of inquiry" (Aikenhead, 2006, p. 2) moving beyond the idea of looking only at marginalized populations, for example, Aboriginal students, to a broader global view of teacher development with the idea of potentially improving teaching and learning science. This is consistent with Abell and Lederman (2007) who claim that improving science teaching and learning is the "ultimate purpose of science education research" (p. xiii). As such, border crossing is used in this dissertation as a way to interrogate, question, and discuss the phenomena of university undergraduate students' who intend to pursue teaching careers and who experience science courses.

From the start of this study, the researcher's intention has been to conduct an inquiry that would transcend politics, race, and gender. The realization that culture is a more significant aspect of the study than first expected has been a somewhat startling revelation. The next chapter presents and describes data and findings that have emerged from the study.

Chapter 6: Data and Results

> My work is an attempt to combine close analysis of fine details of behavior and meaning in everyday social interaction with analysis of the wider societal context …within which the face-to-face interaction takes place… an attempt to be empirical without being positivist; to be rigorous and systematic in investigating the slippery phenomena of everyday interaction and its connections, through the medium of subjective meaning, with the wider social world.
>
> Frederick Erickson (1986), p. 120

This study explores university BA students' a) perspectives, being non-science majors, on learning science; b) conceptions of nature of science, and; c) expectations of how experience in a university elective science course might apply to their future career as elementary teachers. The inquiry began by seeking certain forms to represent participants' experiences, such as written thoughts (text), spoken thoughts (interviews), or creative thoughts (artwork). Giorgi refers to such forms as *physiognomic expressions*, the most concrete form of expression, that represent "the actions of the other, the emotional and non verbal communications, the particularities of the situation in which the other finds him or herself as well as the emotional tone of the proximate and remote past and future" (2005, p. 80). Following the generation of data, a 6-step analytical process was implemented to analyze, make sense of, and present the data.

This process involved the following analytical aspects: (a) collection of metaphoric visuals; (b) construction of four individual narrative vignettes; (c) identification of 279 Meaning Units (MUs) which were subsequently rendered as 279 Transformed Meaning Units (TMUs) in discipline-specific language; (d) reduction of 279 Transformed Meaning Units to 48 categories of description; (e) identification of Situated Structures (3 broad and 18 specific) by drawing on the 48 categories of description; and (f) rendering of the collective data analysis in terms of the Border Crossing perspective. Readers may note that Giorgi's phenomenological explication steps (see Model #3, Chapter 4, section 4.3 D) are embedded within the 6-step process. The final section of the chapter presents five key claims about future teacher's experiences.

6.1 DATA COLLECTION

Participants were selected from a large (N=203), program-wide survey that was conducted to assess Bachelor of Arts (BA) students' views about science. At the end of the survey, the students who were on career paths to Bachelor of Education (BEd) programs were invited to participate in an in-depth study that is the focus of this dissertation. During the brief introductory talk about the survey, participants were invited to consider participating in the in-depth study. With respect to this dissertation, the survey's only function was to serve as a relatively efficient means of communicating a *call for volunteers* within the student body. Survey responses were not selection criteria for potential participants.

Thirty-two students responded to the invitation and were contacted about the in-depth study and invited to attend an information session held outside of class time. Those who attended the information session received an outline of the in-depth study, including background, purpose, and general expectations, time commitment involved, and compensation. Students who were still interested were invited to complete a Questionnaire

(Appendix 1) that collected preliminary biographical and academic background information. Responses to the questionnaire elicited information about students' background in school science and a brief, early view of their interest and beliefs about science.

Based on these responses, a pool of four prospective participants was selected, with the aim of creating an intentional and selective sample of the BA student population (who are on career paths to becoming elementary teachers) that represented variations in age, culture, learning ability, interest in scientific topics, and beliefs about science. The study followed these participants through two science courses (six credits in total) over two 12-week semesters (one academic year), which is the typical requirement for science electives in most BA programs in Canada. The students who volunteered to participate in this study are not referred to as 'subjects' but rather as 'participants' with individual pseudonyms[24]. Objectifications are made about the teaching profession (as a career), the science course, the university, participants' beliefs, or the language participants used during the interview or in their journals.

The *data corpus* is comprised of rich descriptions of phenomena *as lived* by the science students, generated from hand-written personal journal entries in which students were asked to record their experiences, and transcribed (and digitized) text from three extended, individual, unstructured, post-instruction phenomenological interviews. Timing of the interviews were arranged to coincide with key points of the year, specifically, the end of semester 1, mid-point of semester 2, and end of semester 2, when students typically are able to take a cognitive break from their studies, freeing up the time and energy to focus

[24] Refer to Ethical Considerations, Chapter 4, section 4.6.

and think clearly about their experience in the course. In this BA program, the mid –point of Semester 2 is Reading Week (mid February) and the end of semester points were after all final exams had been written (December for semester 1 and April for semester 2).

Drawing on Giorgi's model of phenomenology as method, the participants were asked about what they experienced in their science classes, "whether in their own actions or in another's" (Giorgi, 1985, p. 138). The interview questions, activities, and prompts for journals (see Appendices B and C) were crafted to inquire about particular situations or events that took place during the two semesters of the science courses, paying close attention to Giorgi's idea of looking at the *whole meaning* of an experience[25] as an experiencer understands it to be. During the interview, I did not enact epoché because I could hardly "go back to the things themselves" unless these "things" (as aspects of the experience) emerged unimpeded, unfiltered, untransformed (by the researcher) and described by the experiencer.

6.2 DATA ANALYSIS

One unique aspect of phenomenology requires attention before proceeding with this section. It is not unusual for phenomenological researchers to replace the phrase *data analysis* with *data explication* because "the term [analysis] usually means a 'breaking into parts' and therefore often means a loss of the whole phenomenon…[whereas 'explication' implies an]…investigation of the constituents of a phenomenon while keeping the context of the whole" (Hycner, 1999, p. 161 cited by Groenwald, 2004, p. 17).

[25] See Chapter 4, section 4.2, Model #3:Giorgi, Step 2 for further elaboration.

Explication for this study involved collecting descriptions of participants' experiences, familiarizing myself with their descriptions, deriving Meaning Units (MU), and transforming the MU into the language of science education research. Transformed Meaning Units (TMU) were then used to synthesize Structures that led to claims about students' experiences as future teachers in undergraduate science courses.

During explication, close attention was paid to when and how to invoke (or not invoke) epoché or bracketing, at least to the best of my ability at this time[26], to ensure that I suspended my views, prejudices, and preconceptions about science, science education, and what the experience *might be like* for the participants. Because data explication is a spontaneous and pre-reflective activity involving simple descriptions of experiences "as they present themselves and precisely as meanings for us without taking the further step of stating that they are what they present themselves to be, or that they are what they mean to us" (Giorgi, 1985, p.43), my conscious attention to epoché ensured that my "theoretical prejudices in terms of analytic or explanatory categories do not enter [my] initial descriptions" (Giorgi, 1985, p. 43) as far as is reasonably possible. The next section is a step-by-step guide through the phenomenological explication process.

A) Explication: Familiarization

Guided by Giorgi's (2006) perspective on phenomenology, I acquired a sense of the data as a whole by reading through the descriptions provided by participants (in the interview transcripts and journal entries) in their entirety, several times. In this way, I

[26] See Kierkegaard and truth in Chapter 4.

became more familiar with the language participants used to communicate their experiences and was able to craft concrete descriptions of each participant's experiences in the science course as individual, narrative vignettes. These profiles are presented as *stories* in the next sub-section. As much as possible, I did not interrogate or infer anything during this phase as a whole, but simply established familiarity with the work in preparation for the next step.

i) Metaphoric Visuals as a Representational Form

Each participant's profile is accompanied by a metaphoric image that is taken from the natural world. This section outlines a detailed rationale and explanation for including these images with the narrative vignettes (next section) as a means to acquaint readers with the unique academic and personal backgrounds of the *experiencers*. As such, the profiles are the point of entry to the explication process. Confidentiality is achieved by using a pseudonym for each individual[27]. Each profile is accompanied by a metaphoric image taken from the natural world, but before presenting the profiles, I provide a detailed rationale and explanation for using metaphors in this stage of the study.

The metaphoric visuals were generated by the researcher, not by the participants themselves, only after spending a great deal of time with, and moving through, various stages of the explication process. One reason for generating the metaphors at this point in the study was to facilitate the readers' experience with the data. Several other reasons are explained below.

[27] See Chapter 4, section 4.6, Ethical Considerations for more information about maintaining confidentiality

In their book about science as a creative pursuit, David Bohm and David Peat (2006) discuss scientific revolutions, bringing to the fore the idea of using metaphors to connect and to clarify very different things. Like poets and playwrights, including Shakespeare, who often used metaphor to connect very different ideas, as an example: "All the world's a stage, And all the men and women on it merely players." (cited by Bohm & Peat, 2006, p. 32), scientists often use metaphor to connect ideas about the natural world. One famous example is Newton's unification of the Heavens and the Earth through the theory of gravity. In his early 20's at the family farm in rural England, Newton watched an apple fall toward the Earth. His moment of inspiration came from seeing the moon in the background, apparently stimulating him to theorize that the moon is attracted to the Earth in the same way that the apple is attracted to the Earth. Bohm states Newton's insight could be "expressed in metaphoric form as "The moon is an apple", which is then extended to "The moon is an earth" (2006 p. 33). The moon and the apple seem to be two completely different things, but when connected by the word 'is', a higher meaning of the metaphor emerges.

Clearly, the world is not Shakespeare's stage and the moon is not Newton's apple, yet Bohm tells us that when two ideas, concepts, or objects are simultaneously equated and negated, the result is:

> a kind of tension or vibration in the mind, a high state of energy in which creative perception of the meaning of the metaphor takes place nonverbally. In some cases this heightened perception is the whole reason for using the metaphor in the first place. (Bohm & Peat, 2006, p. 33).

The intention for using the four metaphorical images shown in Figure 5.1 is for the reader to experience a *heightened perception* about the participants: the sprouting acorn *is* Terry;

the nautilus shell *is* Kelly; the passionflower vine *is* Chris; and, the feather *is* Sammy. The image *is not* the participant, but rather the "simultaneous equating and negating" (Bohm, 2006, p. 33) of metaphoric image and participant, intending to charge the reader with energy to understand students' experiences in a science classroom.

Figure 6.1: Representations of Participants' Profiles

A) Acorn

B) Nautilus Shell

C) Passionflower

D) Feather

Borrowing from Bohm's ideas, by using metaphors one's mind "enters a very perceptive state of great energy and passion….such a perception of the basic similarity of two very different things must further unfold in detail and lead to a kind of analogy which becomes even more literal" (Bohm & Peat, 2006, p. 61). The four short biographical vignettes presented in the next section trigger this unfolding about each of the participants and set the stage for presenting deeper understanding of their experiences.

ii) Four Stories

Profiles of the participants are presented as narrative, illustrative vignettes. Collectively, the stories offer readers some insight into the diversity of ages and life experiences of the participants, the amount and richness of their testimonies, and a sense of the participant's ability and willingness to reflect on their experiences and to share those reflections with a researcher. As a result, the length, depth, and breadth of the stories are *unique to the experiencer*.

My position as the author/researcher is to remain true to the phenomenological framework and not represent anything more than an account of each individual's experience. Because cultural issues emerge from Sammy's story, I borrow a tradition enacted by other authors from Aboriginal (Cajete, 1999) and non-Aboriginal (Aikenhead, 1996) backgrounds, when I state that my background as a Euro-Canadian, non-Aboriginal person disqualifies me from presenting Sammy's story in a way that is any different from the other participants. In this way, all four participants are labeled and treated in the same way, avoiding any unintentional distinctions related to age, ability, or culture.

TERRY'S STORY

The acorn metaphor is used to represent Terry because an acorn is a seed that has the potential to become an oak tree. Similarly, Terry has the potential to become a great teacher. Just as new root system, stems and primary leaves emerge from the acorn, Terry's awareness of her new interest and abilities in science emerges from her experiences in the BA science courses. If the acorn lands in a prime location that provides nutrients from the soil, water from the sky, and energy from the sun, then in time, the acorn will grow and develop into a strong and healthy oak tree. If the acorn lands in a barren location lacking in nutrients and energy, then it will simply decay and decompose. Much like the acorn, Terry has the potential to become an effective elementary science teacher when optimum conditions for academic and professional growth are available. Such conditions might include a positive learning environment, such as excellent science curricula, dynamic classroom settings, and adequate technological and pedagogic learning resources. The developing roots and new leaves emerging from the acorn represent Terry's emerging awareness of her new and surprising interest in science topics, and just like the acorn, her growth could easily wither and decay if conditions are not optimum.

After graduating from high school, Terry pursued her dream of becoming a teacher and proceeded directly to university. Science was not a major focus of her high school studies, yet she did enjoy her Grade 9 and 10 academic stream science courses and a Grade 12 general stream physics course[28]. Terry's university program requires her to take first year science elective courses alongside courses in the social sciences and humanities. Even though she arrives at university with no previous teaching experience, she believes that elementary teachers must know something about science before they could teach science. This means that Terry sees a close connection between her science courses and her future career plans. Consequently, she finds science at university to be more interesting than science in high school. As a first year student fresh out of high school, Terry faces some issues making the transition from high school to university. For Terry, the process of learning is involves developing skills, such as learning how to study or how to work with others rather than cognition. For example, in her journal she writes "at start of 2nd course, I am going to improve my study habits…to get a better mark this term (69 - Journal). Like many first year students, Terry does not yet understand that scholarly work at university requires a different type of thinking than she was used at high school. In fact, most of Terry's learning was on the surface of her awareness. When asked about how her own learning was impacted by her experiences in the science course, her responses were limited to class content and skill development, rather than metacognition. Terry feels that science knowledge resides with her professor and banks on her familiarity with the professor to be successful

[28] In Ontario, the academic stream prepares students for studying science at university and the general stream prepares students for college studies.

on exams and assignments. She feels she will be more successful after she determines what the professor expects her to know about science, and how the s/he would craft an exam and evaluate her answers.

Terry's earliest descriptions about her experiences with university science are shy, naïve, and superficial, but nonetheless, highly meaningful to her. This could be due to her younger-than-average age or the process of transitioning from high school to university. She describes science as being about discovery and learning (Journal, p. 12) and equates fun with learning in almost all of the descriptions about her experiences in university science classes. For Terry, learning science is about being playful, engaging, and creative and in doing so, science becomes *real:* "Having fun is very important or else the student will become uninterested in the lesson" (Journal, p. 2).

