LEARNING TO RELATE:
AN EXPLORATION OF INDIGENOUS SCIENCE EDUCATION

by

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Abstract

This dissertation shares the story of my research exploring the transformative possibilities of Indigenous Science Education for catalyzing the emergence of more equitable and sustainable ways of living. It is an educational response to humanitarian and ecological crises, and draws on the holistic frames of complexity and Indigenous knowledges to balance the dominance of the mechanistic worldview in which these crises are rooted, and that permeates school science. Weaving participatory action research and Indigenous research methodologies into an Indigenous Métissage, my research sought to decolonize and Indigenize school science, eventually focusing on sharing my own story of change and transformation. The research was conducted through four years of participation and relationship building in the local Indigenous education community in my hometown of Saskatoon, Saskatchewan, particularly through ceremony, and employed conversation and anecdotal narrative as primary methods. These experiences led me to suggest miskasowin, a Plains Cree term meaning “to find one’s centre,” as a goal of Indigenous Science Education, which I interpret as a process of “learning to relate,” fostering more relational worldviews and identities that connect us in multiple ways with the dynamic, living, patterns of nature. I describe my process of miskasowin as shaped by complexity and Indigenous knowledges and occurring through a “slow pedagogy of relations” that involved ceremony, story, land, and language, and that fostered a deeper sense of humility and reverence for life.
Preface

This dissertation is an original scholarly product of the author, Jeff J. Baker. The study, *Investigating participatory curricula: Indigenous knowledge and science education*, was approved by the UBC Behavioural Research Ethics Board (Ethics Certificate number H10-01774).

Portions of Chapter 1, Introductions, were published in an article co-authored by my late father, Lee Baker (pp. 7-12). The article drew on stories from his childhood to describe how his life influenced my research interests.


A version of Ch. 3, Researching Indigenous Science Education, is being published in a forthcoming book.


Dr. Brent Davis provided Figure 3, Qualities of Indigenous knowledge and Western science, which appears on p. 92.
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I would like to give thanks to all those who have supported me on this journey. To my mother and late father, Shirley and Lee Baker, who gave me life and instilled a respect for creation, and to my daughter, Ena, who has been my greatest teacher, I express my profound gratitude. To my grandparents, Margaret and Norman Wick and Anne Hall and Mah Hee, and the ancestors who came before them, I give thanks for the many gifts you have provided. I would also like to acknowledge the unwavering support of my sister, Carmen Gillies, and her family, as well as that of my aunts, uncles, and many cousins.

I say pilamayaye (thank you) to Don Speidel, for accepting me, supporting my desire to learn, and opening up a new world; and to the entire Speidel family for welcoming me as one of your own. I offer sincere gratitude to Darlene Speidel and Barry Ahenakew for sharing your time and understandings, and for accepting my request to learn and grow with you. I also acknowledge other elders and knowledge keepers who have contributed indirectly to this work: Tracy Wilson, Mike Maurice, Walter and Maria Linklater, Mary Lee, Delvin Kanewiyahiho, Rose Roberts, Norman Fleury, and many others. I further acknowledge the support of my spiritual family: the Speidels, Sanford Strongarm and family, Nelson Genaille, Randy Morin and family, Lionel Tootoosis and family; Bob Badger and family, Bob Merasty and family, Cory McCafferty, Tommy Christian, and the many others who join us to pray and give thanks.

To my supervisor, Dr. Cynthia Nicol, and committee members, Drs. Brent Davis and Jo-ann Archibald, I offer my humble thanks for your guidance, generosity, kindness, and
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For nitânis, who came early, and nohtâway, who left too soon.
Chapter 1: Introductions

1.1 Introductions

tânisi êkwa tawâw. Hello and welcome. This dissertation shares my experience as an âpihtawikosisân (Métis person) pursuing qualitative research in Indigenous Science Education (ISE), an arena of educational inquiry and practice where issues of equity and sustainability intersect and overlap. My research has focused on decolonizing and Indigenizing PreK–12 science education by respectfully bridging and weaving aspects of Indigenous and Eurocentric knowledge systems in ways that might cultivate more relational worldviews and identities. It was conducted through four years of participation and relationship building in the local Indigenous education community in my hometown of Saskatoon, Saskatchewan, particularly through ceremony, and employed conversation and anecdotal narrative as primary methods. I could never have predicted the paths I would travel when I began this research, or the impact that it would have on my life. It has been a challenging, transformative, and rewarding experience, and I am very grateful for it. As with most memorable journeys, where you think the path leads may not be where you end up. Adventures happen. Encounters change you. Relationships open new paths.

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2 nêhiyawêwin (Plains Cree) and other Indigenous languages will be used throughout. These words will be italicized, and the language of origin for non-Plains Cree terms will be provided in the text or a footnote.
3 The Métis are one of the Indigenous peoples of Canada (with the First Nations and Inuit), a distinct nation of mixed Indigenous and (often) European lineage. The literal translation of âpihtawikosisân is “half-son.”
4 The term “Indigenous” is primarily used in this work to denote the First Nations, Métis, and Inuit peoples of Canada, a group who are legally described by the term “Aboriginal” as defined in the Constitution Act of 1982. Indigenous is also often used to refer to First Peoples globally.
5 The terms Eurocentric, Euro-Western, and Western are used interchangeably, as discussed in Chapter 2.
A significant new path opened for me when I met Don Spiedel, a Lakota waokiye with the Saskatoon Public School Division (SPSD), who introduced me to ceremony. I had hoped to develop relationships with the community and work closely with elders and knowledge keepers in my research but had never considered ceremony as a central form of engagement. Nevertheless, soon after meeting Don I was invited to help pick rocks for the sweat lodge, a proposition that both excited and terrified me. I was honoured to have been asked but also scared of breaching protocol, fearful of the unknown. My fears subsided as I began to learn more, and a short time later I found myself participating in an *inipi* at one of SPSD’s seasonal gatherings. I had only attended a sweat once before, several years earlier at the request of a friend wanting someone to accompany her. For that first experience I had known it would be hot but little else, and was mostly focused on surviving it. Despite my ignorance the Ojibwe Elder leading that sweat accepted our offering of tobacco and we were welcomed into the lodge.

This time was different. This was a Lakota sweat being led by a friend and mentor, and I had received teachings regarding the ceremony’s nature and purpose. Perhaps more importantly, I was different too. When it was my turn to speak during the prayer round, my nervousness faded. Clearly and quietly, I gave thanks for everything that had brought me there, and to the elements of fire, earth, air, and water for providing all that was needed for the ceremony to happen. Pausing briefly, I continued, “*this feels like coming home.*” The comment reflected my recent return to Saskatoon after a lengthy absence and a reconnection with my Indigenous roots, but there was more to it than that. Humbly sitting on the damp Earth in the dark warmth of a willow and canvas lodge that

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6 Lakota for traditional helper.
7 A Lakota term for the sweat lodge purification ceremony.
mimicked a mother’s womb, I had found a place where the beliefs and values I had been cultivating were being put into practice.

My experience of coming home, of returning to my community and finding a place where I fit within it, has been central to this research. The decade of international traveling and teaching that preceded my return had taught me a great deal, including the importance of community for maintaining health and enacting change. Hence, my return satisfied a deeply felt need for roots and allowed me to invest in long-term relationships with like-minded people, all of which has contributed to my own journey of miskasowin.\(^8\) to my personal, evolving sense of relationality. My travels also helped me understand the importance of engaging multiple perspectives when addressing problems or issues of collective concern, especially in contexts of cultural diversity. This dissertation explores one way that diverse knowledge systems, those of Indigenous and Eurocentric sciences, might be engaged to address issues of socio-ecological health and well-being.

### 1.2 Research Statement

This research explores the transformative possibilities of Indigenous Science Education (ISE) (i.e., the respectful inclusion of Indigenous knowledge in science education) for catalyzing the emergence of more equitable and sustainable ways of living. It is an educational response to humanitarian and ecological crises, and draws on the holistic frames of complexity and Indigenous knowledge systems to balance the dominance of the mechanistic paradigm in which these crises are rooted and that permeates school science. This exploratory research pursued a number of avenues for change (e.g., the inclusion of Indigenous knowledge systems in science curricula, creation of professional development opportunities, etc.).

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\(^8\) The process of finding one’s centre, or true sense of self.
modules for ISE) and eventually came to focus on the capacity of ISE to catalyze diverse journeys of *miskasowin*—the cultivation of more relational worldviews and identities—sharing the story of learning and transformation that occurred as a means of supporting others striving to respectfully include Indigenous knowledges in their science teaching. It is not intended as a path to be followed, but as an instructive example of the transformative power of ISE.