In her science courses, Terry really enjoys classes involving hands-on activities, interactive demonstrations, or videos and she plans to teach science to her future students this same way. Her favourite way to describe these activities is as fun and playful events, as shown in this quote: *"[science class] made me realize how much fun science can be….you think of physics and chemistry…[and] math… some students might find that boring, but…if you just keep it fun ...and interesting, I think that makes a difference…a clearer understanding of the topic*" (Interview, p. 12). In Terry's view, kinesthetic and experiential activities are much better than reading textbooks because of the social aspects. When working with others, Terry can exchange ideas and opinions; whereas, reading feels lonely and isolating:

> When we all work together it's going to make each others' ideas work together….and own creativity…made it more fun….because if you did it on your own, you may not think as creatively as another person. Then you see somebody else's idea and you think oh my gosh, that would work to much better (Interview, p. 20).

She needs to experience science in a way that she calls *seeing science in action* and she often says that learning science is best when a teacher uses hands-on activities rather than reading from a textbook. When Terry tried to learn equations for physics she reverted back to the textbook to get to the detail that she thinks is needed to resolve her admitted weakness, *"math is not my strong subject*" (Interview, p. 19). She returns to the textbook even though she knows reading is not effective for her "*I just gotta…read them [equations] over and over and make sure…I understand them…before I go to answer the [exam] question or I'll miss the detail"* (Interview, p. 19). For Terry, the textbook is the ultimate source of knowledge, but not necessarily the source of her own learning. As time passes and her confidence as a university student increases, her testimony remains focused on skill development and class content.

Terry's conceptions about the nature of science is that **science as a body of finite, hard, boring knowledge** with rules to be memorized. She believes that because this body of knowledge is hard to access, a student could only make sense of it by getting buried in the details. The connections between science at school and her everyday world are limited to her future work as a teacher. She does not focus on learning the science behind the activities that she loves to do in the classroom.

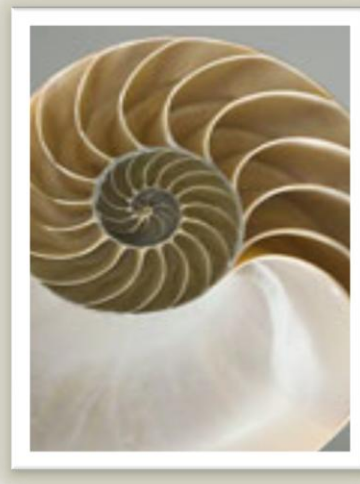
Terry clearly and definitely sees the connections between the science activities in her university courses and her future work as a teacher. She has a clear, highly confident vision of herself applying activities from her university science courses to her future elementary classroom.

> [Class] activities…gave me ideas of how we would approach that chapter for that grade….to make it appropriate….and make a fun activity that the kids would like to do. Make learning fun. Not just books and.. read[ing]… and trying to memorize everything at that age…We got some good lesson plans…using them in class…we kind of feel..how they are done (Interview, p. 42).

Her focus is on engaging students with science that is active and fun, but her approach leaves one wondering how she will learn the science behind the fun.

Returning to the metaphor of the acorn, with Terry's renewed enthusiasm for science, she has the potential to become a highly effective elementary science teacher. The question is how she will deepen her level of learning about science and how will she expand her conceptions about nature of science. What growing conditions (curricula; technology, pedagogy, classroom environment) will Terry and others like her need for the academic growth that will be essential to her career plan? The end of Terry's story in this study is really about the beginning of her story as a teacher. The growth and development of the acorn truly *is* Terry's professional journey.

KELLY'S STORY



A nautilus shell is used to represent Kelly. The cross section of this shell shows a series of logarithmic spirals that grow larger by increasing the size (length and width) without changing proportions. This relationship between ratio and proportion was explored by Plato [247-347 BC] in *The Republic* and is based on the Fibonacci sequence of numbers (Olsen, 1996). This predictable, mathematically-based, series of arcs is prevalent in a variety of natural phenomena, including the following: the arrangement of the nucleotide building blocks of DNA, the lattice networks of certain crystals, the scales of pinecones, the arrangement of seeds in a sunflower, the angles of a starfish, certain architecture and artworks, and even stock market patterns. The shell represents Kelly's strength in science, resilience in her career plan, and predictable views about school science and the scientific enterprise. Much like Kelly's thoughts about science, the shell has a polished exterior that reflects the beauty of nature.

Some might say that Kelly is an *atypical* non-science major student because she absolutely loves science. She arrived at university with a strong science background that she credits to positive experiences in her high school, academic stream science classes that prepare graduates for BSc programs and was very excited when she realized the depth of her prior knowledge, *" [I was] excited just to see that I knew more than I thought I originally had known about it [topic]"* (Interview, p. 6). She has enjoyed an excellent record of academic success at school in general and at science in particular and carries that success forward into her university studies.

> When I learned about that [science topic] in [high school] science…it was like learning to know the knowledge about it. But when I learnt about it this time [at university] it was learning about it in the big picture..helped me have a better sense of how I would explain it to somebody else (Interview, p. 11).

In addition to her enthusiasm for science, Kelly brings a great deal of experience working with children at her part-time job as an early childhood educator at a local Nursery School. Consequently, Kelly's career plan is highly focused on teaching children in Kindergarten or Grade 1.

Kelly is the type of student that teachers dream of having in their classes: highly motivated, confident, and a high achiever in all of her studies. She demonstrates a mature, professional, approach to learning science:

> One of my favourite things about the university course is that you are learning but you are also talking and discussing [with Prof] and with other people…you learn a lot more that way than when you are in high school…..they put it up on the board and tell you you need to know this and this is what happens (Interview, p. 11).

In her university science courses, she was particularly interested in the learning theory of Constructivism and continues to approach her own learning by building new ideas on an established foundation of knowledge. She could shift from abstract ideas (for example, scientific theory) to concrete, practical aspects (for example, about how things work). Throughout the interviews, Kelly stood out as someone who is really into theories related to pedagogy, and because of her appreciation for the constructivist stance, Kelly is very excited when her prior knowledge is validated. She relies on the professor for this

validation.

Kelly repeatedly and enthusiastically confirms that science becomes more real when her science class involves demonstrations, hands-on activities, and real-life examples:

> I loved the classes that we had where [prof] would ..talk about something and explain it to us and then give us the hands-on aspect and give us a try at it. I find it was important, especially..because we are all going to be educators, just to give us that chance to figure it out on our own so that we…get a better understanding and knowledge of what exactly we are doing, Not just kind of 'OK this is what happens (73 – Interview, p. 42).

At this stage of her learning, Kelly feels that experiential explorations are (for her) the best ways to teach science. This might stem from her belief that SEEING and DOING science makes it REAL; whereas, something like READING seems, in Kelly's experience, to be more of an ABSTRACT conceptualization.

Kelly did face some challenges in her science courses, in particular when class activities involve the interpersonal dynamics of group work. As a result of some bad experiences working with others in the class, she completed the second term project on her own even when it took more work or required a longer timeframe to complete the project. Another challenge for Kelly were the scientific equations needed for her classes about physics: *"This week we worked on the study of motion & Newton's laws….I found this topic very challenging, it was hard to remember the formulas*" (Journal, p. 13), and later*, "it seemed a lot of people were confused by the formulas so we discussed and reviewed these"* (Journal. p. 19). She struggles with understanding how equations represent concepts and develops coping strategies, such as memorization. Sometimes, she was able to reduce or

overcome these fears by relating the problem or question to everyday examples, such as how gear ratios work in a bicycle*, " as a learner I find the hands-on with lecture combination most useful …gives me the skill and theory"* (Journal, p. 22), or the high learning value of ***"****everyday examples brought into the classroom so students can make the connections…they can be successful by using the connections"* (Journal, p. 22).

When considering **Kelly's views about the nature of science (NOS),** it was interesting to see how she views school science and the professional work conducted in the scientific enterprise. In her view, science is an objective, highly ordered set of processes and structures, with laws and theories that are well-defined and unchanging. With this perspective, Kelly is the most polarized of the four participants.

> Science involves gaining knowledge and an understanding of concepts, procedures/methods and stats. To understand the way science works you need to be familiar with the facts. The facts aren't constantly changing like in other disciplines (Journal, p. 24).

She finds science as a subject that is very hard, believing that in order to learn science well, one must have deep dedication. For her, learning physics, especially the equations, requires a lot of reassurance that she is on the *right track*, from the Professor (within whom the knowledge resides).

In her view, scientific topics are studied at school and not part of everyday life and this is much different from her other social science and humanities courses. In the latter, she can just walk into class without any advance preparation and understood right away because the scenarios discussed are part of everyday life; whereas, with science classes she must be diligent about preparing for class ahead of time. This advance preparation

takes a great deal of time compared to her other BA courses.

Kelly's **views about teaching science** mirror her views about learning science and she was able to make several connections between activities in her university science classes and her future work as a teacher. She believes that when teaching children, the class has to be fun, engaging, and interesting for students. In other words, when classes are fun then learning is happening.

> I felt this was a great experience because we worked through it to understand what was happening and then we would apply this into our own classroom. I will definitely keep this activity for when I'm in the classroom and also keep in mind that in order to teach it we must understand it (Journal, p. 16).

Experiential explorations are the ideal ways to teach science, and Kelly plans to teach science using the techniques and strategies that work best for her as a learner.

The end of Kelly's story is very simliar to Terry's because the ending is really just the beginning. The nautilus shell with its progressive Fibonacci spirals *is* Kelly. Her knowledge, skills, and abilities continue to grow and develop as magnificent predictable proportions. At this early point, one can only speculate about what this motivated, high achieving future teacher will one day accomplish with her students.

CHRIS' STORY

The passionflower vine represents Chris' attitude toward science teaching, learning, and life in general. The vine produces masses of spectacular flowers and grows to great lengths by sending out tiny tendrils from the main stem. These tendrils attach and wrap around any structure in their path, providing strength and support to the growing vine. Chris' positive attitude toward life and enthusiastic approach to her work are much like the tendrils and flowers of the passionflower vine. Chris may at first appear to be a delicate and perhaps even fragile passionflower, but her resilience, tenacity, and enthusiasm for living life to its fullest are the metaphoric tendrils that reach out and grab hold of structures that can support her personal aspirations. Just as the passionflowers share their natural beauty with the world around them, Chris' personality and zest for life is evident in the relationships she builds with students, colleagues, family and friends.

Chris is a mature, francophone student with the added responsibilities of a husband and two school aged children. Every morning, she begins a new chapter of her story when she wakes up to greet a new day. As a cancer survivor, she has gained a unique perspective on living each day to the fullest, savoring every moment, and learning the lessons that life presents to her. Because of her life circumstances, Chris has not followed the traditional academic pathway toward a teaching career. It would be unrealistic to present Chris as a *typical* representative of a BA student hoping to begin a BEd program; however, she could represent teachers who bring a wealth of human experience to the classroom.

Chris' post-secondary journey began more than ten years ago when she decided to take a few university courses by correspondence. Eventually, she was able to begin full-time studies in a BA program as a psychology major. The correspondence courses counted as transfer credits and this meant she entered academe as a third year student. Chris took her advanced upper year psychology courses alongside the required first year science electives because her academic background lacked any formal education in science subjects. Despite a heavy workload, her work in the science courses indicate that she has an innate appreciation and deep understanding of the natural world.

In the role of teacher, Chris could easily and spontaneously connect phenomena from the natural world to her work in the elementary science classroom, "I had to create a book…for Grade 2….about earthworms…how they create their homes and why they come out in rain and my son did the pictures." (Interview, p. 5). In her role as science learner, it is noteworthy that Chris often struggles to make similar connections between the natural world and her classroom experiences with physics:

> [The prof] went over chapters …. I previously read the chapters, took notes and still a bit confused. I just wish I can get it…..we did some practice question from the book in small groups. It seems I'm not alone with this uncertainty. We did our best to answer the questions but again very unsure. I left class feeling confused and my confidence level has dropped a few notches (Journal, pgs. 15 &16).

When Chris talks about her experiences as an Elementary and High school science student, she admits that her **level of confidence**

about her ability to be a *good science student* could be characterized as low. At university, this under-confidence remains evident when she continues to question her ability to learn science:*" When it is subject matter that goes beyond my control and that I have difficulties with, I tend to lose confidence"* (Interview, p. 54) and *"the minute you lose control of whatever, is when you have really bad anxiety"* (Interview, p. 55). Chris questions if this low confidence might be linked to her recent diagnosis of **a learning disability**.

Some might regard this diagnosis in a negative light, seeing it as a restriction or barrier; in other words, something that one cannot do. For Chris, this was not the case and with the diagnosis in place, she now had an explanation of why certain aspects of school had always seemed difficult for her.

> It is so important what people are being told in school when you are young because you do carry it with you when you don't think you are smart enough to do university because, you know, you would be better off doing this…I am really showing them up now! (Interview, p. 44).

She always knew she was an intelligent person, even though her marks did not always indicate this intelligence. In fact, the diagnosis explained many of her previously unanswered questions about past experiences at school, but sometimes leaves her in emotional turmoil:

> Like the plates slowly moving in our Earth's crust impacting our living environments, my own personal "plates" are shifting and impacting my future choices and decisions. Everyone needs to erupt like a volcano to release pressure and to move and disrupt our day-to-day comfortable lives like an earthquake in order to alter our way of thinking and doing things
> (Journal, p. 5).

Her positive and optimistic approach to her academic career involved developing alternate strategies for learning science, utilizing services for students, and maximizing her potential to for academic success. This meant that Chris often did things a bit differently than other students in her class. There were many weeks in the semester when Chris attended a second (repeat) science class to catch parts of that week's lesson that were unclear or to reinforce elements of the lesson. Also, as a psychology major, she finally understood why she had to expend much more energy to learn (what she saw as abstract concepts of) science than other social science and humanities subjects. After gaining these insights about her disability and finding strategies to help her learn science, her confidence as a learner seemed to improve. At university, Chris finds science lectures to be just plain scary, where too much information is delivered far too fast

> I wish I had more time to develop these units so I could fully understand them. Probably why kids struggle with science. We try and fast track through the information. Too much info is no good. They won't learn anything…just get frustrated and not want to do science! (Journal, p. 21).

She feels there is not enough time to process the information before new facts are introduced and for this reason she learns much better when the class experience uses an inquiry-based approach with hands-on activities in which students can progress at their own pace. Students like Chris, who have learning disabilities, face significant challenges with information overload (reference) yet know they can be successful at university when they learn how to develop and utilize effective coping and learning strategies: "*What a great parallel – my daughter who has a learning disability is all over this stuff. Loving the hands on. We are helping each other*" (Journal, p. 40).

In the science electives. Chris found it particularly difficult to decipher, organize, and prioritize scientific content and also to connect the scientific language as text with a science class activity or learning process:

> I'm stressing cause I just won't be able to perform at an excellent level. I'll have to look for a tutor " and one week later she writes…."Well, I got my assignments back…I got my full 6 marks…this uncertainty towards the subject matter [physics]still freaks me out. I just can't seem to wrap my head around it. I am wondering if I'm just making it too complicated for nothing? (Journal, p. 19).

One may wonder if this difficulty is limited to students with learning disabilities or if students without learning disabilities have similar experiences.

As a future teacher, Chris struggles with the abstract concepts of NOS, particularly areas that she sees related to physics content: *"Science is complex/overwhelming(1 - Journal)….it shapes our world, environment, our lives…bodies and cells … this pen, this paper…Everything is based on a "science"…we breathe it, we see it, we even eat it"* (Journal, p. 42) and a while later she writes: ***"****Science is broad …We incorporate science into our lives…Other disciplines are interesting but can't be touched, manipulated or changed. Science is always evolving – keeping us on our toes….It has the power to deceive, stump, control, and reward us*" (Journal, p. 42).

As a result of her struggle with these abstract nature of her views, Chris spends hours on end trying to sort out in her mind, how physics concepts such as gravity, motion, energy, connect with her professional work and her everyday life at home with her family.

During the interviews, Chris often spoke about how she found university level science to be much more engaging because she was clearly **able to understand how her work in the university classroom was linked to her career aspirations**. She states that it is very easy to find the connections between science and other subjects, often quite

spontaneous and enthusiastic way: *"When preparing my [elementary] science classes, how can I incorporate the material in other subjects and how can the other subjects be used [in science]?"* (Journal, p. 50). This might be due to that fact that Chris has a great deal of prior teaching experience and also because she is an upper year undergraduate majoring in psychology.

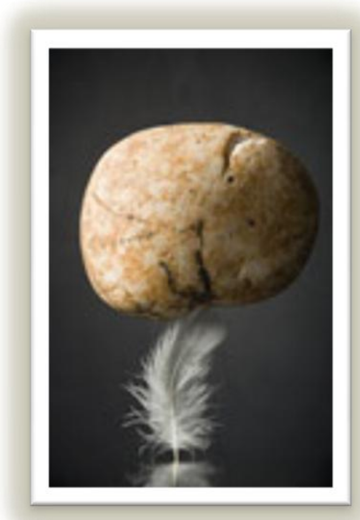
> You can't just teach science between 2:30 and 3:15. You have to be willing to… be flexible… let's say it's a rainy day and there are dew worms … in the yard … and you're doing…[a] lesson in Grade 2….you can get them [students] dressed up and you go and take a look at these worms. I think it's really, flexibility is very, very important and being able to incorporate science in other subjects. So you know you come back in from that class going to look at the worms outside, then you say 'OK let's take our your journals now because we are doing French and every morning you are supposed to do your journal…so now, let's talk about what just happened outside'. So you are doing science but you have incorporated your French and your grammar. …I think it's so important to be able to bring in science throughout the year and not just in that timeframe (Interview, pgs. 60 & 61).

In other words, for Chris, teaching is already very *real*. She understands first-hand that in order for students to be engaged and make connections between science and everyday life, a teacher must ask questions, use demo/visuals and hands-on activities. She also understands and utilizes the principles of constructivism indicating that it is important for teachers to recognize and correct their own mis/conceptions before they begin to teach in order to NOT pass on these misconceptions to their students.

At the time of writing this dissertation, I am happy to know that Chris is living her dream. She is in the final phase of completing the francophone BEd program and teaching at an Ontario elementary school. Living her passion, Chris tells me that she has enjoyed the praises of the Principal and fellow teachers who already consider her to be a credit to their school.

Chris' story is about courage, tenacity, and dedication in the face of a disability and a life-threatening disease. As a mature learner, she juggles the responsibilities of student, mother, and wife and overcomes hurdles that might have crippled others in order to live her dream of becoming a francophone teacher. The passion she found for teaching science to elementary children is noteworthy and profound. It would be unfortunate indeed to underestimate the importance of how Chris' experiences in the university science classroom have affected her confidence, ability, and effectiveness as a learner and teacher of science.

SAMMY'S STORY

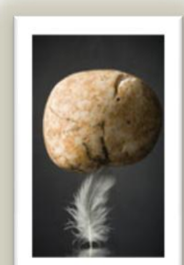


The metaphor chosen to represent Sammy is a stone balancing on a feather, with the intention of transcending the obvious connection with First Nations culture. If the feather represents Sammy's hopes and dreams about one day becoming a teacher of First Nations children, then the rock represents the opposing cultural, social, and curricular forces that operate at several levels. First, at the university level, the science curriculum for non-science majors in BA and BEd programs is what Sammy experiences as a *learner*. Second, at the elementary level, the provincially-established science and technology curriculum is what Sammy would experience as an *elementary teacher*. Third, embedded throughout all of Sammy's experience are First Nations Peoples' cultural and historical, beliefs, norms, and related complex social issues.

Using a scientific explanation, the rock is held above the feather by an equal and opposite force to the gravitational force acting on the rock. If the force being exerted by the feather is not maintained, or if additional forces (to gravity) act on the rock, then the rock could potentially crush the feather. This metaphor applies to Sammy's plan to become a teacher. If Sammy is the feather, then her courage and determination to reach her goals counter-balance the sociocultural and curricular forces of the Western culture in general and the Western sub-culture of science in particular. If her initiative and drive were to wane or weaken, or if the opposing forces of culture society, opportunity, power, curricula were to increase, then her dream of becoming a teacher might be crushed.

Sammy is a mature, married student with a First Nations People's background whose school-aged son loves science and provides her with the inspiration and motivation to learn more about science. Like many mature students, high school science is many years in the past alongside more deeply buried memories of horrible and often humiliating experiences.

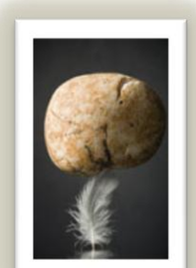
Her story opens with early experiences at school in rural Ontario. Even though she did not suffer the oppression of a residential school, life at school was not a positive experience and she *"never passed a science course in [her] life…elementary or secondary*" (Journal, p.1]. Later, Sammy dropped out of High school, "*[In] grade 11….I dropped out of school and ran away from home and made my life.* (Interview, p. 43) and as time passed, she realized that she wanted more out of life. As a young adult with no attachments to partner or children, she made a decision to enroll in a community college program to better herself, because *"it beats working in a factory and that kind of thing, right?*



(Interview, p. 44*).* Before entering the college's Office Administration program, she was required to earn the equivalent of Grade 12 diploma in an upgrading program. Typically, this takes about 2 years for most students to complete, but with her great determination, Sammy finished the upgrade courses in less than half the time with outstanding academic performance. She entered the two-year Office Admin program well ahead of her anticipated schedule and worked part-time as a tutor for college students. In retrospect, this was a bright omen for her future success as a university student.

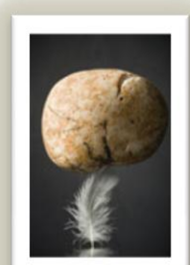
Sammy found her teacher's heart when she worked at a local high school with native teens as an Educational Assistant. Working alongside two mentors who would eventually have a profound impact on her life, she saw how learning science could be fun rather than the horrific experience she had as a student where learning science was like being tortured (Interview, p. 72). Sammy blossomed under the shining light of her mentors and they encouraged her to follow her dream of becoming a teacher , when the time was right. During this phase of her life with a husband and baby, Sammy settled into the full-time duties of mother and wife with a focus on raising her *"late-in-life miracle baby"* (Journal, p.1).

The years passed and she often thought about her dream of being a teacher. She knew that going to university on a full-time basis would likely create conflict at home because her attention would shift away from the roles of mother, wife, cook, housecleaner, and caregiver that had been central to the dynamic of the family. Her



decision was highly criticized: "*Oh you think you are so smart – grumble, grumble – so I [had to] live with a lot of conflict*" (Interview, p. 31) and her partner's attitude left her feeling alone and un-supported. In time, Sammy learned how to navigate the tension and conflict at home and eventually her partner agreed, with some reluctance, to take on some of the household duties. Because time at home was focused on her son and related family matters, Sammy knew she would have to maximize her time on campus, particularly in the classroom. The limited time factor would become a very important aspect of her learning experience.

Despite the tension at home and the significant financial burden of attending university, Sammy was determined to better herself for the sake of her son's future. When she made the decision to attend university, she was granted transfer credits for her college diploma and entered as a second year BA psychology major with a requirement to take first year science electives. Adding science electives might overwhelm an already ambitious course-load, yet Sammy's academic success, including making the Dean's List, provide evidence of this non-science major's scholarly promise. Despite her past experiences with school science, she began to nurture her life-long, but suppressed, interest in science and even though she has a great deal of professional experience working as a aide in a specialized program with high school students, she remains unsure about whether she can teach science at the elementary level. This low level of confidence about teaching science translates into a great uncertainty about her career plans.

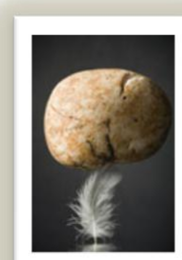


Beginning a BA program was a feat that involved facing complex challenges that are not uncommon to many mature students:

> When I am sitting in science class and I sit beside some of the younger ones, they can just go yip, yip, yip. Then I think, oh my God, I wish I had your [young]brain…there are lots of young people [who] haven't been that far removed [from science classes] so they can grasp it and they can remember it and they can talk [to the professor] about it. But then there are a few of us who are older in there that are going 'Oh my God, do you remember this crap? (Interview, p. 12).

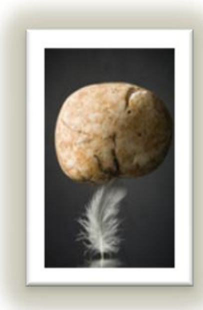
Even though these feelings of inadequacy are not uncommon for mature students starting university, for Sammy other issues emerged which are a function of First Nations people's culture, including feeling isolated and alone, having low confidence about her ability to be successful in her studies, and facing racism from people she perceives as being in power (faculty and administrators). Sammy is actually crossing <u>two</u> borders; one from First Nations People's culture to Western culture AND a second subsequent crossing into school science.

Sammy often felt like an outsider in her science classroom. Her feelings about being "native" were at the surface of her experience, for example, *"I am so conscious of being Native here" (interview, p. 15)*. She often speaks about this feeling of being the *only one* thinking this way or that way (interview p. 15, 27, 31, 38, 69) and even feels people make exceptions for her because of her First Nations background: *"because I am native, people are nicer to me*" (interview, p. 15) or *"did I really earn that [mark] or did you feel sorry for me [a] poor native woman*?" (Interview, p. 17). Sammy truly believes that she gets through the program easier than other students because of consideration of her culture, rather than her ability and performance as a student. This feeds her **low confidence about her ability to be a learner of science** and a future teacher of science. She feels people see her as



"dumber than a stick" (interview, p. 21) because she is struggling to pronounce scientific words and phrases and she experiences self-doubts about her own capacity as a learner in the science classroom, *"I have so many doubts about my ability"* (Interview, p. 47). Sammy enacts Fatima's Rules[29]. Even though she scores highly on tests, exams, and assignments, for example earning a grade of 85 in the first science course (Interview, p. 6), she claims to know very little science: "*science is making me go OOOOOH, I don't learn. It's making me doubt my intelligence because of the fact that there is so much there to remember*" (Interview, p. 20).

Sammy's low level of scholarly confidence is reflected in her **thoughts about being a teacher of science**. At the beginning of the study, Sammy was emphatic about having no ability to teach science whatsoever: *"I don't feel that I could…spew it off. I couldn't teach anything"* (Interview, p.7) and "*I am thinking, maybe I am not cut out to be a science teacher because I can't do that"* (Interview, p. 21). Sammy's words suggest science is something one learns by rote (as a student) and then reel off in the classroom (as a teacher) which on a higher level, speaks to her views about NOS as a fixed, objective body of knowledge that resides with experts. As she progressed through her science courses, Sammy's confidence improved, *"I'm good at this kind of thing [assignment] and I know I should be able to get a 10 [out of 10] out of it*" (Interview, p. 33*)* and "*it would be pretty awesome to be a science teacher"* (Interview, p. 40), but then she would quickly revert to the previous low confidence, stating:



[29] Memorizing enough class content to earn grades but not acquiring a deep understanding of science

> I couldn't do that [teach science] because my brain just couldn't absorb all the stuff that you have to know for science. But you know, if I was asked to teach a certain thing, I don't think I would really shy away now….I could just briefly skim it [the topic] until the next day until the real science teacher takes over (Interview, p. 40).

After successfully completing her two science courses, Sammy reflects on her dream of being a teacher. Even though she would be forced to teach science, her confidence reached a more stable point when focused on helping kids:

> I have the ability to be a good role model to these kids and I've learned that….it is my responsibility to get them interested in [science]…because that's important to life on Earth…so maybe its my job to grab science and give it a shake and say OK I can try to do this but maybe only at a lower level (Interview, p. 73).

At university, Sammy faced several instances of **racism from people in positions of power** which had a profound impact on her self-esteem, identity as a First Nations person, and career plans for teaching. Sammy recalls remarks from a professor about her career plans:

> Before he even knew who I was, my marks or anything, said 'You know if you are thinking about going to teacher's college, you might consider a smaller school because they're not going to expect so much and you gotta remember that there are back doors for Natives also (Interview, p. 15).

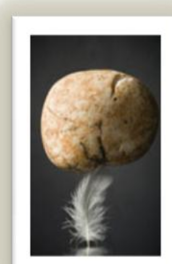
This left Sammy wondering if the person would say these sorts of things to students who were not Native (Interview, p. 15). Another professor reviewed a model Sammy had built and submitted for a major course project. Creativity and individualization of the work was encouraged as part of the assignment, so Sammy had adorned her model with a native symbol because she *"wanted [her] voice to be on [it] without anyone knowing who made [it]* (Interview, p. 39). She recalls comments from the professor who at first offered praise for the excellence of her work but then added, "*leave it to you the warrior woman"* (Interview, p. 38*)* and she was *"offended by this comment"* (Journal, p. 17) asking if the unspoken meaning

behind the comment was that *“because I’m Native, I’m violent and hard to get along with*?” (Journal, p. 17) and later finding out that the Professor erroneously assumed that she was from the north and one of those people who were part of “*the sad state of the [First Nations] people from northern Ontario”* (Journal, p. 17). Sammy corrected this by informing the professor that she was raised in a small town, not on a reservation, with a father who worked every day, a stay-at-home Mom in a family setting with no addiction problems. She also highlighted the ingrained family values about the importance of education and good moral character.

Under such circumstances, how could one help but wonder why Sammy feels alone, isolated, and often questioning her scholarly ability? Do these teachers, in their positions of power over students, appreciate the fact that students hold cultural values that might involve crossing borders to enter the culture of another discipline, such as science? Aikenhead (2006) states:

> If teachers themselves formed new professional identities to embrace teaching science as cultural transmission sensitive to the dangers of cultural assimilation (colonization), then the educational soundness of their work would be more defensible (p. 127).