1.3 Context and Scope

When communicating across diverse worldviews it is often useful to establish a shared context that enables collective understandings to emerge. A shared language is central to this but also problematic, as worldviews and beliefs are deeply embedded in language. Significant issues of translation can arise when communicating across the verb-based, mostly oral structure of Indigenous languages and the noun-based, written form of Indo-European languages (Archibald, 2008; Ong, 1982; Whorf, 1950). While *nēhiyawēwin* and other Indigenous languages are referred to throughout, a central limitation of this work involves engaging Indigenous knowledges primarily through written English. A second substantive limitation regards my nascent understandings of Indigenous knowledges (largely Plains Cree and Lakota). While this research constituted an intensive learning process over a number of years, I am conscious of how very little I know (in comparison to what there is to be known), and offer this story as a single snapshot from an ongoing, life-long process of learning.

The scope and scale of humanitarian and ecological crises (e.g., poverty, climate
change, HIV/AIDS, biological and cultural diversity loss, etc.\(^9\) across *okāwimāwaskiy* (Mother Earth) comprises a foundational context for this research. We are living in an age of human induced biospheric decline—the systems on which we rely for survival are undergoing radical change as evidenced by measures of human and planetary health, with human activities largely responsible. I am concerned with my complicity in these crises and am critical of the multiple oppressions that fuel them. Indigenous peoples are often on the front lines of these crises, and this research brings Indigenous knowledges further into the fray. I consider this weaving of Indigenous and Eurocentric knowledge systems an act of creative resistance, attempting to identify, co-create and participate in effective educational responses.

While a multitude of knowledge traditions possess valuable insights with regard to remediating these crises, this research has been shaped by the contexts of my ancestry, my life experience, and *mînsihk* (place of berries), the city of Saskatoon, Saskatchewan, where I grew up, where I again reside. My focus on Indigenous and Eurocentric sciences is partially pragmatic, a reflection of my ancestry and experience as a science educator. It is also strategic, as science is frequently viewed as the dominant knowledge of the West (Smith, 1999) and science classrooms are critical sites of contestation where non-Western students and knowledges are often marginalized (Aikenhead, 2001). As a result, few Indigenous peoples pursue programs or careers in science, thus limiting our capacity for economic development and sovereignty. Hence, this research is an attempt to improve science education for Indigenous learners while simultaneously fostering *miskasowin*.

\(^9\) For more information on these crises please see the United Nations Human Development Report (2014), the Millennium Ecosystem Assessment (2005), and the most recent report of the Intergovernmental Panel on Climate Change (2014).
The city of Saskatoon, Saskatchewan, is home to a rapidly growing demographic of young Indigenous peoples,\textsuperscript{10} many of whom are mired in cycles of poverty, addictions, violence, and other health-related issues (e.g., diabetes, HIV/AIDS) stemming from the intergenerational impacts of Canada’s colonial history and ongoing forms of oppression. The attempted cultural genocide perpetrated against Indigenous peoples; which included the forced removal of children to Residential Schools, the control of movement and economic activities of status Indians via the Indian Act, and the intentional starvation of uncooperative communities; is continued in ongoing education funding inequities and other contemporary forms of marginalization. There is thus a dire need for research that directly addresses the abovementioned issues and provides immediate support.

While my research aims to improve science education, it is unlikely the sharing of my story will provide immediate relief to those in the situations described above. This is a significant limitation of my research, and I have seriously considered the effectiveness and ethics of this work. I view this research as complementary to that occurring on the ground (e.g., in a homeless shelter, classroom, or youth centre) or addressing systemic issues of policy organizational structure. Immediate interventions and systemic changes are needed to ethically and effectively create more equitable and sustainable societies but a further important aspect of the change required is personal, pertaining to the attitudes, perceptions, and beliefs we hold about one another and the world we inhabit. It is crucial for research to contribute to specific interventions and larger systemic change but it must

\textsuperscript{10} In the 2011 National Household Survey 1,400,685 people self-identified as having Aboriginal identity, representing 4.3\% of the total Canadian population (Statistics Canada, 2013). Canada’s Indigenous population increased by 232,385 people, or 20.1\% between 2006 and 2011, compared with 5.2\% for the non-Indigenous population. The largest numbers of Aboriginal people lived in Ontario and the western provinces (Manitoba, Saskatchewan, Alberta, and British Columbia).
also help foster individual change, and the emotive power embodied in sharing our stories is perhaps our most powerful agent of personal change and transformation.

1.3.1 nitâcimowinisin (A little of my story)

In contextualizing the story of transformation that occurred through my research it is important for me to share nitâcimowinisin as an attempt to articulate the beliefs and values I brought into this research and my reasons for pursuing it. Laying out the path I travelled prior to this research may also help contextualize the changes I experienced, particularly with regard to my personal, evolving senses of Indigeneity and miskasowin. In sharing nitâcimowinisin I also honour the Indigenous protocol of introducing oneself, allowing those you are meeting to place you in their understanding of local relations (Moreton-Robinson, 2000; Steinhauer, 2001). The dual purpose of this introduction is to allow me to connect with the educators and scholars reading this work, and to locate myself in relation to my research (Absolon & Willett, 2005).

I was born in the late fall of 1973 in Uranium City, a mining town in northern Saskatchewan, but moved to Saskatoon before my first birthday, where I spent the next twenty years. While my ancestry is diverse (Norwegian, Chinese and Métis ancestry), the cultural orientation of my upbringing was that of a Western, middle class, nuclear family. My parents, like many others, were disconnected from their cultural heritage by a variety of factors. My maternal Norwegian great grandparents immigrated in the early 1900s and experienced difficulties maintaining their culture with an educational system predicated on creating English-speaking, patriotic citizens (Katz, 1976; Osborne, 1999). Oppressive race-based policies (e.g., Indian Act, Residential Schools), the collapse of the fur trade, and increasing numbers of European settlers forced more violent dislocations on my
Indigenous ancestors.\textsuperscript{11} My father was severed from his Chinese heritage at age three when his father passed away, and from his Métis roots when he chose to disassociate himself from his family later in his youth.\textsuperscript{12}

I was fortunate to have had a chance to speak with my father at length while preparing a co-authored paper addressing his influence on my academic work (Baker & Baker, 2010). Foundational experiences canoeing, backpacking, and cross-country skiing with him had helped deepen my sense of connection with the natural world. Despite not having gone camping until he was living in an orphanage as a teenager, he had somehow retained a spiritual appreciation for nature. In his words:

\begin{quote}
I've always been in awe of the power of nature. Like a tree that can grow on a rock when there's not a bit of dirt around, or a plant that will shoot up between a crack in the cement. Nature is really powerful, and I just like being a part of it. (p. 106)
\end{quote}

In speaking further his understanding of spirit became more apparent, including a sense of humility with respect to the mystery of creation, an underlying purpose in nature, and the presence of a power animating all life. While I was never aware of it growing up, and it was never termed Indigenous, these conversations helped me understand how my father had influenced my own evolving sense of relationality and Indigeneity.

My earliest recollection related to a personal sense of Indigeneity occurred in grade school during a solitary lesson on Indians. The teacher put up a drawing of a man in a headdress and discussed how Indians used the buffalo to meet their needs, how they wasted nothing, and how we could learn from their example. Faced with the stoic face on

\textsuperscript{11} See Daschuck (2013) and Savage (2012) for some recent work examining this dislocation.
\textsuperscript{12} For a more thorough discussion of my father and his influence on my life and research, see our co-authored article (Baker & Baker, 2010).
the overhead, I reflected for the first time on what being “Indian” might mean. Who were these people? Who was I? And who was my father, if he was one of them? These questions remained but lay dormant until I enrolled in the Saskatchewan Urban Native Teacher Education Program (SUNTEP), my first prolonged encounter with Indigenous peoples and cultures. I was quickly accepted as one of the family, and was struck by the sense of warmth and community that bonded our cohort. It was a positive experience, one that initiated a long, uneven, and ongoing process of reclaiming my Indigenous identity.

While at SUNTEP I completed my teaching internship at a high school in New Zealand, where roughly half the students were Maori, as were several teachers and staff. I was struck by how similarly Aotearoa’s Indigenous peoples had been impacted by colonization but also buoyed by their progress. In addition to the presence of Maori students, teachers and staff in the school there was a marae on the school grounds where elders provided counseling and taught classes in Maori culture and language. My experiences in New Zealand helped me understand that the depth of the racial divide that characterized my experiences in Saskatoon—including the exclusion of Indigenous peoples, knowledges, and practices from institutions of formal education—was not inevitable.

My experiences in New Zealand also marked the beginning of a transformative period of travel. Over the next decade I spent time living and working in England, Italy, Canada, Taiwan and Turkey. These experiences profoundly impacted the way I related to the world, strengthening feelings of interconnectedness and empathy with diverse people and places, and broadening the boundaries of my ethic of care (Noddings, 1984). I gained

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13 A Maori term for New Zealand.
14 A traditional cultural meeting place.
a greater appreciation for our common humanity, as most people I met seemed to want the same things: health, happiness, and a future for their children. I also began to view diverse cultures as unique, successful adaptations to specific contexts and places, and realized that my own culture, which was and largely still is, Western culture, is a force of globalization and homogenization. I began searching for a source of common ground, as both a foundation for collaborative actions toward social and ecological justice and a means of remedying my own internal contradictions (e.g., the Métis experience of being oppressor and oppressed (Richardson, 2001)).

These experiences prompted reflection on what the purpose of education might be, including my own role as an educator, in an age of human-induced biospheric decline, and spurred my pursuit of M.Ed. studies. It was during graduate studies that I began to consider the value and concept of life as a potential source of commonality, an interest that became personalized when introducing myself to my classmates in graduate courses. After describing my ancestry I would sometimes be regarded with a curious look and the innocent but somewhat off-putting question, “So, what are you?” to which I eventually began replying, only half-jokingly, “Human” or “Alive.” After learning of the perils of anthropocentrism (a human-centered perspective) through a review of environmental philosophy, I began to focus more intensely on biocentrism (Agar, 1997, 2001), on the value and concept of life, as a potential source of common ground and as a growing element of my own identity.

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15 The inherent value placed on life in most cultures positions it as a potentially unifying concept. Competing ideas over what life is and which forms are of most worth, however, have overshadowed this commonality, as evidenced in today’s high rates of human fatality and species extinction.

16 In short, a human-centered view risks alienating humanity from the environment, positioning us above the Earth and our non-human relatives, and viewing both narrowly as resources for human benefit.
In my search for a conceptual frame to guide my critique of formal education as a site of cultural homogenization that was diminishing possibilities for creative change and evolution, I was directed toward some work in education that drew on the complexity sciences (Davis & Sumara, 2006). I had previously engaged with some work in this field (e.g., Glieck’s *Chaos* (1987) and Capra’s *The Turning Point* (1982)) and immediately was drawn to this new offering. Considering life through the lens of complexity thinking, which is concerned with “the philosophical and pragmatic implications of assuming a complex universe” (Davis & Sumara, 2006, p. 18), helped broaden my understanding of life, and of myself, from that of the individual organism\(^{17}\) to one inclusive of the dynamic relationships with other organisms and systems (e.g., ecological, climactic, geologic, social, cultural, etc.) on which we rely for survival (Capra, 1996).

Complexity thinking (Davis & Sumara, 2006) also helped me identify and critique the mechanistic worldview into which I had been enculturated through K–12 schooling, largely through science education. Mechanistic thought arose during the Enlightenment and Scientific Revolution, and has contributed to contemporary crises through ideas of reductionism and certainty (Capra, 1996), which led to individual-focused notions of self devoid of interdependence with ecological systems, and rendered divergent knowledges irrelevant, silencing them as unscientific. Among the ideas erased through this silencing were notions of holism that viewed humanity as co-existing with an animate, personal universe. These were replaced by a view of an inert, impersonal universe subject to being controlled by those with sufficient knowledge for their own purposes. While critical of the universal application of mechanistic thought, I remain aware of its power and utility,

\(^{17}\) A noun, often defined as an object that can be distinguished from its non-living environment (www.dictionary.com).
and thus view complexity and Indigenous knowledges as means of complementing it, an attempt to balance its dominance rather than eliminate it.

Hence, my interest in ISE grew from my M.Ed. thesis on biocentric education (Baker, 2008), which drew on biocentric (i.e., life-centered) philosophy (Agar, 1997, 2001) and complexity thinking (Davis, 2004; Davis & Sumara, 2006) to explore alternatives to mechanistic perceptions of formal education and life. If contemporary crises are indeed rooted in a “crisis of perception” (Capra, 1996), where the dominance of a mechanistic worldview has positioned humanity as both separate from and capable of controlling the more-than-human world, then they directly challenge “those institutions presuming to shape minds, perceptions, and values” (Orr, 2004, p. 27). My doctoral research builds on my M.Ed. (Baker, 2008), relating how complexity thinking opened a path to Indigenous knowledges and prompted a return to my home community where I began the process of reconnecting with the Indigenous education community and seeking to enact transformative educational change through the respectful inclusion of Indigenous knowledges in science education.

1.4 nikiskinohamâkêwak (My teachers)

I would like to acknowledge and honour those most closely involved in my research, my advisory committee and the elders and knowledge keepers who so graciously shared their time and experience. I have learned a great deal from these kiskinohamâkêwak, and these words do little to express the sincerity of my gratitude for their contributions.

18 My MEd was completed in the Department of Educational Policy Studies (Theoretical, Cultural and International Studies in Education) at the University of Alberta under the supervision of Dr. Makere Stewart-Harawira.
19 Plains Cree for “teachers.”
My doctoral supervisor, Dr. Cynthia Nicol, has been instrumental in supporting the creation and completion of this work. Cynthia introduced me to participatory action research and Indigenous methodologies as a student in her research methodology class, and I gained valuable experience working with her on research in culturally responsive mathematics education. Cynthia is a prominent scholar in Indigenous Math Education and has strong connections to Haida Gwaii on British Columbia’s Pacific Northwest coast, where she taught prior to pursuing her academic career.

Dr. Brent Davis has been equally supportive as a committee member and former supervisor, and inspired me to pursue doctoral studies when I met him at the University of Alberta near the completion of my Masters degree. Brent’s work in complexity and education has been instrumental in helping me comprehend the limitations of mechanistic thinking and the need for more holistic perspectives, and he has steadfastly supported my journey toward Indigenous knowledges as a personal and academic pursuit.

Dr. Jo-ann Archibald (Q’um Q’um Xiiem), of the Sto:lo Nation, has provided invaluable insight and feedback as an Indigenous member of my committee. Jo-ann also provided a crucial foundation for my work by instructing the only doctoral level course in Indigenous education offered at the University of British Columbia during my studies. I was fortunate to have also learned with Jo-Ann in some scholarly work with Cynthia and as part of an editorial team with the Canadian Journal of Native Education.

Donald Speidel (Hoksila tatanka) is a Lakota waokiyé and cultural liaison with Saskatoon Public Schools who I was introduced to soon after returning to Saskatoon. For the past four years I have been working with Don and his family as a ceremonial helper,

20 Dr. Davis was my doctoral supervisor until his departure to the University of Calgary.
21 Lakota for “Buffalo boy.”
22 Lakota for “traditional helper.”
and have come to regard him as a relative, friend, and mentor. Don is from the Standing Rock Sioux Reservation in South Dakota but has lived most of his life in Saskatchewan. By introducing me to ceremony and prayer, Don has had the largest impact on me of any relationship developed during my research. *Pilamayaye kola.*

Darlene Speidel (*Kimimilaskawin*) is Don’s mother, and I first met her early on during one of the ceremonies I was helping with. Her knowledge of Lakota lifeways has been supplemented by work with diverse elders and knowledge keepers through work with the Saskatchewan Indian Cultural Centre. Darlene holds an M.Sc. in Educational Administration, and has provided important guidance as a role model capable of walking in traditional Indigenous and academic worlds. I am grateful to Darlene for her patience, and for sharing time and food with me talking at her kitchen table.

Barry Ahenakew is a *nêhiyaw* ceremonial leader and former Chief of the Atâhkakohp Cree Nation in Saskatchewan. I relate my first encounter with Barry, which occurred three years ago, later in this work, but would here like to express gratitude for his support of my research; for sharing sacred stories and allowing me to record them in print, inviting me to his ceremonies, encouraging me to pursue a career in academia, spending time on the land, and his prompt responses to my occasional text messages about *nêhiyaw* terms. *kinanâskomitin.*

1.5 Overview

This dissertation is structured to mirror my experience progressing through my doctoral research from its inception to completion, and documents processes of learning through

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23 Lakota for “Thank you my brother.”
24 Lakota for “White butterfly woman.”
25 Plains Cree for “Thank you.”
increasing participation and immersion in Indigenous educational contexts, including ceremonies.

In Chapter Two, *Complexity as a Path to Indigenous Knowledge*, I outline the conceptual frame I brought to my doctoral research, reviewing and synthesizing literature on complexity and Indigenous knowledge systems, and highlighting complementarities, tensions, and combined transformative possibilities. Tensions include issues around spiritual belief and values, and similarities include a focus on patterns, relationships, and valuing holistic understandings. Combined transformative possibilities are addressed through discussion of decolonization and Indigenization, shifting aspirations for control toward those of co-existence and fostering *miskasowin*.