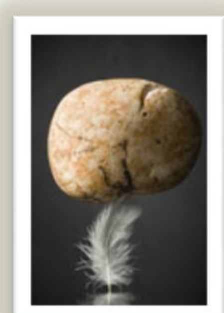
Assuming these professors are well intentioned and would not consider themselves to be racist, would they rise to the considerable challenge of forming new professional identities and embrace a science curriculum, such as Vision III that renegotiates the culture of school science? Only time will tell. Until that time, students like Sammy will likely continue to feel like misunderstood outsiders.



In her studies, Sammy found that the **crossing borders** between Aboriginal culture and the Western sub-culture of school science to be a **problematic and hazardous process.** Consequently, at many times throughout the study, Sammy refers to a Native perspective on science and recognizes that *"science is important, even if I don't like it"* (Interview, p. 24), highlighting the **need for a pluralist view on science curriculum,** such as Aikenhead's Vision III (see Chapter 1) in university science courses for non-science majors on career paths to becoming elementary teachers.

Many of Sammy's **conceptions about NOS** are similar to the other participants, who also see science as precise, concrete, unchanging, and non-creative. Cultural aspects add unique colouring to her views where the Western, hegemonic, colonizing, oppression of First Nations culture is held clearly and distinctly from her Aboriginal lifeworld. Sammy's view carries over to her views about teaching science using what she refers to as *native ways of knowing science* versus teaching *science for the white kids*. She feels confident about the *familiar* former and under-confident about the *foreign* latter in her descriptions about a science activity, *"That's for Native kids. If I was teaching at an all white school and all white kids, I would probably do [other activities]"* (Interview, p. 55).

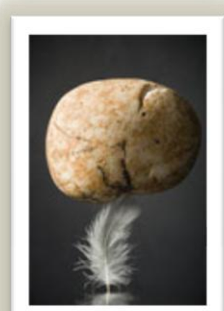
Finally, Sammy's connection between school science and her lifeworld is even more pronounced. She claims that l**earning happens when everyday knowledge is integrated with scientific knowledge in a practical <u>and</u> authentic context.** In-class demonstrations and hands-on activities are better than listening to boring lectures, but to make sense to her, knowledge of science comes from a context that makes it real for learners, for example, *"telling stories about the patient" (Interview, p. 19)* or *"the Native kids would…go out trapping muskrats…learn about where they live, how they*



hibernate" (Interview, p. 25) or "*fire-starting…using different types o f rocks….[to] learn about textures of the rocks…what was sedimentary, what was metamorphic…and explain all that stuff [science] at the same time."* (Interview, p. 25).

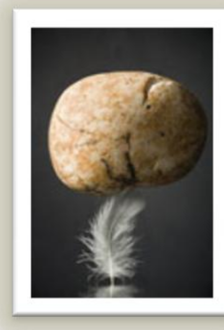
During her struggles as a science learner, and during some of her toughest times, Sammy found her son to be her greatest motivator. He loves science and she feels a strong need to connect with him during their talks about science: "*He would say 'Mommy what did you learn in science?'…that was a really good thing for me…to teach him what I kind of learned and it reinforced me because he was interested* (Interview, p. 8). Now, at the end of her undergraduate experience, Sammy is determined to learn more about science because her son has asked her to promise to "*do science experiments over his summer holidays…..[and] have science parties in [the] backyard*"(Journal p.20) .

Post study, I happened to meet Sammy in the hallway of our department. She was oozing excitement and quickly told me that she had been accepted into a highly competitive BEd program. We both smiled and reminisced about the times she doubted her ability to become a teacher. It seemed that her experiences in the BA program might have helped her develop the confidence and enthusiasm needed to take this next step toward becoming an elementary teacher in a native community. I continue to smile, remembering her primary goal of *"trying to reverse the negativeness that goes with being a Native person"* (Interview, p. 51). She continues to struggle with the thought of seeing herself teaching science, but she does see herself as someone who can and will make a difference in the lives of students. Her future students might never imagine their good fortune of having Sammy as their



teacher….but, it has not always been that way, and might never have been that way because of the struggles Sammy had faced in her life. Her story is one of courage, perseverance, self-discovery, and absolute devotion to her young son who loves science. True to the metaphor of the rock and the feather, many forces weighed heavily upon her shoulders, but she has overcome them one by one to become the emerging teacher she is today.

The end of Sammy's story, as one participant in this study, is really the beginning of a new story about her life as a teacher. But for her dedication and tenacity, we might have lost such a gift to teaching as this woman, and the children she will teach would have lost something of their own as well.



In summary, the previous section presented the collection of metaphoric visuals and construction of four individual narrative vignettes. As the first two stages of the analytical process, readers have been introduced to the unique academic and personal backgrounds of each of the four *experiencers* who participated in the study. Their stories were intended to provide a point of entry into the phenomenological explication process. The next section continues with an explanation of Meaning Units.

B) Explication: Meaning Units & Transformed Meaning Units

As the stories were composed and polished, I began a second-level analysis by re-reading the data, sorting through the core elements to distinguish similarities from differences and eliminate redundancies, and focusing my attention on the words, phrases, and terms that participants used in their descriptions, being careful to retain the context as much as possible. Next the descriptions were organized into 314 quotations from the interview transcripts and journal writings as follows: Terry (82); Kelly (65); Chris (76); and Sammy (91). Close attention was paid to the literal content, the number of times something is stated, and the manner in which it is stated. During the later parts of this phase, 35 descriptions were put aside to be either eliminated at some later point of explication or noted for triangulation between the interviews and journal writings.

In this way, I begin to assign priority to the description of the individual's experience. A total of **279 Meaning Units (MUs)** were developed from: **Terry (65); Kelly (59); Chris (70); and Sammy (85)**. Recalling Giorgi's key point (1985) about drawing on the phenomenological idea of *whole* versus *parts*: "grasping the whole meaning of the experience, instead of dividing it into parts without understanding the basic meaning structure, which gives sense to the whole experience" (De Castro, 2003, p, 47), I was careful to keep my initial abstractions focused on the experiencer rather than my own perspective so that I did not introduce meanings that were not described by the student(s).

Explication continued as I re-visited the MUs and questioned what they told me about students' experiences in science courses. Next I *transformed* the day-to-day, common language used in the descriptions of the MUs into the language of science education research, or into **Transformed Meaning Units (TMUs),** as outlined by Giorgi (1985), by drafting a statement about the meaning of the description in the language of the discipline, then interrogating the meaning against the research question. In other words, I used the data as a guide in my efforts to approach the *essence* of the phenomenon.

Following Giorgi's thinking about including raw and processed data in a study involving descriptive research, I agree that even though raw data can be lengthy and inappropriate to include into a body of work such as this dissertation, there are certain studies that are improved by including all of the raw data. For this study, because of the extensive number of Descriptions, MUs, and TMUs, I include representative samples rather than the entire raw dataset in Table 6.1 on the next page. The number in brackets below the pseudonym is the actual original MU identifying number for that participant. These examples should be sufficient to illustrate the process of how TMUs were derived from the descriptions and MUs provided by each participant.

The four examples in Table 6.1 demonstrate how the everyday language of the 279 MUs was transformed into the science education research language as TMUs. It should be noted that 279 MUs were transformed into 279 TMUs in this manner prior to advancing to the next step of the explication process.

Table 6.1: Examples of Deriving Transformed Meaning Units

Name (MU I.D. #)	Sample Meaning Unit	Transformed Meaning Unit
Terry (125)	[When asked about her most significant learning moment of the year, she replies:] when I worked on the group project [2nd semester not 1st semester]…our group worked well together…equally shared the workload…meeting after class…to discuss where we are in the project and keep on track….following the [marking] rubric (Interview, p. 39). I found that the light bulb moment….was we worked so well together….when I came out from doing the presentation, I felt a lot more confident. [When asked what she learned from that, she replied:] teamwork is important and if you have a good team then everything goes much smoother *[When asked why this was important she replied:]* " first of all the mark…it was a big percentage of our [final] mark (Interview, p. 39)	***Her experience in 1st semester with a low functioning group (where she did most of the work, felt overloaded, underprepared, with low self-confidence) that earned low grades SHIFTS in 2nd semester with a more effective team (even though one group member was the same) that earned a high grade when the assignment was worth a higher percentage of her final grade in the course (higher stakes). At no point does she translate team effectiveness into her own learning – it was all about the grade earned.***
Kelly (71)	Learning…is totally different in the science class than any of the other classes. I know one of the journal joules …was about the difference…and I think it is total, like what we learned in [science is] totally different…it did kind of play like to realize things that you would learn about in real life but it wasn't exactly the same. Like it was just totally different. It was more like the natural world….different topics (Interview, p. 40).	***She sees no connection whatsoever between topics in her science classes and topics in her other classes – even AFTER doing the activity in Interview #2.***
Chris (19)	Using videos [objects] gives me ideas of how to relate these principles to everyday experiences so now that I've known it I can go back and either teaching it to my own kids and grab a piece of paper and blow and do this and say do you know that's science? And have them go 'really???' And be able to say 'yeah! this is what is happening when I am doing this'….it is just about being able to make it [science] less complicated (Interview transcript, p. 29).	***Relevance to everyday life as a teacher and as a parent, she is making connections between school science and everyday life in the context of science learner, future teacher and parent. Everyday objects made abstract concepts more understandable then she can relate the concept BACK to other (new) everyday things. Learning is less complicated after making connections to everyday life***
Sammy (175)	I have so many doubts of my ability that I'll question something that I know is probably right, see there, I said, I didn't say right, I said that it might be probably right. And there is a lot of kids out there that don't have confidence and they are not going to have that confidence. So they are functioning the same way as me and I think about the Native kids that I worked with and I can really associate with those Native kids now because I am in their shoes (Interview, p. 47).	***She has low confidence about being in the position of science learner and can relate first-hand to First Nations' students. Science is about being right or wrong, demonstrating inadequate conceptions about NOS***

C) Explication: Integration and Synthesis of Structures

The final step of explication involved synthesizing and integrating new insights and ideas about the phenomenon. The 279 TMUs were organized into Situated Structures (SS), or *essences* of the participants' experiences, by making my best attempt to use *imaginative variation* (Giorgi, 1985) to "stretch the proposed transformation to the edges" (Polkinghorne, 1983, p.55).

Each TMU was singled out, read and re-read several times, and then organized with other similar TMUs into **48 Categories of Description**. The number of individual TMUs in each Category varied from 1 to 16, originating from one or more participants' description(s) from interviews and/or journal sources (see Tables 6.2 and 6.3). Categories of Descriptions that appeared similar to each other were collapsed into one common description, whereas Categories of Descriptions that were related yet still retained a degree of distinction were placed in close proximity to each other for further rendering.

Drawing on Giorgi's phenomenological explication, the reduction of 279 TMUs to 48 Categories of Descriptions led to the generation of several **Situated Structures (SS)**[30]. In this synthesis phase, 18 ***specific*** **Situated Structures** were generated from the Categories of Description. As the synthesis continued, a second higher level of meaning became obvious in the form of 3 ***broad*** **Situated Structures**. These Broad and Specific descriptions of the Situated Structures are presented in Table 6.2 in the blue heading and body of the table, respectively.

[30] See page 105 for a comprehensive explanation of Situated Structures.

Table 6.2: Structures Derived from Transformed Meaning Units

<table>
<tr><th colspan="3"><u>BROAD DESCRIPTIONS of SITUATED STRUCTURES</u></th></tr>
<tr><th>Views about
Nature of Science</th><th>Views about
being a Science Learner</th><th>Views about
being a Science Teacher</th></tr>
<tr><th colspan="3"><u>SPECIFIC DESCRIPTIONS of SITUATED STRUCTURES</u></th></tr>
<tr>
<td rowspan="2">1. Science is about being right or wrong (4)

2. Science is a separate ‘thing’ that is all around us (5)

3. Science is sociocultural (2)

4. Science is a body of knowledge to be remembered and mastered (3)

5. Science is a fixed, unchanging body of knowledge that resides with experts (Professors) (9)</td>
<td>6. Affective aspects of science learners:
a) Positive attitude (11)
b) Determination/motivation/inspiration (5)
c) Confusion(1)
d) Confidence:
i) High confidence (4)
ii) Low confidence (15)
iii) Increasing confidence (5)
iv) Perfectionism (2)
v) Exam anxiety (5)
vi) Counsel for children (5)
e) Level of Interest
i) Engagement (3)
ii) High interest (9)
iii) Tentative interest (fear) (2)
iv) Linked to specific activities (4)

7. Cognitive aspects of science learners:
a) General comments (16)
b) Overload – time & energy (7)
c) Mature student issues (2)
d) Learning disability issues (1)
e) Language – formulas, equations (3)
f) Validation of effort (2)

8. Key strategies for learning science:
a) General comments (7)
b) Using real-life examples (2)
c) “doing” science with hand-on activities (10)
d) Advance prep and review** (7)
e) Working with others (3)

9. Comparing science classes to other BA classes (12)

10. Cultural aspects (8)

11. Academic Performance (10)

12. Subject matter is hard and overwhelming (3)</td>
<td>13. Must learn science before you can teach science (4)

14. Attitudes about teaching (11)

15. Making science feel more “real” for students, using:
a) Creativity (6)
b) Cultural slant (2)
c) “Doing” science (6)
to help students make connections with everyday life

16. When science is seen as fun the level of engagement is greatly increased when compared to a traditional approach which is seen as boring and disconnected from students everyday life . The fun factor cancels out perceived difficulty.(14)

17. Science class curricula connects directly with future career:
a) Lesson plan assignment (4)
b) Group presentations (6)
c) Other activities (14)
d) Chair assignment (5)
e) Re-evaluating career plan (1)</td>
</tr>
<tr><td colspan="2">18. Classroom Activities:
a) General / broad view on activities (4)
b) Specific activities that were successful (8)
c) Personal impact (10)</td></tr>
</table>

Table 6.3: Detailed Summative Cross-Reference of Structures by Participant

STRUCTURE	TOTAL # of TMUs	TMUs TERRY	TMUs KELLY	TMUs CHRIS	TMUs SAMMY
1	4			13, 14, **<u>18</u>**	175
2	5		**<u>48</u>**	42, **<u>24</u>**, **<u>27</u>**	**<u>100</u>**
3	2		**<u>54</u>**		**<u>102</u>**
4	3	99, **<u>75</u>**			153
5	9	112	48	**<u>25</u>**	152, 175, 187, 193, 197, **<u>101</u>**
6a	11		48, 53, 72, 86	130, 131, **<u>8</u>**, **<u>9</u>**	155, 167, 170
6b	5			39	132, 139, 164, **<u>82</u>**
6c	1			**<u>12</u>**	
6d (i)	4	91, 121	84	32	
6d (ii)	15			34, 35, 36	134, 136, 143, 150, 170, 173, 177, 184, 188, **<u>83, 85, 99</u>**
6d (iii)	5	125		27	144, 189, 196
6d (iv)	2			37, **<u>13</u>**	
6d (v)	5	93, **<u>78</u>**	**<u>38</u>**	**<u>19, 21</u>**	
6d (vi)	5	116	69	23	182, 183
6e (i)	3		56, 81	40	
6e(ii)	9	**<u>55</u>**	73, 85, **<u>53, 33</u>**	24, 38, 45, **<u>29</u>**	
6e (iii)	2				147, 190
6e (iv)	4	90, 97	52, **<u>39</u>**		
7a	16	90	54, 55, 75, 67, **<u>34, 39</u>**	17, **<u>17</u>**	138, 149, 157, 171, **<u>87, 88, 91</u>**
7b	7		**<u>31, 40</u>**	7, **<u>15</u>**	142, 159, **<u>90</u>**
7c	2				141, 160
7d	1			**<u>14</u>**	
7e	3		66, **<u>41</u>**		165
7f	2			**<u>11, 20</u>**	
8a	7	96, 106, 113, 114		18, 29, **<u>2</u>**	
8b	2	102	**<u>42</u>**		
8c	10	100, 126	64, 77, **<u>47</u>**	20, **<u>23</u>**	178, **<u>94, 95</u>**
8d	7	101, 103	43, 63, 71, **<u>45</u>**		176
8e	3	127	5		168
9	12	123, 125	71	28, **<u>28</u>**	137, 148, 162, 163, 191, 192, **<u>98</u>**
10	8			**<u>26</u>**	140, 145, 146, 169, 181, 199, **<u>97</u>**
11	10	88, 92, 95, 120, **<u>80</u>**		2, 33	166, 190, **<u>92</u>**
12	3	101, 122	58		
13	4		62	10, 11, **<u>30</u>**	
14	11	119, **<u>56, 57, 60</u>**		22, 41, 46, **<u>6</u>**	151, 194, 195
15a	6	**<u>61, 67, 72</u>**	47, 68		200
15b	2				151, **<u>25</u>**
15c	6		65, 78, **<u>49</u>**	16	174, 179
16	14	105, 110, 115, **<u>58, 62, 63, 65, 66, 68, 70</u>**	79, 87, **<u>52</u>**	**<u>1</u>**	
17a	4	129, 130, **<u>64</u>**	**<u>35</u>**		
17b	3	**<u>77</u>**	**<u>50</u>**	3	
17c	14	94, 98, 108, 128, **<u>44, 59, 74, 79</u>**	57, 60, 82	21, 1	**<u>93</u>**
17d	5	**<u>76</u>**	**<u>32, 46</u>**	**<u>4</u>**	**<u>96</u>**
17e	1				**<u>89</u>**
18a	4	107	59	43, **<u>3</u>**	
18b	8	**<u>71, 73</u>**	49, 74, 76	8, 15, 19	
18c	10			4, 5, 6, 12, 26, **<u>7, 22</u>**	156, 180, **<u>84</u>**
48	**279**	**65**	**59**	**70**	**85**

Format key: *Numbers in regular text are taken from interview transcripts (example: 13)*
Numbers in bold underline are taken from journal entries (example: **<u>*18*</u>**)

Table 6.2 is a representation of the evolution of 48 Categories of Descriptions as 18 *specific* Situated Structures. Each specific SS has been assigned an identifying number in the title label and another number in parentheses, placed at the end of the description, to indicate the number of TMUs associated with that particular structure.

For example, Table 6.2 lists one Specific Structure as: **4. Science is a body of knowledge to be remembered and mastered (3).** The number 4 serves as an identifier of the SS relative to the other structures, and the number (3) refers to the three TMUs associated with this structure. Referring to Table 6.3, interested readers can cross reference the structure to the source and nature of each TMU that make up SS #4. By locating Specific Structure #4 (under the heading Structure – left column) and following the row to the right, one can see that this SS was rendered from TMU # 99, 75 and 153 (from Terry's interview, Terry's journal, and Sammy's interview, respectively). Note that *Specific* Situated Structures # 1 to 5 and 9 to 14 are organized and presented in this same manner.

Some Categories of Description were found to be closely related and as such did not constitute a separate SS, yet there remained a degree of uniqueness that warranted further representation. Consider for example, specific SS **#6, Affective aspects of science learners**. Keeping in mind that 13 Categories of Description and 71 TMUs are embedded within this structure, the complexity of this structure is addressed by multiple levels of organization. This particular SS was assigned 5 related but unique sub-descriptions, labeled (a) through (e). Considering **6 (d) Confidence**, another level of sub-sub-description was added, labeled (i) through (vi). Using this form of organization, data from participants about low confidence [6d(ii)] is held distinct from data supporting high confidence [6d(i)], and increasing confidence]6d(iii)]. It is important to keep in mind that these sub structures collectively form the situated structure labeled, **Affective aspects of science learners.** Situated Structures # 6 to 8 and 15 to 18 are organized and presented in this manner.

The term *broad* is used to represent a higher level of meaning that was synthesized from the Situated Structures. Drawing on the 18 *specific* Situated Structures, it became apparent that the essence of the participants' experiences were related to their views about the nature of science and their views about being learners and teachers of science. For this reason, this additional category of organization has been included in the synthesis step of phenomenological explication. Note that situated structure #18, *Classroom Activities* falls under the views of science learner and science teacher because it became evident during the explication that when the participants were engaged in classroom activities as learners, their experiences were closely intertwined and often inseparable from their experiences as science teachers. This is evidence of Giorgi's requirement to preserve contextualization of the TMU while synthesizing structures.

In summary, following the steps of becoming familiar with the participants' descriptions, generating 279 MUs and TMUs, and synthesizing 48 Categories of Description, 18 *specific* Situated Structures, and 3 *broad* Situated Structures, the next step in the analytical process involved rendering the collective data analysis in terms of Aikenhead's Border Crossing perspective. In doing so, I was attempting to broaden the scope of the process by providing a perspective of the analysis within and across all four participants.

i) Using Border Crossing as a Lens for Thinking About Participants' Experiences

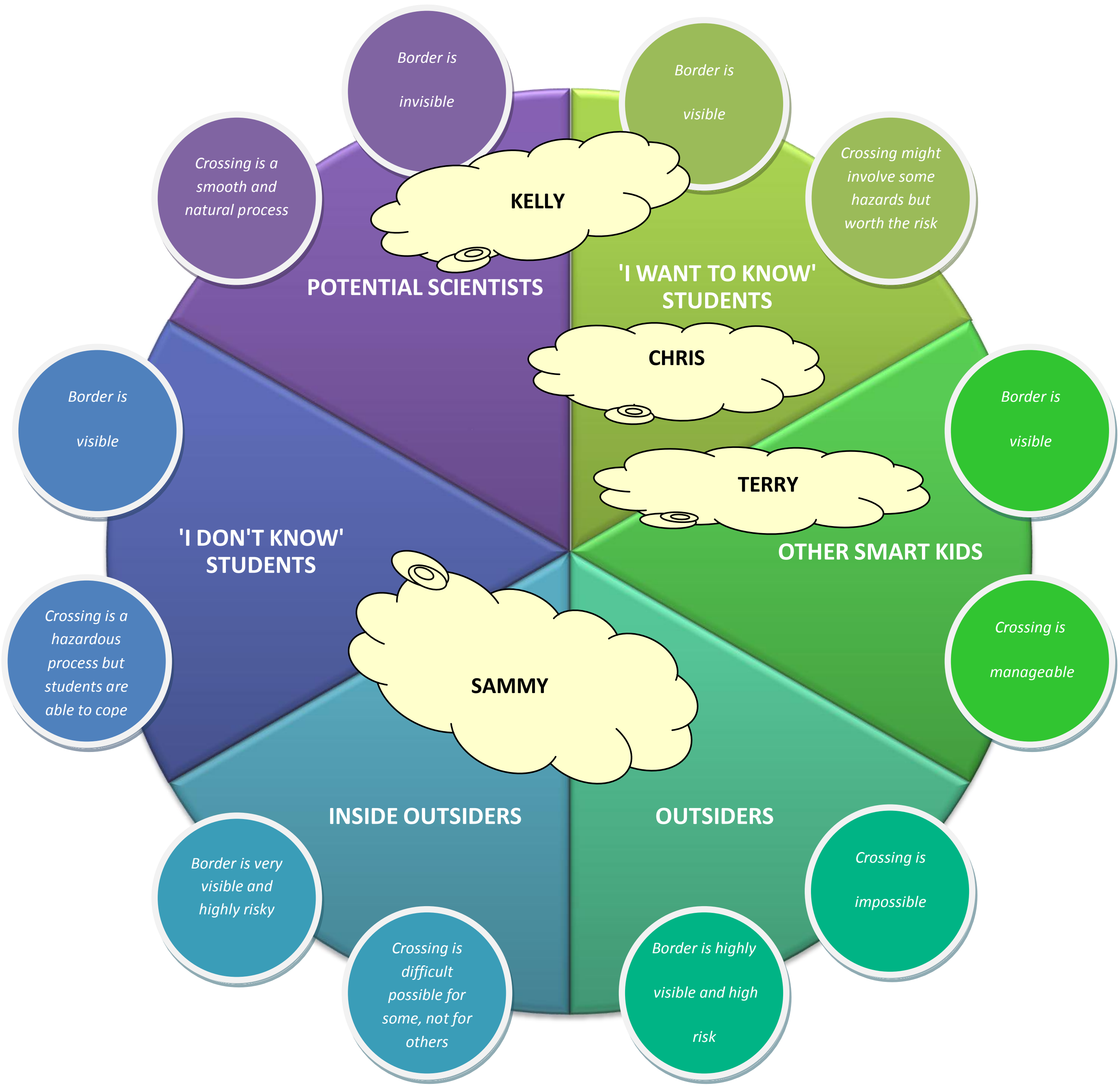
Earlier chapters of this dissertation state that by adopting a phenomenological approach to the study, my position is to not commit to a specific theoretical framework until after I developed a *feel* for the participants' experiences as non-science majors (NSMs), and especially for Sammy's experience as an Aboriginal Person. Based on the development of the TMUs and their subsequent categorization into situated structures, patterns in the data emerge that called for further analysis. It was at this point that Aikenhead's border crossing perspective provided greater insight into the phenomenon under study and brought some data, such as culture, into light that might otherwise have been discarded.

This section demonstrates one way to use Aikenhead's BC perspective to understand students' experiences in university science courses. First, I generated a visual representation of the six categories of cultural heterogeneity[31]. Next, drawing on the participants' descriptions of their experiences, I mapped the location of each participant (see Figure 6.2). In this way, readers are provided with a collective overview of the data, within and across different individual accounts of experiences. Following is an account explaining each individual placement on the map.

TERRY: The majority of Terry's experience fits with one category (Other Smart Kids) with a small overlap into a second category ('I Want to Know' Student). As an **Other Smart Kid**, Terry finds the process of border crossing to be manageable. Her performance is science courses can be categorized as good, but she continues to see science as something

[31] Categories are explained in detail in Chapter 5, section5.3

Figure 6.2: Map of Participants' Experience as Cultural Heterogeneity



that is about rules and facts to be memorized. Traditional approaches to learning science, such as lecture and reading books, do not promote effective learning. She is only able to become fully engaged as a learner is when science classes are *fun*. The map shows Terry's experience overlapping slightly into the **'I Want to Know' Student** category because she understands how science is essential to her career as an elementary teacher.

KELLY : During high school and at university, Kelly is very comfortable with science and enjoys the challenges of the subject area. As a **Potential Scientist**, the border between science and her worldview is unproblematic making the border crossing natural and smooth. Kelly is fully enculturated in the sub-culture of science. Math and equations related to physics are scholarly barriers that (likely) prevent Kelly from making a career as a scientist. For this reason, her experience overlaps into the category of **'I Want to Know' Student** where her personal worldview resonates with science but she is noticeably impeded by the barrier of math.

CHRIS: Similar to Terry and Kelly, Chris' experience overlaps more than one category of cultural heterogeneity**.** She had little interest in science before university and is not fully enculturated into the scientific enterprise. Chris demonstrates a relatively high interest in learning science and earns high grades in university science courses. Her personal worldview resonates with science but is usually limited to the context of her career or parenting her school-aged children. For Chris, crossing the border is hazardous when studying physics, but worth the risk because she realizes the positive impact that science will have on her career plans. The map shows Chris' experience slightly overlapping into the category of Potential Scientist because in her university studies, Chris stands at the top of her science class. This small overlap indicates that even though she is highly motivated about science, most of her experience remains in the “I Want to Know” Student category because she does not reject the social values of curriculum (subjective, epistemological, cultural, etc) that are typically held by Potential Scientist students.

SAMMY: During elementary and high school, Sammy was an **Outsider**. Her views about school in general and science in particular were discordant with her personal worldview. For Sammy, the border between her worldview and school was impossible to cross, resulting in her dropping out of high school. At university, Sammy’s experiences indicate that she overlaps into the **Inside Outsider** category of BC theory. Here grades in science were over 80% and she made the Dean’s List. She attributes her growing interest in science to her son (who loves science), but she sees the borders between her worldview and the university system as extremely hazardous, but at times, potentially comprehensible with science. Even though she continues to lack a support network from friends and her husband, the inspiration of her son seems to be a primary motivator and this leads to also demonstrate qualities of the **‘I Don’t Know’ Student**. She does well in her science courses but consistently plays Fatima’s Rules so she does not look dumb or stupid in front of her peers and teachers.

In summary, mapping and categorizing participants’ experiences generated more complex questions about how the BC perspective can be used to understand a phenomenological inquiry. Given that this is a different way to think about a science classroom, BC becomes an important aspect of the analytical process. Chris’ and Terry’s experiences are mostly contained within one category, but in both cases, there is a small but noticeable overlap into another category. Kelly's experiences span a good portion of two categories. Sammy's experiences in education spans three categories of cultural heterogeneity. These findings are taken up in the discussion presented in Chapter 7.

D) Summary of the Explication

Throughout Section 6.2, readers have been guided through a step-by-step process of explicating the data corpus. Drawing on Giorgi's methodological framework of applied phenomenology, the process involved familiarization to acquire a sense of the data corpus as a whole; generation of 279 MUs from participants' descriptions of their experiences and transformation of MUs into 279 TMUs, expressed as language of science education research; and finally, organizing and integrating all TMUs and subsequently synthesizing 18 situated and 3 general structures. The final step involves generation of claims.