In Chapter Three, *Researching Indigenous Science Education*, I discuss the methodology through which I pursued my doctoral research, describing how complexity and Indigenous knowledge led to interests in participatory action research and Indigenous research methodologies, which I wove into a form of Indigenous Métissage that employs emergent research processes and seeks to create diverse knowledges, relationships, and transformations. I share a narrative of my research journey and discuss conversation and anecdotal narrative as relational research methods that were employed. I conclude by addressing the benefits and challenges of this approach to research.

In Chapter Four, *Conceptualizing Indigenous Science Education*, I relate my understanding of ISE as a process of respectfully including Indigenous knowledges in science education as a means of complementing and balancing the predominantly mechanistic orientation of school science. I also introduce *miskasowin* as a goal of ISE that links issues of equity and sustainability; address ISE through connections to
transformative learning, culturally responsive education, and place-based education; discuss key realizations that led to my interest in ISE; and review bridging, two-eyed seeing, and weaving as metaphors for teaching ISE.

Chapter Five, *Practicing Indigenous Science Education*, describes the impact of ISE on my own teaching practice in terms of movement toward a “slow pedagogy of relations.” I also discuss the need for foundational professional development, articulate *miskasowin* as a process of “learning to relate,” and position complexity as a path to ISE, drawing connections between concepts from complexity and the meanings of relevant terms in *nēhiyawēwin*. I conclude this chapter by offering a few activities and resources as examples of possibilities for ISE that arose through this research.

Chapter Six, *Closing Reflections*, offers a brief summary of my doctoral research and provides an opportunity for me to reflect on my journey. I discuss identity, story and ceremony as aspects of the personal change I experienced; share a few recommendations for teaching and research in ISE; and list directions for future research in ISE. I close with an acknowledgement of the need for constant change and adaptation in a living, relational universe, and the hope that my doctoral research may contribute in some small way to this realization.
Chapter 2: Complexity as a Path to Indigenous Knowledge

2.1 Complexity as a Path to Indigenous Knowledge

Educators seeking to foster *miskasowin* by respectfully engaging Indigenous knowledges in their teaching face a number of challenges. Acknowledging the socially constructed and culturally situated nature of all knowledge, and thereby the existence and viability of diverse knowledge systems, are initial challenges for many teachers. My story of change through this exploratory research in ISE, however, begins after those challenges had been met, largely through my international teaching experiences and studies in biocentric education (Baker, 2008). Other factors have also aided my journey toward Indigenous knowledges. A deeper appreciation for reconnecting with our roots (i.e., land, ancestors, histories) to remediate contemporary social and ecological crises and of the limits of Eurocentric science for addressing these crises have both been important factors in my movement toward Indigenous knowledges.

A further challenge encountered by educators, that this chapter is intended to address, is how to connect with and comprehend Indigenous worldviews, especially when they may differ from one’s own. In my experience, complexity (i.e., the interdisciplinary study of complex systems) has offered an important lens that opened a path to Indigenous knowledges and helped me to understand the holistic epistemologies and ontologies of Indigenous worldviews. In this chapter I review some of the literature on complexity and Indigenous knowledge systems (IKS), highlighting areas of complementarity, tension, and combined transformative possibilities. It is worth noting that this chapter is focused on a period of *learning about IKS* prior to the experience of *learning IKS* through

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26 I am not downplaying the importance or potential difficulties involved in overcoming these challenges, which are addressed later in Chapter 4.
ceremony that significantly deepened my understanding (Newhouse, 2008). I share this frame connecting complexity with IKS in hopes that it will open a similar path and lead to deeper engagement with IKS for others as well.

2.2 **Introducing Complexity and Indigenous Knowledge Systems**

Reading literature by Indigenous scholars and dialoguing with colleagues helped sharpen my awareness of similarities between biocentric complexity thinking (Baker, 2008) and IKS, prompting the realization that many peoples live through worldviews based on revering life as understood through a deeply relational lens, and that some are relatives and recent ancestors of mine. I have also been emboldened by those scholars, Indigenous and non-Indigenous, who have recognized the creative possibilities that exist at the intersection of Indigenous and Eurocentric worldviews, and the importance of these syntheses for sustaining life in the twenty-first century (e.g., Barnhardt & Kawagley, 2003; Cajete, 2000b; Knutson & Suzuki, 2006; Peat, 1994).

Before engaging in discussion on the complementarities, tensions and combined transformative possibilities of complexity and IKS, an introduction to each is provided. “Complexity” refers simultaneously to the complexity sciences, complexity theory, and complexity thinking (Davis & Sumara, 2006), all of which are described in more detail below. The term “Indigenous knowledge systems” is used to denote Indigenous bodies of knowledge, ways of knowing, ethics, values, and ontologies of being.\(^{27}\) Complexity and IKS are rooted in radically different cultural milieus, with complexity emanating from the relatively recent development of the new sciences (e.g., evolution, ecology, quantum physics) and IKS based in millennia of experience with places and landscapes, however,

\(^{27}\) Other terms are also used in the literature, including “Indigenous knowledge” (Battiste, 2002), “Indigenous ways of living in nature” (Aikenhead & Michell, 2011), and “Indigenous science” (Colorado, 1988; Snively & Corsiglia, 2001).
numerous commonalities have also been identified (e.g., Barnhardt & Kawagley, 2003; Cajete, 2000b; Capra, 1996; Little Bear, 2000). In brief, complexity comprises a way of perceiving and examining reality as a matrix of interconnected adaptive systems and Indigenous knowledges embody millennia of experience striving to live in balance with a mysterious, animate and complex reality.

2.2.1 Complexity

The field of complexity studies is a collection of emergent areas of inquiry that examine adaptive, non-linear systems (Smitherman, 2005; Waldrop, 1992). These systems exist on scales from the micro to the macro, and include swarms of insects, weather systems, the Internet, the brain, and societies. The increasing attention paid to such systems in physics, biology, economics, cognitive science, and computer science (among others) prompted physicist Stephen Hawking to dub this century the “century of complexity” (Davis & Sumara, 2006, p. 3); a sentiment echoed by Urry (2005) in his assertion that a “complexity turn” has taken place in the physical and social sciences.

Fleener (2002) identified the origins of the new complexity sciences with the work of Darwin in 1859 and physicists Bohr, Heisenberg, and Einstein in the 1920s (p. 53), who were among the first to challenge the classical notion of a mechanistic, stable universe and acknowledge the inevitability of change and uncertainty. Chaos theory, cybernetics, artificial intelligence, fractal geometry and nonlinear dynamics have all contributed to the emergence of the interdisciplinary field of complexity (Davis & Sumara, 2006, p. 8). Richardson and Cilliers (2001) described three general streams of complexity: hard complexity science, soft complexity theory, and complexity thinking. The hard approach is aligned with the quest for a “theory of everything” in physics and is
based in the belief that the richness of reality can be reduced to “a handful of powerful, all-embracing algebraic expressions” (p. 5). The soft approach involves the application of concepts derived from hard complexity in the social realm. “Complexity thinking” lies somewhere in between, addressing the “the philosophical and pragmatic implications of assuming a complex universe” (Davis & Sumara, 2006, p. 18).

The sudden rise of complexivist research and the “ubiquity of complexity” (Richardson & Cilliers, 2001, p. 7) in nature may prompt assertions that complexity constitutes a totalizing metanarrative (Lyotard, 1984) similar to classical, mechanistic science. While the hard complexity sciences may warrant this label, complexity thinking embraces intersubjectivity, abandoning classical science’s assumption that “that there are irrefutable, foundational truths out of which other truths might be constructed” (Davis & Sumara, 2006, p. 35). Rather than a metadiscourse, complexity thinking comprises an interdiscourse among diverse disciplines, and may thus serve as a frame for bringing diverse knowledges into further conversation. This research embraces the sensibilities of complexity thinking, eschewing hard complexity’s quest for a theory of everything.