Before presenting these claims, it is important to re-visit a point considered earlier (Chapter 4[32]) about how some phenomenological researchers (Hycner, 1999; Colaizzi, 1978) include a final validation step, in which the renderings of the data are taken back to the participants for verification. Taking the same stance as Giorgi, in which he criticizes Hycner's final step of returning the final results to the participant for approval or validation, this study does not include this form of validation for several reasons. First, is the inconsistency between the testimony of the experiencer (which is lodged in their lifeworld), and the phenomenological perspective that is used to interpret that testimony. Second, is Merleau-Ponty's argument (1964) that "the experiencer is not necessarily the best judge of the

[32] See Model #3: Giorgi, page 97

meaning of his or her experience" (Giorgi, 2006, p. 311). Third, is the practical concern is that the lengthy second order analysis is not necessary when the first order testimony of the experiencer is what this researcher is seeking.

The overarching purpose of the analytical process is to bring one closer to the essence of the participants' experiences with science. In Chapter 4, I explained how Giorgi considered structures as "the most comprehensive invariant meaning, which is what an essence is" (1985, p. 70). This essence is presented in the next section as key claims about students' experiences.

6.3 CLAIMS

The study set out to explore university BA students' (a) perspectives, being non-science majors, on learning science; (b) conceptions about nature of science, and; c) expectation of how experience in a university elective course might apply to their future career as elementary teachers. With this in mind, I constructed metaphoric visuals and narrative vignettes from a phenomenological explication. The process involved identifying 279 Meaning Units that were later transformed into discipline-specific language as TMUs. Next, these TMUs were used to synthesize 18 specific situated structures and 3 broad situated structures, all of which were subsequently rendered in terms of Aikenhead's Border Crossing perspective. From this analytical process, I was able to generate five key claims, some of which confirm findings in the literature and others that add to the body of knowledge about science education research. The five claims emerging from this study are presented below.

Claim #1

All four participants entered the course understanding science to be about a search for an absolute truth that resides with experts and for this reason held preconceptions that learning science (particularly physics) would be hard, complex, and boring.

Claim #2

Of the four participants, Kelly and Terry, who arrived in the course with a strong background in high school science considered science to be independent of human [perception]; whereas, Chris and Sammy, students from non-Western and non-science backgrounds, considered science to be part and parcel of the culture in which it is constructed.

Claim #3

The participants' social sciences background and interest in environmental issues seemed to influence their strong views about the way science knowledge is used and further conveyed that this awareness would influence their future work as elementary science teachers.

Claim #4

All four participants found science learning to be most effective through direct, hands-on, creative activities that help them build confidence in their abilities to learn science and make deeper connections between school science and their personal worldviews.

Claim #5

As future teachers, all four participants were most engaged in the course when enabled to make direct application of many of the instructional strategies used in the course with their career, due to what they claimed to be the strategic resonance with their natural modes of learning.

In summary, it is not my intention to present these claims to represent the experiences of all students in a universal sense, but rather to present key claims about these participants' experiences in their university science courses. The claims presented above are closely aligned with the research question. **Claim 1 and Claim 4** align with participants' perspectives, being NSMs, on learning science. **Claim 2** aligns with participants' conceptions about the nature of science. **Claim 3 and Claim 5** align with participants' expectation of how experience in a university elective course might apply to their future career as elementary teachers. Each claim is taken up further in the Discussion and Implications sections of the next chapter.

Chapter 7: Discussion, Conclusion and Implications

> When I disclose what I have seen, my results invite other researchers to look where I did and see what I saw. My ideas are candidates for others to entertain, not necessarily as truth, let alone Truth, but as positions about the nature and meaning of a phenomenon that may fit their sensibility and shape their thinking about their own inquiries."
>
> (Peshkin, 1985 (p. 280), cited by Clandinin and Connelly,1996, p. 8)

This final chapter of the dissertation presents a deeper discussion about each of the five key claims that emerged from the analytical process described in Chapter 6. Conclusions about future teachers' experiences in undergraduate science elective courses follow the discussion section and lead to implications for theory, curriculum and instruction, and science education research.

7.1 DISCUSSION

The findings indicate that these future teachers hold inadequate conceptions about NOS. ***All 4 participants entered the course understanding science to be about a search for an absolute truth that resides with experts and for this reason held preconceptions that learning science (particularly physics) would be hard, complex, and boring (Claim #1).***

The participants held views about science as a vast body of knowledge that is all encompassing and set apart from knowledge about other disciplines[33], for example:

> **Terry:** [science is] all about discovering and learning about the world and how it functions….all about having fun and learning at the same time (75 - Journal).

> **Chris:** [science is] all the things that surround us… there is stuff changing, evolving, and growing before our eyes. This would happen if we were here or not. This is universal – some things stay the same (27 – Journal).

> **Kelly:** I feel that science is universal….Science is natural; it happens everywhere & everyone can see it (54 – Journal).

> **Sammy:** Science is very precise, natural forces, plant/human structure, earth's formations, etc are definites. Unlike philosophy, history, sociology, psychology, these subjects change over time and nothing is set in stone. Everything is just a 'could be'. Natural science though is more definite…gravity is gravity, plants grow the same not just like they did 5000 years ago. Opinions change in all areas except science, Science continuously builds on to existing knowledge (101- Journal).

These views about scientific knowledge led to further preconceptions that science, as a subject at school, is very difficult to master. Despite earning high grades in their first semester course, every participant was convinced that the second semester course, with its focus on physics, would be extremely challenging. Based on this preconception, they expected their science grades to plummet in the second course.

> **Terry:** I know [for] some students, science is a hard subject…that's why it is important to make it fun. Some students just can't learn by reading the textbook and memoriz[ing] notes and stuff for tests…maybe doing these activities will help them. If there is a test…they will remember doing that activity (101 - Interview).

[33] This point is taken up in the discussion of Claim #3 on page 195

Sammy: science doesn't come naturally to me whereas the other courses…are interesting and they give you examples, they apply it somehow. Whereas science it is just all facts…this is the way it is (148 - Interview).

Their misunderstandings were further complicated by the view that science, physics in particular, is a complex body of knowledge that resides with experts, in this case the professor, and relies heavily on abstract, incomprehensible mathematical expressions and equations. Even though physics topics comprised a significant amount of the second science course curriculum, participants were able to maintain their grades, but they still left the course with inadequate understandings of science as tentative, subjective, creative, and socially-embedded profession (aspects of NOS). At the end of the second course, two participants did hold adequate conceptions about the socio-cultural aspect of NOS[34], in which culture influences the way science is interrogated, practiced.

Chris: I think that science can be powered by social and cultural values. Depending on where you live in the world, the environment you share between species and nature (26 – Journal).

Sammy: I believe that science reflects social and cultural values. In our highly industrialized and affluent country, society strives to improve its living/life conditions. Huge amounts of money is invested into medical research. Pharmaceutical companies making millions providing better medicine. The need for more efficient power usage, clean water, cleaner air, and more efficient vehicles, appliances, homes etc. has created more scientific research into these areas. But I also feel that because of our societies need to be more advanced than other countries, it has caused a lot of harm to our earth (102 – Journal).

Not all of the participants shared these views:

Kelly: I feel that science is universal…. The only way I feel science differs is by the way people see and understand it, and this is the same in every culture (54 - Journal).

Even though the significance of cultural and sub-cultural aspects of science and science education are explored in greater depth in subsequent sections of the discussion, culture also informs this discussion about the first claim because one might wonder about the

[34] See Figure 3.2 and Table 3.3

socio-cultural milieu in which the participants' understanding of NOS is experienced. By integrating these findings about NOS with Aikenhead's Border Crossing perspective, one could posit that the norms, values, beliefs, and expectations, or conventional actions that constitute the border between school science and one's everyday world are noticeably expressed in participants' views about NOS. Participants' testimonies about their teachers, learning materials, and texts are extrapolations of their border crossing process, a topic that is taken up in the discussion about the second claim.

Perhaps an NSMs negative history with school science leads to the view of science as a discipline that is opaque, abstract, conceptual, and hard-to-learn. Similarly, it seems that NSMs' approaches to learning science often include superficial rote memorization of facts for an exam, with a quick *memory dump* afterwards, echoing Aikenhead's reference to students who play Fatima's Rules[35]. The NSMs in this study either see science as a disembodied collection of facts to be memorized or subject matter that exists behind a *veil* that they just do not get past. As noted earlier, the intention of the study is not to suggest that this is a universal finding for all future teachers; however, these four participants' responses confirm existing knowledge reported by Lederman's claim (2007) that teachers hold inadequate conceptions about the NOS. This claim leads to several questions about the implications for science education research discussed in Section 7.2 (C).

The second key claim makes a cultural distinction between students with strong backgrounds in science and students with non-Western and non-science backgrounds. ***Of***

[35] See Chapter 5, section 5.2 for a detailed discussion about Fatima's Rules.

the four participants, Kelly and Terry, who arrived in the course with a strong background in high school science, considered science to be independent of human [perception]; whereas, Chris and Sammy, students from non-science and non- Western backgrounds, respectively, considered science to be part and parcel of the culture in which it is constructed (Claim #2).

Sammy considers science to be socioculturally constructed, presumably because of her First Nations Peoples', non-Western, non-science background. During the explication phase, there was a noticeable emphasis of culture in the majority of Sammy's descriptions of her experience and many grounds for this claim have emerged from the process of writing Sammy's Story. As I became more familiar with Sammy's descriptions of her experiences and began to synthesize structures, the discipline-specific sub-culture of NSMs began to emerge. Sammy's process of crossing the border between science and her Aboriginal Peoples' lifeworld perspective was difficult and sometimes impossible. When Sammy was asked about her experiences as a science learner, she replied, *"It wasn't so much that I learned….it was more like copying. Did I really learn anything about tectonic plates…from [the professor]…or from this class?"* (138 – Interview).

On the other hand, Kelly, who was categorized as a *Potential Scientist* and *'I Want to Know' Student* was able to naturally and smoothly navigate the cultural borders between science and her lifeworld, much like students with strong science backgrounds reported by Aikenhead (1996, 2001). When Kelly was asked how she would counsel students who are afraid of science, she replied: *"I would tell them about how there isn't really a reason to be* *afraid of science because I think it is just more about understanding the difference concepts and maybe using the hands-on matter taught better"* (69 - Interview).

Border crossing for Terry and Chris often presented similar challenges, as expressed in Terry's Story and Chris' Story in Chapter 6[36]. As a mostly *Other Smart Kid,* Terry's crossing was manageable but not without hazards and as an NSM, Terry talks about congruence between personal lifeworld and university, but only at the most superficial level of connection between her personal world and science. Her interest in science is limited to teaching children and held separate from her own everyday understandings about the natural world. For Chris, who is predominantly an *'I Want to Know' Student*, border crossing is also hazardous, especially in the early stages of her physics studies, but worth the risk because of her awareness of how a good foundation of physics will have a positive impact on her career as a teacher. For her, there is some congruence between the worlds of science, school, family, and peers; however, the borders remain evident for a variety of reasons, including her learning disability and her level of confidence as a science (physics) learner.

Sammy (First Nations Peoples' culture) and Chris (non-science as a Western sub-culture) both wrote extensively in their journals about how they *considered science to be part and parcel of the culture in which it is constructed;* however, Terry, who did not see science as part of her lifeworld, made no explicit references to culture. Kelly arrived with such a strong affinity for science that she might almost be considered a science major

[36] Section 6.2

because she often drew on her prior science learning (from high school) when talking about her present experiences at university:

> **Kelly :** [I was] excited just to see that I knew more than I thought I originally had known about [a certain topic]…and….being able to place it into kind of more if a life situation in real terms so I liked that a lot too…better awareness of the Earth and things around us (48 – Interview).

Knowing that all four individuals have different perspectives on the socio-cultural aspects of school science as well as the scientific enterprise, it would not seem unreasonable to suggest that future inquiries consider and interrogate cultural distinctions that exist or emerge in science classrooms.

The third claim expands on the cultural distinction made in Claim #2 to a disciplinary distinction that influences future teachers' professional work teaching science. ***The participants' social sciences background and interest in environmental issues seemed to influence their strong views about the way science knowledge is used and further conveyed that this awareness would influence their future work as elementary science teachers (Claim #3).***

The data support the idea of these undergraduate NSM students' strong views about science, particularly for students in the first year of a BA program, because they hold early and naïve views of the social sciences and humanities as disciplines which are "simply" extensions of their own everyday lives. As undergraduates, they not have yet acquired the scholarly sophistication or the conceptual equipment needed to theorize about society in a completely different way, as would a more advanced thinker such as an MA or PhD student who understands the highly theoretical nature of the social sciences. Consequently, as science learners, these four participants view science as a practical and applied discipline that is characterized by discrete and achievable goals in contrast to the social sciences which they see simply as conceptual extensions of their everyday lives:

> **Kelly:** [in] science it was…getting the knowledge before class and then…listening and collecting the knowledge and then it was retrieving and recapping what I had learned afterwards…..[a social science course] we just kind of talk about it and you just kind of understand it right away...you don't have to go back to anything else (71-Interview).

All four participants consider scientific knowledge about the natural sciences as discrete, different, and separate from knowledge of the social sciences and humanities.

> **Terry:** For English…you can relate it to the real world, kind of….[for] science you can but it comes in the detail part of it…not as much common knowledge. You need more focus on it…English was more reading…whereas science [had] more practical stuff involved…[studying] science …..[is] just reading over…equations…it's harder to understand….for English..you can just read (123- Interview).

As learners, these individuals assumed that they had to apply a different style of learning to the natural sciences than they did to the other social science and humanities courses of the BA program. Kelly's view indicates that students do have an intuitive understanding of what is happening in their BA courses but lack the tools to examine the subtle nuances involved. For Kelly, science appears to be more esoteric with less intuitive understanding of what is happening and she opts for more superficial approaches of acquiring and memorizing knowledge.

For these four NSMs, there is a sense that taking a science course involves 'new' learning that requires a different approach. For some students this can lead to frustration so they default to rote learning, as illustrated by Chris' description of her experience:

> **Chris:** I talked to [prof] about my frustration … and I lost it – very emotional – teary and upset….I told [Prof] about my worries with problem-solving math questions and conversions and what formulas to use and how I'm mixing stuff up (12 - Journal).

This line of thought leads to a distinction between science majors who are intent on becoming scientists, and NSMs who are required to study science at university. This distinction might be characterized as another form of cultural divide analogous to a divide that sometimes isolates non-Eurowestern students from Eurowestern students. One could argue that I have not thoroughly weighed the real implications of this Eurowestern versus non-Eurowestern divide. Consider two students from Western culture, one wants to be a scientist and the other does not, but both must learn science at school. How might these students navigate the border crossing process? The findings of this study suggest that a student who does not intend to be a professional scientist (a NSM from Western culture) must cross borders between their everyday world and the world of science. Furthermore, for NSMs, the hazards and challenges of crossing borders have much in common with the experiences of a non-Western student who may face a cultural border when they attempt to learn science. This border-crossing process into science transcends race, gender and class, as noted in quotes from all four participants below:

> **Terry:** I know [for] some students, science is a hard subject… students just can't learn by reading the textbook and memoriz[ing] notes and stuff for tests…maybe doing … activities will help…. (101 - Interview) [and] When I was doing the reading before the lecture I found it …confusing …then when [Prof] went through how to do it, it made more sense to me…it was still hard but it makes more sense (103 - Interview).

> **Kelly:** Remembering the formulas…are so different ...second guessing myself about what formula goes with what [concept]… I am actually doing this formula for this and it is going to work out the way that I want it to work out (66 - Interview).

> **Chris:** Physics is so difficult for me…you have to change things…kilometers to meters...or weight to mass…we talked about joules…pascals…neutrons…these are words that are not used frequently in my vocabulary and I am having a really difficult time organizing..[what] goes with what….[for example] velocity goes with what? So it's making the connections [between] the wording and the actual of what we are doing (17 - Interview).

Sammy: I can honestly say that science has been the most stressful, the most confusing, and the most time consuming [course]…. it was just plain difficult for me. …a new topic every class… (Journal, p. 19)…. It's always been 'what do I need to know this for? (98- Journal).

Recalling the claims presented in Chapter6 and participants' descriptions about their experiences above, it could be inferred that NSM students may view a divide between the natural sciences and the social sciences and humanities as a border that they are reluctant, unwilling, or terrified to cross, something that has considerable implications for science education researchers. See Sections 6.3 (A) Implications for Theory and 6.3 (C) Implications for Research.

Another key claim of the study is about how NSM students' learning is a function of the design and implementation of university science curriculum. The findings indicate that ***all four participants found science learning to be most effective through direct, hands-on, creative activities that help them build confidence in their abilities to learn science and make deeper connections between school science and their personal worldviews (Claim #4).***

If students were more engaged by doing science through hands-on experiments, live demonstrations, or computerized simulations, and if these students were NSMs who, despite their backgrounds in the social sciences and humanities, had inadequate conceptions about the NOS in general and the sociocultural aspects of science in particular, and if engagement is linked to success of a science learner, then the importance of including hands-on/minds-on activities for students in BA courses for NSMs cannot be over-emphasized.

This being said, it is important to acknowledge that the scope of this particular discussion about student learning and engagement does not extend to other related issues, such as the following: the nature of knowledge and how that knowledge is structured; the language of science and how scientific ideas and phenomena are reified; forms of assessment and learners' perceptions about whether these forms are authentic or not; and how any of these issues might be related to students experiences beyond the classroom.

Without making a universal claim about the learning experiences of non-science majors, anecdotal evidence from my colleagues and myself, as members of the Science Faculty Team (currently in our 10^{th} year teaching non-science majors), also supports this claim. We continue to notice that NSM students are more engaged when their science classes involve hands-on activities. This view leads to several implications for curriculum and instruction of university science courses for NSMs that are taken up later in the chapter in section 7.3 (B). This stance is validated by the research of Lunetta, Hofstein, and Clough (2007) who find that students who are involved in activities (doing science, e.g. laboratory experiments), are more engaged through what they call a minds-on component along with the hands-on component. In other words, there is a cognitive and tactile focus leading to engagement in these activities. Similarly, findings from other studies with pre-service teachers (Hoban, 2007; Hoban & Nielsen, 2010) indicate that when teachers (as science learners) are engaged by need to know activities (e.g. Slowmations), their level of science content knowledge is improved.

This claim connects some of the dots in the moving target of science teacher education. Throughout the interviews and journal writings, all four participants consistently and repeatedly assigned a high level of importance to experiential activities, in terms of affecting their own learning and also as activities that are directly applicable to their future work in the elementary classroom. In this way, the participants highlight their dual roles: first, as NSMs who are learning science; and second, as future teachers who will one day be teaching science to elementary students. For example, in her description of the term project that involved building a chair, Sammy reported that this creative project resonated with her because she was an artistic person, thus the application of physics principles to an artistic work helped to reinforce her learning (178 – Interview). Similarly, the other three participants' descriptions support the claim about the learning value and applicability of hands-on activities from science class:

Terry: Demonstrations…helps explain the topic..more in depth…especially physics. Seeing how it works was more appealing and makes it easier to understand…you just pick it up faster than..just reading it…you think you know it and then once you see it, it really reinforces how much you really do know about it (100 – Interview).

Chris: [I] kind of go "Oh, that's simple enough'. You know when you actually see it being done and go 'Oh, …if you look at it that way it just makes so much more sense'. So I think that is just where if you are relying on a textbook and somebody lecturing where things get to be a little bit more scary because you're not getting that 'this is how easy it really is' perspective (20 - Interview) .

Kelly: We actually got to be at the activity and test out the activities ourselves while there were a few questions that were on the board that we would answer as we went. I thought that was really helpful…. it helped me remember because I actually had a chance to do it. So it was tying it all together and getting me to understand what I was doing. That helped me understand better (64 – Interview).

For future teachers, the incorporation of appropriate and effective learning activities in the BA science curriculum becomes very important to their views about the connections between science, NOS, and everyday life. The fifth and final claim elaborates on this line of thinking.

As future teachers, all four participants were most engaged in the course when enabled to make direct application of many of the instructional strategies used in the course with their career, due to what they claimed to be the strategic resonance with their natural modes of learning (Claim #5).

As the participants deepened their understanding of scientific subject matter in their BA courses, they envisioned how they might effectively apply their experience at university (as science learners) to their future experiences at the elementary level (as science teachers). As their understanding of the subject matter grew and developed, their level of confidence escalated accordingly:

> **Chris:** Every time I did research on the questions [from class]….I was building my resources…for when I become a teacher…I created a data bank on the computer…and paper data bank….of quick cue cards that I can pull out…if a student asks me a question…and I can't recall but I know I did it in my class (1 – Interview).

> **Sammy**: This assignment has shown me the importance of the rubrics, as a teacher, it sure would make it easier to keep the marking fair (96 – Journal).

For these participants, noteworthy teaching experiences that would engage their future students were a result of how activities were implemented in their BA science courses. Similarly, when the BA science curriculum is designed to meet the needs of science learners *as future teachers*, the findings from this study indicate that students are more engaged and confident in the course and leave with heightened awareness about their own understanding of science: "…activities…help them build confidence in their abilities to learn science" (Claim #3) .The following comment from Terry is representative of similar views held by the other participants:

Terry*:* I would definitely consider doing this lesson with a bike [physics -gears] because I think kids would be interested to learn how science works in everyday life (71 - Journal), and …this week…we learned about waves and sounds which is also one of my favourite topics because I love music (73 - Journal).

I attribute this to the way students have been enabled to integrate their learning about science, as a topic at school, with common everyday happenings in their life outside of school and "make deeper connections between school science and their personal worldviews" (Claim #3).

7.2 CONCLUSION

When I began writing about the findings of my inquiry into the phenomenon of human experience in the science classroom, Peshkin's words (framed in the quote at the beginning this chapter), resonated with my thinking about how to guide readers to the meaningful aspects of this work.

This dissertation extends an invitation to other educators and researchers to *"look where I did and see what I saw"* (Peshkin, 1985, p. 280). As I set out to explore how undergraduates on career paths to become future teachers experience science courses, I was keen to answer the question: What are the university BA students' (a) perspectives, being non-science majors, on learning science, (b) conceptions of nature of science, and (c) expectation of how experience in a university elective science course might apply to the future careers as elementary teachers? The findings indicate that as science learners, these NSMs pre-suppose that sciences such as physics are difficult and boring and that the most effective learning is through experiential inquiries. The NSMs in this study hold different views about the socio-cultural aspects of science, some of which are a function of disciplinary as well as racial barriers. In addition, all four participants made explicit and strong connections between their experiences in their university courses and their future teaching. These findings have important implications for theory, curriculum and instruction, and raise many questions for future science education research.

In summary, my work offers readers an opportunity to read, explore, and interrogate my stance about *"the nature and meaning"* (Peshkin, 1985, P. 280) of four future science teachers' experiences, in the spirit of sharing how others might *"shape their own inquiries"* (Peshkin, 1985, p. 280). Returning full circle to Hackerman's ideas about improving how science is taught so that everyone develops *"some sense of where science fits into the affairs of the human race"* (1996, p.78) and Loughran's call for more attention to research to *"place more emphasis on elementary teachers as learners"* (2007, p. 1049), I propose that one way to do a better job of teaching science to children is by inquiring, exploring, and interrogating science curriculum for aspiring elementary teachers, such as Sammy, who writes:

> Maybe it is my job to grab science and give it a shake and say OK I can try and do this! …. I would … incorporate hands-on stuff and explain why we are doing this…because I learn that way, I can teach it that way. ….when [students] are young, that's how they need to learn science….they need to have fun doing it. … to build some enthusiasm…watching something explode…that would be the best way to learn. …… like all gung ho, and then the next thing it's like 'Oh my God what was I thinking? (Interview, p. 75)

The key to our success at doing a better job of explaining science to learners is to do a better job of developing effective teachers of science whose vision of science includes science as a socio-cultural, creative, subjective, tentative pursuit. As such, teachers might be more likely to convey this understanding to their students.

7.3 IMPLICATIONS

This final section of the dissertation offers my views about how the findings have implications for theory, curriculum and instruction, and science education research.

A) Implications for Theory

Some new dimensions of Aikenhead's border crossing perspective emerge from the study, including participants' age, translocation across multiple categories, application of cultural distinctions for non-science majors, and consideration of a future science teacher as someone who learns science before they teach science.

Aikenhead's work focuses on students of school science in elementary and high school, mostly with children aged 11 through 16 (2006). My study moves beyond school science at the elementary and secondary levels, to **consider adult science learners** at the post-secondary level (university), whose ages range from young adults (age 19) to mature adults (over age 40). The difference between children and adult learners becomes significant when considering students' cognitive abilities to move from conceptualizations and speculations about their experiences to more concrete descriptions of their experience, referring back to Polkinghorne's (1983) statement about the need for one to understand

and comprehend one's experience pre-reflexively[37]. There is an underlying assumption that adult participants in this study, as successful undergraduate students, have gained a higher level of scholarly maturity or sophistication with more advanced cognitive skills (than children) that is needed to consciously understand their experience and the language needed to articulate detailed descriptions of their experiences. This assumption is corroborated by the diversity of length, density, and complexity of the Four Stories, each of which if unique to the experiencer (presented in Chapter 6 [38]).

Related to this maturing process, is a dynamic **translocation** of participants' placement in each of Aikenhead's six categories of cultural heterogeneity of science students, explained in Chapter 6, Figure 6.2, where I state that, over time, students move or translocate from, or between, one category to another. For example, Sammy's description of her experiences in elementary and high school demonstrate qualities from two categories, *Outsiders* AND *Inside Outsiders*. Later, at university, Sammy continues to hold conceptions that fit with both categories and as her new experiences (as an adult) at university unfold, some of her conceptions align with a third category, the *'I Don't Know' Students*. In this way, Sammy's experiences actually span <u>three</u> categories of Aikenhead's cultural heterogeneity. Similarly, the other participants span more than one of Aikenhead's categories[39].

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[37] As per Laverty, 2003 in Chapter 3

[38] See p. 144.

[39] The text accompanying Figure 6.2 presents a detailed explanation of each participant's placement on the map of cultural heterogeneity.

In addition to this translocation across two or more categories, the findings of this study indicate that as students' interests and motivations for science change or evolve, the student can translocate two or more categories, while often retaining characteristics of the original category, to varying degrees. I do not necessarily mean to say that the participants are jumping around from one entire category to another, but rather that findings suggest that students explore new categories while retaining some or all qualities of the original category. The process of mapping students' positions and translocation is taken up in Section 7.3 B, Implications for Curriculum and Instruction.

I also question the **cultural distinction of adult NSMs** who plan to become future teachers. Aikenhead and Jegede (1999) find that even Western students sometimes struggle to cross borders into the sub-culture of science. I would add that when one learns that an understanding of science is absolutely essential to one's career, as opposed to just being scientifically literate citizens, the *stakes* for learning science become much higher. In this study, even Euro-Western participants, who thought they had left their science studies behind them in Grade 10 (such as Chris), found themselves as adults, having to navigate the borders between their life-world and science. For example, during an interview Chris states:

> … drawing from past experiences [with science]…. as a kid …. you always struggled with and those barriers that have always been there and as much as you are trying to get past these barriers, there's always that little guy behind you, in the back of your brain that says you can't do it (Chris p. 54).

She is referring to conceptual barriers that continue to block her learning. This position might account for Chris' overlap into two categories of heterogeneity in which she demonstrates perspectives of BOTH categories, in different contexts because she is never fully able to overcome what she calls a *barrier*, or in theoretical terms, Aikenhead's borders.

In my experience, many science majors in the Potential Scientist category see minimal (or nil) value for the sociocultural, political, subjective aspects of science that are key principles of studies in the social sciences and humanities. If culture in this study is the norms, values, beliefs, expectations, and conventional actions of a group[40], then culture of science majors (Potential Scientists) can be distinguished from the culture of non-science majors (Inside Outsider, 'I Don't Know' Student, or Outsider categories where these participants are located). The cultural distinctions between Potential Scientists and the 'I Want to Know' student and Other Smart Kid categories are not as clear; however, Aikenhead attributes this as the high interest in career. Both categories see only minimal impact of personal worldview.

The final point about added dimensions to Aikenhead's border crossing perspective continue from Chapter 5, where I allude to how this study brings a unique aspect to the theory because participants' experiences come from the perspective of ***students as future TEACHERS of science***, who will one day, consciously or unconsciously, act as *border brokers* or *cultural assimilators* or *border guards* in *their* science classrooms with their science students who will experience science class as a cross cultural event (as opposed to participants as *students who as learners of science* make transitions across cultural borders).

If one agrees with the circular path of science education presented in the Introduction (see Figure 1.1) indicating direct **connections** between the pathways teachers and students as the ***dots in the moving target of science education***, then the human experiences of future teachers are also connected to the experiences of future students.

[40] Refer to Chapter 5, p. 116.

When human experience is viewed through the lens of Aikenhead's border crossing perspective where teachers can become cultural brokers, guides, or agents, then the connections with future students become even more important. When the theoretical principles of border crossing are expanded to consider future teachers, especially those with non-science majors' backgrounds, as learners of science, then more meaningful questions can be raised for future research of curriculum and instruction.

B) Implications for Curriculum and Instruction

Development, review, and revision of undergraduate science electives, such as those courses required for BA programs, must pay closer attention to the cultural heterogeneity of students in the classroom including *Indigenous* People, *Non-Indigenous* People, to include *Non-Science Majors*. This point is of particular importance for BA students who are on career tracks to become elementary teachers who will one day be teaching science. If success at university science requires learners to cross borders between their personal culture and the sub-culture of science, then how will course curricula provide learners with opportunities to understand how science (as a subject in school) is more than practices of the scientific enterprise, but also an important component of life in the 21st century.?