2.2.2 Indigenous Knowledge Systems

Indigenous knowledge systems have arisen through a plurality of peoples’ long-term experiences living within particular localized places and landscapes.28 IKS denote both “bodies of knowledge” and “ways of knowing,” and are deeply rooted in Indigenous languages, which reflect complex relationships among people, land, and nature (Brayboy & Maughan, 2009). IKS do not include the contemporary knowledge of all Indigenous people, as many (including myself) have been well marinated in Western paradigms, but

28 Because of this diversity, some scholars prefer the term ‘Indigenous knowledges’ (e.g., Brayboy & Maughan, 2009).
refer instead to the diverse and comprehensive systems of knowledge that exist among land-based peoples globally. Rather than a purely academic construct, Indigenous knowledges refer to active ways of living and being in the world. While most Indigenous populations have names in their own languages, often translating roughly to “the People” or “the First People,” the term *Indigenous* has been selected by Indigenous groups in international forums and signifies the global population of First Peoples (Smith, 1999). In the Canadian context it includes the First Nations, Inuit and Métis peoples, and is used synonymously with *Aboriginal* and sometimes *Native.* These latter terms are sometimes critiqued for their divisiveness, for homogenizing diverse Indigenous peoples, and for the negative connotations they have carried through Canada’s racist and colonial history (Beck, Walters, & Francisco, 1990, p. xiii). The term *Indian* also falls into this category, and is less often used in public discourse, a notable exception being among some First Nations and Métis peoples who have embraced the term. At various times during my research I have been regarded as an Indian, or as “becoming Indian,” a signal of my acceptance within the community.

Indigenous knowledges have also been referred to as “folk knowledge,” “local knowledge,” “non-formal knowledge,” “culture,” “indigenous technical knowledge,” and “traditional knowledge” (Battiste, 2008, p. 90). To varying degrees these terms entail an undervaluing and limited understanding of IKS. For example, identifying IKS solely as “traditional” impedes consideration of their adaptive nature and contemporary relevance.

29 In the United States, Indigenous includes the Native Americans or American Indian, Alaska Native, and Native Hawaiian populations.
30 Alfred (2005) shuns the term Aboriginal as enshrined in the Canadian constitution, refusing to be defined by a nation founded on the oppression and attempted genocide of his people.
Hence, Indigenous knowledge is in part a political term\textsuperscript{31} asserting both the existence and contemporary importance of IKS. IKS has also been deemed “naturalized knowledge” derived from observation of the natural world, mirroring the knowledge of fishermen, farmers, and hunters etc. (Lickers, 1997). While similar in their ecological and cyclical understandings of nature, the comparator “naturalized knowledge” ignores important differences regarding the spiritual beliefs and values of IKS (McGregor, 2008).

The variety of contexts in which IKS evolved has resulted in a diversity of locally-specific knowledges (Battiste, 2002) that remain united by a sense of relationality, notions of responsibility to self, community, and creation, and a responsible use of power (Castango & Brayboy, 2008, p. 951). Castellano (2000) offers further commonalities, noting that Indigenous knowledge is sourced from the interaction of traditional teachings, empirical observations and revelation, and is “personal, oral, experiential, holistic, and conveyed in narrative or metaphorical language” (p. 25). As summarized by Michell et al. (2008), Indigenous knowledge is “action and wisdom with elements of spirituality and empiricism—a holistic approach that seeks harmony with nature for survival” (p. 7).

2.3 Divergent Origins

This discussion of complexity and IKS is situated within a broader interaction between Western and Indigenous cultures, knowledges, and worldviews. Due to the varied forms of oppression, exploitation, and genocide that have characterized this relationship, this tension is of primary importance. The othering of Indigenous peoples required to justify colonization has become manifest in common perceptions of Indigenous culture as archaic and/or romantic (e.g., the “eco-Indian” or “noble savage”) (Marker, 2006),

\textsuperscript{31} As is the term Indigenous science (see Cajete, 2000b; Michell et al., 2008; Peat, 1994).
reifying Indigenous knowledge as an artifact of the past and attenuating its contemporary value as the way of life of a people.

Complexity’s rootedness in Western scientific discourse also evokes tensions with IKS, as science was used to support the racist beliefs justifying colonization (e.g., notions of evolutionary superiority (Deloria Jr., 2004)). While this mentality is now challenged, its impact and the residue of systemic racism have resulted in a common mistrust of Western societies among Indigenous peoples. As described by Cajete (2000b):

> Whatever form the discussion may take—political, social, economic, cultural—Indigenous people are always aware of the past and present instances of sharing with Western peoples when such relationships benefited the latter far more than Indigenous people. (p. 210)

These feelings of trepidation are especially poignant in contexts of academic research, where Western-trained scholars have othered, objectified, and taken ownership of Indigenous knowledge (Smith, 1999).

Complexity, however, has also been influenced by non-Western mystical and spiritual traditions. Bohr and Heisenberg, two founders of quantum physics, both found resonance between Buddhist philosophy and insights derived through their work (Weber, 1982). Zukav (1979) also perceived parallels with Eastern philosophy, using the Chinese phrase *wu li*, or “patterns of organic energy,” to describe the quantum physics. Hinduism (Laszlo, 2007), Taoism (Capra, 1975), and Buddhism (Varela, 1999) have all also been identified as consonant with complexity. While not as prominent in the development of

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32 Feelings I have encountered personally (as both emoter and receiver) when discussing research.
complexity, a number of scholars have also identified synergies between quantum physics and IKS (Duran, 2013; Peat, 1994).

The complexivist shift from “classical” science to the “new” sciences is perhaps of most importance with regard to resolving the tension arising from the divergent and often conflicting roots of complexity and IKS. As discussed in the following section, classical science’s dominant metaphor of the “machine” has contributed to unrealistic beliefs in the certainty of its knowledge claims, which in turn have spawned ideals regarding the human capacity for control. In contrast, complexity and IKS acknowledge a degree of uncertainty in all knowledge claims, shifting attitudes about relationships from those of control and domination toward those of balance and co-existence.

A related tension is the use of Western perspectives to validate IKS, often (mis)interpreting Indigenous perspectives to fit more neatly into Western discourse (Smith, 1999; Wilson, 2008). Indigenous knowledge has enabled generations of people to survive and prosper for millennia, and in many cases has successfully resisted oppressive policies of assimilation and attempted cultural and physical genocide. While suggesting that IKS require external validation from a more recent mode of thought that is inflicting considerable planetary harm is highly questionable, IKS must be acknowledged as viable “before a dialogue that will benefit both sides” (Cajete, 2000b, p. 308) can take place.

2.4 From Mechanistic to Non-mechanistic Perspectives

Despite their divergent origins, complexity and Indigenous knowledge present remarkably similar ideas regarding the nature of reality (Cajete, 2000b; Duran, 2013; Little Bear, 2000; Peat, 1994). Urion (1999), for example, cites chaos theory, fractals (e.g., Gleick, 1987), and the cybernetics of living systems (Maturana & Varela, 1980) as
areas of academic discourse in which “Native scholars recognize ‘new’ knowledge as being consistent with our ‘old’ ways” (p. 15). While unique, these discourses are united in their provision of more holistic, non-mechanistic perspectives, and are discussed here in contrast to the mechanistic constructs of classical science.

The mechanistic view of reality that arose through the scientific revolution and Enlightenment is a key element of modernist thinking and classical science (Doll, 1993; Bocock, 1992). As noted by Davis and Sumara (2006), it was mechanistic systems that “captured the attention of Galileo, Descartes, Bacon and Newton” (p. 9). While many of these individuals did not view the universe in simple, linear terms but were compelled to analyze it as such due to limitations in calculation power, following the successes of their approaches to understanding nature “picturing the universe as a giant clock [became] the dominant metaphor for the modern perspective” (Fleener, 2002, p. 21). Similarly, while this “machine-world” perspective may not be shared among contemporary scientists it remains central to conceptions of science as taught in schools. Inherent to this perspective are important ideas regarding reductionism, linearity, causality, certainty, and control.

Mechanistic systems can be understood through a reductionist analysis of their parts, leading to identification of fundamental particles and laws that describe their behavior. As the components and interconnections in a mechanistic system are fixed, the system behaves in a highly predictable manner. This is akin to the linear-causality of the billiard ball model of reality, where all matter is made of particles that obey the laws of Newtonian physics. Mechanistic systems are also considered closed systems (excluding inputs and outputs) that exist and function independently of context. Furthermore,
analysis of mechanistic systems through the experimental approaches of classical science demands the isolation of these systems and control of all but a few variables.

The mechanistic belief in certainty is perhaps best expressed in French scholar Pierre-Simon Laplace’s assertion that a sufficiently vast intelligence could “embrace in the same formula the movements of the greatest bodies and those of the lightest atom; for it, nothing would be uncertain and the future, as the past, would be present to its eyes” (Davis & Sumara, 2006, p. 27). The belief that nature can be known with complete predictive accuracy led to the possibility of, and eventually aspirations for, total control. Indeed, one of modernity’s great myths is that “it is to the benefit of all, the common good, for nature to be controlled by science and civilization” (Doll, 1993, p. 167).