In reference to the discussion about Claim #1, these NSMs view science as an abstract and inaccessible disembodied collection of facts to be memorized or subject matter that exists behind a metaphorical *veil*. For reasons beyond the purposes of this study, this seems to be especially true in the physical sciences, such as physics and chemistry. The great irony is that the areas of science that present the <u>greatest difficulty</u> to future teachers with NSM backgrounds comprise a significant part of the elementary level Science and Technology Curriculum (Ontario, 2007)[41].

Finally, given that science and technology are components of everyday life in today's world, any considerations for improving university science curriculum, especially for NSMs who intend to become future teachers, will also benefit those who do not intend to become teachers, but who still need to be scientifically-informed citizens.

A second implication for curriculum and instruction is how Figure 6.2 and Table 6.2 might be used or adapted as pedagogical tools. First, Fig. 6.2: Map of Participants' Experience as Cultural Heterogeneity is one tool that could be used by science teachers/educators as a different way to think about a science classroom of science learners at any level (elementary, high school, post-secondary). A teacher might use this simple tool to map an entire class of students, or a group of students working on a particular collaborative learning activity, or simply one student, across Aikenhead's categories of heterogeneity (1996), and in doing so acquire a heightened understanding and better insight of their abilities, potential problem areas, and/or challenges to learning. Second, Table 6.2: Structures Derived from Transformed Meaning Units is another tool that science teachers/educators could use in a classroom to observe and understand students' experiences. The structures and sub-structures may provide a scaffold for understanding student behaviour, managing a classroom, facilitating learning, or building learning confidence with science.

[41] Ontario Curriculum (2007), Topics and Broad Connections in science and technology (p. 19), particularly the Fundamental Concepts of: Understanding Structures and Mechanisms; Understanding Matter and Energy; and to some degree, Understanding Earth and Space Systems.

A third implication for curriculum and pedagogy involves the literature syntheses of science education and the nature of science (Chapters 2 and 3, respectively). Besides the contribution to knowledge from investigating the research question, these literature syntheses revealed patterns and trends that are also reported as significant contributions to knowledge.

In summary, the potential of adapting Figure 6.2 and Table 6.2 (which were used to communicate findings about a research study) to be used as a classroom tool by teachers, educators, or researchers at any level of education, to make sense of and respond to student issues, concerns, and conceptualizations about science, is an important contribution to the body of knowledge about science education.

C) Implications for Research in Science Education

If one accepts the idea that science as a sub-culture of Euro-Western society and the idea that learners who are not in the category of *Potential Scientist*[42] can experience difficulty with border crossing into the sub-culture of science, then when learners are NSMs from backgrounds in the social sciences or humanities, even for those who hold Euro-Western worldviews, differences in cultural become even more apparent. With this in mind, one might also ask if research about elementary teacher education requires recognition of NSMs as a distinct disciplinary sub-culture of science.

[42] As learners who have family members or other role models from professional science who enjoy the challenge of school science and who easily satisfy the canonical, political, and economic interests of the discipline.

Drawing on the implications for Theory in section 6.3 (A), Aikenhead's BC perspective can be used to view NSMs with backgrounds in the social sciences and humanities as culturally distinct from science majors. There is a call for future research studies to expand the existing cultural views of Indigenous, Non-Indigenous, and the Euro-Western worldviews (with the sub-culture of science) to include ***disciplinary cultural differences*** in which NSMs are asked to navigate ***borders*** between the culture of social sciences and humanities and natural science.

In this section, it is important to note that the process of conducting this study and generating the resultant claims have prompted me to make several about-turns in the way I carry out my professional work as a science educator/researcher, including:

- Interactions with NSM students in and out of the classroom;
- Design, development, renewal, and revision of university science curriculum; and
- Collaborations with fellow teacher/educators/researchers of science as well as collaborations with my colleagues from the social sciences and humanities.

My interactions with NSM students, especially those who intend to become elementary teachers have changed considerably since the start of the study. As a person who found the border between science and everyday life to be invisible (Aikenhead would have categorized me as a Potential Scientist student), I possessed only a superficial and intuitive understanding of the true nature of the struggles that NSMs faced in my classroom. As a result of this study, my practice has shifted from a position of caring and empathy for the emotional turmoil an NSM might face in his/her attempt to learn science, to an informed perspective, grounded by the findings of a research study, about the complex nature of the metaphoric border crossing process as a cultural journey to a discipline that can be viewed as foreign and sometimes hazardous. For all of my NSM students, and especially for those who are on career tracks to teaching children, I have acquired the language and conceptual understanding to communicate, explore, and observe student's translocations from one category of cultural heterogeneity to another. In doing do, I have added another dimension to my professional teaching practice.

Related to these changes in my approach to teaching and pedagogy is a shift in my work with science program curricula. In the past, I have led the Science Faculty Team in the development of 12 science elective courses for the BA program, with the intention of offering a curriculum that weaves scientific topics throughout the curricular threads of social sciences and humanities topics that are of interest to students who intend to major in one of these disciplines. These science elective offerings have met the needs of many (but not all) of the BA students, but my sense is that we can improve this record if we broaden our views of cultural heterogeneity from race, culture, gender and age, to include the beliefs, norms, expectations and practices of NSMs who have much different disciplinary interests than do students who are keenly interested in science. This study has challenged me to dig deeper into my own understandings about the social sciences and humanities, in terms of how science might be affected by politics, power, morality, religion, society, and philosophy.

With these new understandings about pedagogy and curriculum, I am also highly aware of the shift in my thinking about and interactions with fellow scientists, science educators, and colleagues from the social science and humanities. For much of my career, as the only full-time (permanent) science faculty member in a department of over 80 faculty members (the other 79 colleagues came from the social sciences or humanities), I often felt like a strange person in a strange land. My interactions with colleagues were always very positive, but I must admit that I withdrew from some of the scholarly conversations that, for me, seemed to have little in common with science.

If my vision of the social sciences was that of a *strange land* that felt foreign to me, then does it make sense to think that the opposite might also be true? Post-study, I have come to a realization that the border crossing process is something that I have experienced first-hand and even though I was not a participant in the study, I can now understand that my own experience with border crossing was an interdisciplinary/cultural journey. This realization has heightened my awareness and understandings about how individuals from outside the culture of science, such as a student, might view science as a *strange land*, with highly visible borders that are accessible to some but not to all.

My sense is that as a result of this study, my professional work with students, curriculum, and other members of the academy has been greatly enriched and that any future research programmes can draw on these new understandings and become even more fruitful.

When considering future research in science education, the scope of this study does not make universal claims about all future teachers' undergraduate experiences with science; however, the claims presented in this study do point to more questions in a larger context of future research. Given that all four participants have inadequate conceptions about NOS (Claim #1), then how will these future teachers will be prepared in their BEd program or through their professional experience, to teach NOS to their future students?

Also, what conceptions, or *alternative* conceptions, about NOS will they pass on to future students through their teaching? Discussion about this claim underscores Lederman's call to improve teachers' and students' conceptions about NOS. For future teachers with NSM backgrounds, BA science electives courses are their first adult experiences with science. These courses may offer the ideal opportunity to address Lederman's call (2007) to improve teachers' conceptions about NOS by explicitly integrating NOS into university science courses.

Further, if BA students complete their science elective courses, holding inadequate views of tentativeness, creativity, and subjectivity that are the backbone of the scientific enterprise, and then transition to BEd programs, carrying alternative conceptions about NOS, then several questions emerge. First, after completing their BA science electives, when and how will these future teachers be presented with opportunities to correct those conceptions? Second, will the upper year BA courses provide these opportunities for NSMs to correct their inadequate conceptions about NOS? Third, will the BEd curriculum provide such opportunities? Fourth, do professional development programs for practicing teachers provide such opportunities? Finally, without such opportunities, what conceptions about science and NOS will these teachers pass along to their future students?

Also, given that elementary teachers are required to teach science to their students, and if NSMs see science as a foreign discipline, and if future elementary teachers come from NSM backgrounds, then university science curriculum in BA programs is one place where the cultural aspects of teaching and learning science can be addressed.

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Figure 4.1, p. 73: Bergere, T. original photograph (April 2008).

Figure 6.1, p. 142 Representation of Participants' Profiles**,** Royalty Free images retrieved January 18, 2010:

Acorn from http://www.fotosearch.com/photos-images/acorn-sprouting.html

Nautilus Shell http://www.fotosearch.com/photos-images/sea-shell.html

Passionflower from http://www.fotosearch.com/photos-images/passionflower.html

Rock from http://www.fotosearch.com/photos-images/rock.html

Appendix A

Ethics Documentation

UNIVERSITY PARTNERSHIP CENTRE
GEORGIAN COLLEGE

October 21, 2008

Trudy Bergere
University of British Columbia Graduate student

Dear Trudy,

Re: Science for Bachelor of Arts non-science majors

This letter is to advise you we have received the final approval letter from British Columbia Office of Research Services. The Georgian College - Research Ethics Board have processed your application though an expedited review process. Your research project is now approved for a one year period.

This approval may be extended after one year upon request. Please be advised that if the project is not renewed, approval will expire and no more research involving humans may take place. Please note that REB approval policies require that you adhere strictly to the protocol as last reviewed by the REB and that any modifications must be approved by the Board before they can be implemented. Adverse or unexpected events must be reported to the REB as soon as possible. Finally, if research subjects are in the care of a health facility, at a school, or other institution or community organization, it is your responsibility to ensure that the ethical guidelines and approvals of those facilities or institutions are obtained and filed with the REB prior to the initiation of any research.

If you have any questions regarding your submission or the review process, please do not hesitate to get in touch with Cherylyn Cameron

Congratulations and best of luck in conducting your research.

University Partnership Centre, Research and Scholarship

On behalf of the Georgian College Research Ethics Board

One Georgian Drive, Barrie, ON L4M 3X9 tel: (705) 728-1968, ext. 1831 fax: (705) 722-5109 www.georgianc.on.ca

Appendix B

Interview Documents

Interview #1

January 2009

1. So far, which courses have you completed in your BA program? *building a biographical sketch*

2. Which university science courses have you completed?

3. Do you feel that the grades you have earned are representative of your LEARNING about science?

4. Metaphor Activity (6 cartoons) *Exploring their CONCEPTIONS of teaching and learning science*

A) Please take a moment to review the metaphors.

B) Each cartoon could be a metaphor for teaching and learning science.

C) On each cartoon, please indicate who or what represents

   a. the learner
   b. the teacher
   c. describe how learning is taking place.

Other prompts:

Which metaphor would be your STRONGEST preference? Why?

Which one do you LEAST prefer? Why?

5. Can you give me an example of a time or situation in your SCIENCE course when you felt you learned something NEW or DIFFERENT?

continuing to probe their assumptions about teaching and learning (in general) and how the assumptions are being challenged and/or reinforced as a result of the science course

6. What was that like? How did you feel?

7. Can you give me a sense of you found challenging In your science course?

8. What stands out for you as something you REALLY learned about science?

Explore their attitudes about learning science

9. Can you remember WHY this stands out for you?

10. Can you give me an example from class activity?

11. Why so you think it is so significant to you this semester?

12. Given that you want to become a science teacher, how have your experience(s) this semester affected your views about how you will (one day) teach science?

Probing how attitudes and conceptions are transferred to career as teachers of science

Interview #2

Semester Mid-Point, March 2009

Please complete the following sentences:

13. I liked it when the Professor did…….because……..

14. In our science class, the teaching I responded to the best was……..because……..

15. One of the greatest challenges I am facing in this class is…………… because I feel…………..

16. As a LEARNER, what sort of learning activities or situations have you found to be most rewarding? Why?

17. As a FUTURE TEACHER, what connections do you see between *science in the classroom* and *science in the*

everyday world?

18. As a FUTURE TEACHER, what advice or counsel would you offer to a student who is:
    a) afraid of science as a subject; or
    b) convinced they cannot be academically successful
    c) do you see these points as the same or different?

Probe Activity (selection of photos)

Exploring the way they think about science in the world AND the way they think other people think about science in the world

Imagine you are a teaching a new class of elementary students

You are planning to introduce new topics in science

- Which 3 (or 4) photos would you choose to engage the class and get them talking about science?
- Why? (explain each photo)

Interview #3

1. Think back over the past two semesters and
compare your experiences as a learner in science
class to other classes……

    - What was different?
    - What was the same?

    Additional Prompts:

    a) in terms of skills, and abilities needed for
    academic success (studying, writing, etc)

    b) in terms of attitudes toward the subject
    (motivations, emotions, etc)

Distinguish their experience in science from experiences in other BA courses

2. Over the past year, can you recall any "turning points" or
"light bulb" moments?

    - Can you tell me more about what happened before that?
    - After that?

Key on attitudes and conceptions about learning science and learning ABOUT science

3. Now that you have completed the science credits required
for your BA degree, is there anything that happened (related to
science) that surprised you?

4. Do you think this experience was significant?
    - Why/why not?

5. In your opinion, and based on your experiences as a learner and future teacher in this science course, how have your experiences affected the skills, attitudes, and abilities you think you need to teach science?

Impact of science courses on future career as an elementary teacher, teaching science

Manipulative Activity – Scenario Cards

1. Take some time to read through the cards.

2. Organize the cards into 3 stacks:

- a) Best representations of how I would teach science
- b) Does not represent how I would teach science
- c) unsure

Make explicit the beliefs that they NOW hold about science

3. Take the cards in the "Best Representation" stack and make a continuum :

EXACTLY my style ………………………………..NOT my style (at present)

4. Analyze the arrangement of the cards.

Prompts:

- Think about your goals and purposes for teaching science
- What is similar about the cards grouped together?
- What is different?
- Does this tell you anything new (or unexpected) about yourself or your teaching style?

Appendix C

Journal Documents

Journal Joule #1

Personal ponderings about teaching and learning science

What, in your view, is science?

What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry

(for example, religion, philosophy, history, sociology, etc.)?

Source: adapted from VNOS-C question # 1 (as explained in Chapter 3) (Lederman et al., 2002, p. 509)

JOURNAL JOULE #2

Please consider the following information and record your thoughts and ideas in your journal. Remember this is not a test and there is no right or wrong answer. Journal joules are simply sparks to ignite new ideas.

Some claim that *science is infused with social and cultural values*. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that *science is universal*. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.

- **If you believe that science reflects social and cultural values, explain why (defend your answer with specific examples*).**
- **If you believe that science is universal, explain why (defend your answer with specific examples*).**

NOTE: examples could come from your experiences in science class, other LU classes, or even from your personal, family, or work life

Source: adapted from VNOS-C question # 3 (as explained in Chapter 2)

(Lederman et al., 2002, p. 50)