In contrast to the reductionist thought of classical science, complexity and IKS offer more holistic understandings, albeit in different ways. While complexivist studies might be framed in transdisciplinary or interdisciplinary terms, “No separation of science, art, religion, philosophy, or aesthetics exist in Indigenous thought; such categories do not exist” (Battiste & Henderson, 2000, p. 40). Complexity might be considered an effort to reestablish holistic perspectives from the fragmented detritus of Western disciplinary specialization, and IKS sets of diverse, living, holistic perspectives rooted in long-term connections to place. While sharing views regarding non-linearity, interconnectedness, and the whole as greater than its parts, attentiveness to the importance of emotion and spirit within IKS remain as area of tension with complexity.

2.4.1 Nonlinearity and Interconnectedness

Nonlinearity is a central theme for Fixico (2003), who describes “Indian Thinking” as “seeing things from a perspective emphasizing that circles and cycles are central to the
world” (p. 1). The circle, often referred to as the “Sacred Circle” or the “Medicine Wheel” (Lane et al., 1984), symbolizes the cosmic order, with four interdependent sections representing the four directions (north, south, east, and west), the four cycles of life (birth/infancy, youth, adulthood, and elder/death), the four elements (fire, water, wind, and earth), and the four seasons (spring, summer, fall, and winter) (Lane et al., 1984; Regnier, 1994). Cycles are also an important aspect of complexity, particularly in the fields of ecology and cybernetics (Weiner, 1946), a precursor to complexity focused on feedback loops that link processes and systems. Indigenous teachings of the circle also invoke connectedness, as all things in the circle are related. With respect to the grand circle of the horizon, “all things are related within the universe” (Fixico, p. 1).

The nonlinear patterns of decentralized networks (Figure 1) (Barabási, 2002) and fractals (Gleick, 1987) also characterize complexity. Fractals and decentralized networks are found throughout nature and are described as “scale-free” because of their self-similar appearance at multiple levels of magnification.

![Figure 1 - A two-dimensional representation of a decentralized, scale-free network](image)

Indigenous people are also aware of these patterns in nature, including “that the weather’s dynamics are not unlike the mathematical characteristics of fractals, where patterns are

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33 E.g., the interdependence of the planet’s atmospheric, geologic, and oceanic cycles.
reproduced within themselves and the parts of a part are part of another part that is a part of still another part, and so on” (Barnhardt & Kawagley, 2005, p. 12).

Barnhardt and Kawagley’s (2005) depiction of fractals also reflects nestedness, a further area of conceptual congruity entailing interconnectedness. Nestedness is reflected in the Indigenous perspective of holism outlined by Archibald (2008) and Armstrong (2000) (Figure 2), which Cajete (2000b) has described in terms of “concentric rings of relationship” (p. 277). Through the lens of complexity, nestedness is reflected in the fact that complex systems are “simultaneously autonomous unities, collectives of autonomous unities, and subsystems within grander unities” (Davis & Sumara, 2006, p. 90).

Organisms provide one example of this structure, as each organism is at once an autonomous unity, a collective of autonomous unities (e.g., genes, cells and organs), and a subsystem within grander unities (e.g., a community, society, or ecosystem). The noted congruency of ecology with IKS can be attributed to this common attention to nestedness. Cajete’s (2000a) description of Indigenous education as learning about relationships in

Figure 2- Indigenous Holism (adapted from Archibald (2008) and Armstrong (2000))
context also connotes nestedness, as context begins locally with family, and broadens to include clan, community, tribe, land, and eventually “all of the world” (p. 183). Capra (1982) has noted that this layered structure need not imply the top-down power relations of hierarchy, instead referring to nested structures as “stratified” (p. 282). He uses the familiar example of the tree to illustrate this point:

As a real tree takes its nourishment through both its roots and its leaves, so the power in a systems tree flows in both directions, with neither end dominating the other and all levels interacting in the interdependent harmony to support the functioning of the whole. (p. 282)

In nested structures, all levels are connected to and capable of influencing others. For this reason, strictly reductionist analyses are inadequate, as they do not take account of the broader contexts in which phenomena are situated.

Smuts’ (1926) definition of holism as “the tendency for nature to form wholes that are greater than the sum of their parts through creative processes of evolution” (p. 26) reflects a further source of connectedness central to complexity thinking, emergence. While nestedness describes connections of the present, emergence speaks to historical relations of evolutionary origins. As described by Davis and Sumara (2006), emergence is used to describe how “agents that need not have much in common—much less be oriented by a common goal—can join into collectives that seem to have clear purposes” (p. 83). Complex systems like ant colonies and brains arise and maintain a coherent unity not through centralized control but through the nature of the relationships among their parts (Johnson, 2001). Each nested level of a complex system emerges from lower levels of complexity and contributes to the emergence of higher levels of complex coherence.
Emergence connotes the inherent creativity of nature (Doll, 1993) and has also been described as “self-organization” (Johnson, 2001). Kauffman (1995) has similarly described emergence as “order for free” and asserts that it amounts to nothing less than the reinvention of the sacred, shifting scientific perceptions of life on Earth from “we the accidental” to “we the expected” (p. 89). For Kauffman, emergence provides an important supplement to Darwin’s theory of evolution by natural selection, in that selection operates on emergent patterning, rather than random genetic mutations. The concept of emergence also more closely parallels Indigenous understandings of kinship within an animate universe than the static, inert universe of mechanistic science.

2.3.2 Emotion and Spirit

In the Indigenous perspective of holism (Archibald, 2008; Armstrong, 2000) (Figure 2) the emotional and spiritual aspects of human existence are given equal precedence with the physical and mental. The four quadrants and concentric circles of relationship are mutually dependent and interrelated, and achieving balance among them is a considered a central goal of Indigenous life (Cajete, 2000b). Complexity is generally focused more narrowly on the mental and physical, however, there is some complexivist work that complements this Indigenous perspective. Damasio (1994), for example, has drawn on neurological studies of patients with impaired brain functioning to argue that, contrary to popular wisdom, emotions and feelings provide the context and motivation needed to facilitate rational thought.

From an Indigenous perspective, emotion is closely tied to and derived from feelings of connectedness. In traditional teachings, for example, when a person lacks family or community a portion of their emotional self is said to be missing, contributing
to a lack of balance and wholeness (Armstrong, 2000, p. 39). Relationships are also characterized by feelings of empathy and care, rather than responsibility, which can be transformed more readily into actions that control and dominate. As noted by Archibald (2008), “It is respect and caring that guides my feelings and actions, not an obligatory sense of duty” (p. 61). While the lens of complexity thinking also infers a deep sense of interconnectedness, it does not assert how one should feel about those relations.

Cajete (2000b) has also discussed emotion in terms of hope, which provides “the emotional impetus to act and learn” (p. 276). The connection between hope and emotion has also been touched on by complexivists. Fullan (1997), for instance, equates hope with emotional intelligence, noting that it does not infer “a naïve, sunny view of life” but instead signifies “the capacity not to panic in tight situations and to find ways and resources to address difficult problems” (p. 221). As suggested by Moll and Baker (2009), a growing body of emotionally difficult (Alsop, 2005) knowledge regarding global crises may be impeding our collective emotional intelligence. Many are unwilling or unable to fully engage with their affective reactions to issues of such size and scope, thus limiting the capacity for collaborative responses.

The spiritual aspects of Indigenous holism are perhaps most difficult to convey, and present both complementarities and tensions with complexity thinking. Confusion around Western and Indigenous meanings of spirit is one primary source of tension. As explained by Abram (1996), the Western notion of spirit is derived from Judeo-Christian religions and defined as a form of metaphysics, in contrast to matter or flesh, and often with a primarily human association. From an Indigenous perspective, spirit animates all matter, bridging the realms of the physical and metaphysical, and embraces “those modes
of intelligence that do not possess a human form” (p. 13), including animals, insects, rivers, mountains, forests, winds, rain, and more.

Resistance to associations with spiritual New Ageism is evident from both perspectives. Professed connections between complexity and New Age thinking are generally considered erosive to complexity’s academic integrity. This is partially due to the often-dubious nature of this literature but can also be traced to the emergence of institutionalized science as a response to the dogma and mysticism of Judeo-Christian religion (The Vienna Circle, 1929/1973); where matter and measurement, rather than miracles and myth, were deemed adequate bases for knowledge. More recent attempts by complexivist cognitive scientists to explain the human need for God and spirit as resulting from neurological phenomena (e.g., Newberg, 2001) also exist in tension with the centrality of spirit to Indigenous knowledge.

Some Indigenous scholars have expressed caution about engaging in “the mystical, misty-eyed discourse that is sometimes employed by indigenous [sic] people to describe our relationships with the land and the universe” (Smith, 1999, p. 12). Smith (1999) has critiqued the Western fascination with New Age spiritualism for making Indigenous belief systems “available, yet again, for further mining and exploitation” (p. 6). She concedes, however, that Indigenous concepts of spirituality “are critical sites of resistance for indigenous peoples [and are] one of the few parts of ourselves that the West cannot decipher, cannot understand and cannot control … yet” (p. 74).

While the spiritual beliefs and teachings of Indigenous groups vary, they are united by a common belief that creation consists of energy; “All things are animate, imbued with spirit, and in constant motion” (Little Bear, 2000, p. 77). Fixico (2003), for
example, noted the importance of the Muscogee (Creek) word *ibofanga*, which signifies “that all things have spiritual energy” (p.11). Spirit is thus a central element in Indigenous understandings and feelings of interrelatedness and respect. As expressed by Little Bear (2000), “If everything is animate, then everything has spirit and knowledge, then all are like me. If all are like me, then all are my relations” (p. 78). As everything is imbued with spiritual energy, all things should be respected for their potential (Fixico, 2003, p. 2).

The Indigenous notion that existence is manifested through a flux of spiritual energy has drawn comparisons with theories of quantum physics (e.g., Little Bear, 2000; Peat, 1994). As Urion (1999) commented, “It is old hat now to remark that modern theoretical physics uses metaphors that are consistent with First Nations’ cosmologies” (p. 15). Quantum theory has revealed a limit of reductionist analysis by suggesting that fundamental particles of matter can only be described in terms of probabilities within fields of energy (Capra, 1982). At the subatomic level particles have also been observed influencing one another over great distances, and even existing in two places at once, indicating a high degree of interconnectivity and challenging some fundamental ideas of classical, mechanistic science (Bohm, 1980).

Quantum theory also accepts uncertainty, with Heisenberg’s uncertainty principle noting that the location and velocity of subatomic particles can never be simultaneously specified with total accuracy as the act of observation alters these variables. Complexity thinking provides further acknowledgement of uncertainty at the level of everyday human experience. As complex systems inherently behave in novel and unpredictable ways, when assuming the ubiquity of complexity in nature “the limited and provisional nature of all understanding has to be recognized” (Richardson & Cilliers, 2001, p. 8). IKS also
“make no claims to universality” (Castellano, 2000, p. 25). Rather than recording exact, objective measurements of nature, Indigenous knowledge has emerged through millennia of adaptation and co-evolution with the dynamic, shifting patterns of nature. IKS express “a living relationship with a specific environment that is not conceived of as either universal or conventional” (Henderson, 2000, p. 260). A further acknowledgement of uncertainty in IKS is evident in discussions of the Great Mystery (Cajete, 2000b), a term synonymous with the Great Spirit that signifies a sense of humility with respect to the place of humanity in the grand mystery of creation.

2.3.3 Epistemology, Ethics, and Values

Ideas regarding the nature of knowledge also reveal tensions and complementarities between complexity and IKS. Both perspectives view knowledge as relational processes that engage the other-than-human world, rather than an objectively based compilation of mental constructs in the human brain. The tangible relationship between observer and observed at the quantum level, for example, has prompted suggestion that the term observer be replaced with participant (Bohm & Hiley, 1993). From both Indigenous and complexivist perspectives, all knowledge is derived through participatory processes. This shared perspective is derived from the constant presence of the animate other, whether through spiritual energy or the ubiquity of complexity.

This relational, participatory perspective is also reflected in ideas of knowledge as embodied and enacted. In complexity thinking, learning is “a matter of transformations in the learner that are simultaneously physical and behavioral” (Davis & Sumara, 2006, p. 13). As complex systems adapt/learn their physical structure is altered; complex systems
thus embody their histories. Understanding learning as “a defining quality of all complex systems” (Davis, 2004, p. 169) thus expands conceptions of learners to include:

…social and classroom groupings, schools, communities, bodies of knowledge, languages, cultures, species… One might also move in a micro direction, extending the list to include organs or bodily subsystems, cells, neurons… (Davis & Sumara, 2006, p. 14)

As complex systems are both individual learners and collectives of learners, behavior does not arise through centralized control (e.g., in the brain) but instead emerges as the embodiment of collective impulses that are enacted in relation with the broader context in which the system is situated.

Brayboy and Maughan (2009) describe IKS in similar terms as processes that “encapsulate a set of relationships rather than a bounded concept, so entire lives represent and embody versions of Indigenous knowledge” (p. 3). They continue, stating that people “live and enact their knowledge and, in the process, engage further in the process of coming to be—of forming a way of engaging others and the world” (2009, p. 4–5). It is in the spiritual domain, where powerful knowledge can be revealed through dreams, visions, and intuition (Castellano, 2000),34 that IKS may part ways with complexivist approaches to knowledge and learning. While little complexivist work has addressed spiritual or quantum understandings of learning, complexity’s openness to possibilities means that such explorations may still occur.

Concepts of embodied and enacted knowledge challenge the conventional Western view of ethics as abstracted moral standards, instead considering ethics as

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34 Some forms of revelatory knowledge are considered too sacred to be shared publicly, and require special training to prepare the potential knowledge keepers for the responsibility of its appropriate use.
demonstrated through actions. This perspective resonates with Schweitzer’s (1923) belief that “true ethic begins where the use of words stops” (p. 260) and is paralleled in Varela’s (1999) concept of “ethical know-how.” Varela notes that most human activity does not result from long pontification over ethical standards but instead occurs spontaneously as we cope with what is directly in front of us. This coping is very much in the moment and occurs through processes of embodied and enactive cognition. As described above, our actions emerge through the interaction of our “ethical know-how” (i.e., embodied history) and the situation at hand.

Values and goals constitute another area of difference and potential tension between complexity thinking and IKS. IKS value life and embrace living with nature’s mysteries holistically for the purpose of survival (Aikenhead, 2001; Henderson, 2000; Lane et al., 1985; Snively & Corsiglia, 2001). As described by Cajete (2000b), seeking life pervades the various expressions of Indigenous knowledge to such an extent that it is seldom discussed or questioned (p. 272). Complexity thinking, while emphasizing our interconnectedness, does not assert particular values and can be used to exploit systems as easily as sustain them. Reflecting the dominant values of today’s societies, it has more frequently been employed in business than in education; restructuring organizations to become more adaptive, responsive, and efficient at generating profit through the exploitation of human and natural resources (Battram, 1998; Beinhocker, 2006; Lewin & Regine, 2000).

2.5 Transformative Possibilities: Decolonization and Indigenization

The preceding discussion has attempted to bring complexity and IKS into respectful conversation to highlight areas of tension and complementarity. I now turn to identifying
their combined transformative possibilities with a focus on balancing the dominance of the mechanistic worldview. I articulate these transformative possibilities as processes of decolonization, deconstructing and challenging colonial thought and practice (Smith, 1999), and Indigenization, a consciousness-raising process “focused on how Indigenous thought and action become transformative” (Archibald, 2008, p. 90).

2.5.1 Deconstructing the Mechanistic Foundation of Colonial Thought

The mechanistic paradigm of the Scientific Revolution and Enlightenment has been identified as a key element of the modern worldview (Capra, 1996), and may also be viewed as having influenced colonial thought and practice. European colonial expansion was largely driven by mercantilism (a precursor to capitalism) and the desire to access new sources of human and natural resources. Mechanistic ideas regarding certainty and its resulting hierarchy of knowledge systems were taken up by the political and financial elite of the day, supplementing pre-existing (self-serving) interpretations of Christianity, to position existing social hierarchy as part of the natural order, justifying the continued oppression and marginalization of the lower classes.

From the perspective of the colonizer, those sitting atop the hierarchy could not only control nature for their own benefit but could also feel justified in controlling those below them. In a cruel twist of humanitarian logic, the colonizers’ belief in the certainty and superiority of its knowledge in some cases led to a sense of responsibility for those below them, and a desire to lift them to the colonizers higher level, for their own good. This attitude prompted the establishment of residential schools for First Nations peoples in Canada (which demonized IKS) and the destructive paternalism that has characterized
relations between colonizer and Indigenous populations across the globe. It survives in persistent views of Indigenous knowledge as an archaic remnant from an earlier time.\(^{35}\)

This view also reflects a linear view of socio-cultural evolution and development (where successive cultures improve over time) and a reductionist focus on the individual (rather than a more relational, collective sensibility), further elements of the mechanistic worldview. The linear view of social and human evolution complemented the hierarchy established by the belief in certainty, and located Indigenous peoples and knowledges below the more recent (and believed to be advanced) European elite. The reductionist view on the individual also facilitated the ease with which these attitudes could be maintained, serving to distance and other the lower classes and Indigenous peoples, limiting emotional responses that arise through consideration of our shared humanity.

### 2.5.2 From Control to Co-existence

The nonlinearity of complexity and IKS is useful in decolonizing this mentality. From a circular or cyclical perspective, socio-cultural development takes a different meaning. All are viewed as striving for wholeness, united within the circle and changing in recursive cycles. Bifurcating patterns, which characterize decentralized networks and the prevalent Indigenous symbol of the tree, also challenge a linear view of development. In the tree of humanity, Indigenous peoples simultaneously occupy the roots and numerous branches. Thus, from this perspective Western cultures cannot move past Indigenous cultures any more than one branch of a tree can progress beyond the others; they remain united as aspects of the same entity. Furthermore, as roots are crucial to the tree’s survival,

\(^{35}\) I.e., a previous stage in human cultural evolution that is irrelevant to today’s contexts.
grounded in the Earth and providing essential nutrients and water, IKS similarly embody a deep connection to and respect for okâwîmâw askî.\textsuperscript{36}

The acceptance of uncertainty and mystery within complexity and IKS also challenges the colonial desire for control, and entails a shift toward a mentality of co-existence, co-adaptation and co-evolution with diverse beings and perspectives through an imperfect knowledge of a dynamic and evolving universe. Acknowledging a degree of uncertainty in all knowledges also opens space for intersubjectivity and an appreciation of pluralism, embracing the value that multiple sources of knowledge can bring to any endeavor.\textsuperscript{37} This does not entail an “anything goes” approach with no regard for the source of knowledge claims (Slattery, 2006) but rather encourages a “both/and” approach (Davis & Sumara, 2006) to consideration of diverse views (e.g., both Indigenous and Eurocentric views have value), replacing the “either/or” mentality of mechanistic and colonial thought (e.g., either Indigenous or Eurocentric views are correct).

The shift from control to co-existence does not deny that difference and diversity can lead to conflict but instead signifies a complementary view cognizant of diversity as essential for processes of co-creation. For example, diversity is vital to learning via the introduction of new ideas, and to life via the functions of and interactions among species in ecosystems. Further, from both Eurocentric and Indigenous lenses, it is the confluence of two sets of opposites, water and fire, and air and earth, through which organismic life on okâwîmâw askî has been co-created and is sustained. The notion of complementary binaries characterizes both IKS (Cajete, 2000b; Mohawk, 2010) and complexity thinking (Davis & Sumara 2000). Waters (2004), for example, described Indigenous languages as

\textsuperscript{36} Plains Cree for “Mother Earth.”

\textsuperscript{37} As reflected in the research practice of triangulation.
expressing a pattern of nondiscrete nonbinary dualism, where what are often taken to be distinct and oppositional pairs in English (e.g., good/evil; male/female; self/other etc.) are viewed as concepts that interpenetrate and balance one another.38

2.5.3 Toward Relational Worldviews and Identities

The interrelatedness of complexity and IKS also provide ways to foster the development of miskasowin, expanding one’s sense of self to include the animate other, balancing the mechanistic (i.e., reductionist) focus on the individual and thus responding to the crisis of perception (Capra, 1996) underlying today’s humanitarian and ecological crises. A relational worldview and sense of identity are common among Indigenous peoples, as reflected in Kovach’s (2005) description of Indigenous identity as “self in relation” (p. 21) and Cree Elder Stan Wilson’s (2001) similar concept of “self as relation” (p. 91), which extends beyond the individual to include relationships among the human and natural worlds. The complexivist concept of nestedness highlights one’s interdependence with a myriad of human and natural systems, while concepts of emergence and quantum physics serve to reanimate the inert, static, reality of mechanistic thought, suggesting a relational ontology where all elements of creation are physical manifestations, emergent patterns, of quantum flux (or spiritual energy) (Little Bear, 2000).

The fostering of miskasowin is an inevitable part of Indigenization that occurs when learning Indigenous knowledge (rather than learning about Indigenous knowledge). According to Newhouse (2008), learning IKS is invariably transformative:

It changes a person in unexpected ways. It makes you keenly aware that
you are living in an interconnected world, that the world is alive, that there
is an animating energy/sprit, and that we are only a small part of the

38 This understanding is also present in the Yin Yang symbol.
universe. Learning IK teaches humility, gratitude, and forgiveness, an awareness of the cycle of life and death, and how to begin to live in a powered universe. (p. 192)

Importantly, learning IKS requires long-term engagement and participation with elders, the land, and others who are the keepers of Indigenous knowledges (Newhouse, 2008).

2.5.4 Complexity as a Path to Indigenous Knowledge Systems

A final combined transformative possibility for decolonization and Indigenization involves the use of complexity as a path to introduce IKS to scholars and practitioners in a variety of fields, alerting them to the limits of the mechanistic paradigm (in which many social institutions are rooted) and making them aware some alternatives. The notion of biocentric complexity thinking (Baker, 2008), which is based on the inherent value of life and explicitly recognizes complex systems as living systems, may also be useful in this regard. As Cajete (2000b) has noted, for Indigenous peoples “seeking life was the all encompassing task” (p. 2, emphasis in original). Complexity’s rootedness in Eurocentric science positions it as an especially useful path helping science educators to connect with IKS, a possibility that is further elaborated in Chapter 4: Conceptualizing ISE.
Chapter 3: Researching Indigenous Science Education

3.1 Researching Indigenous Science Education

My research on ISE as a catalyst for personal and systemic change was informed by the qualitative frames of participatory action research (PAR) and Indigenous research methodologies (IRM), which I chose for their collaborative nature, transformative intent, and fit with complexity and Indigenous knowledge. These methodologies are also open and responsive to community needs, allowing the research to adapt and change, sometimes unexpectedly. This occurred a few times in my research, and I eventually made the difficult decision to focus on my own research experience of miskasowin as a resource for others interested in ISE. My experience is not intended as a “how to” guide, as there are many routes to miskasowin through ISE, but rather as a helpful map of one possible path.

I first came across PAR during a course on Education Action Research, and was drawn to it as a frame for my interest in adaptive, culturally responsive curriculum making that incorporated local knowledge and responded to local needs (Barnhardt & Kawagley, 2005). It was also during this course that I first encountered IRM. At that point IKS were still on the periphery of my research, and it wasn’t until later that I began to explore the methodological work of Indigenous scholars. Following the path of my own learning, I provide brief introductions to PAR and IRM before discussing my

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40 Drawing on the work of Becker (1996), Denzin and Lincoln (2005) have listed securing rich descriptions, acceptance of postmodern sensibilities, and capturing the individual’s point of view as key criteria for qualitative research (p. 15-16).

41 Plains Cree for “finding one’s true sense of self,” which I use to denote the emergence of more relational worldviews and identities.
weaving of these methodologies into a form of Indigenous Métissage (Donald, 2012) and highlighting areas of complementarity that have shaped my research.

3.2 Participatory Action Research

PAR is a term for qualitative research that positions the researcher as co-learner and emphasizes community participation as a catalyst for action, learning, and change (Minkler, 2000, p. 192). PAR has been developed in diverse fields (e.g., education, health, business, etc.) (McTaggart, 1991; Minkler, 2000) and has been recognized as a more effective way of achieving outcomes in complex social settings than more positivist approaches (Stringer, 2007). I focus here on the methodologies of action research (Lewin, 1946; Reason & Bradbury, 2006a; Stringer, 2007) and participatory research (Fals-Borda & Rahman, 1991; Hall, 1981; Tandon, 1988) as two contributing discourses to the field of PAR.

The pioneering of action research is generally attributed to the work of social psychologist Kurt Lewin (1946, 1952), who developed a form of research that “stressed the active involvement of those affected by the problem in the research through a cyclical process of fact finding, action and reflection, leading to further inquiry and action for change” (Minkler, 2000, p. 191). A number of theoretical lenses, including complexity theory, have been drawn on in the action research literature (Phelps & Hase, 2002; Stringer, 2007; Sumara & Davis, 1997). Through the lens of complexity thinking (Davis & Sumara, 2006), action research is an emergent process that is adaptive, contextual, and devoid of standardized procedures (Minkler, 2000). Importantly, through complexity

42 Instructed by Dr. Cynthia Nicol.
43 See Kemmis & Taggart (2005), Reason & Bradbury (2006b), and Zeichner (2001) for a fuller account of this development.
Thinking action research is also “a site for learning, and hence transformative of both individual and collective” (Sumara & Davis, 1997, p. 403).

Participatory research focuses on issues of social justice and strives to include participants throughout the research process (Hall, 1981; Tandon, 1988). The term was first used by researchers seeking to motivate villagers to evaluate their strengths and needs by including them as participants in research on village development (Yarmol-Franko, 1988, p. 3). It was further developed by adult educators confronted by a contradiction between their practice of giving learners autonomy over their own learning and the dominant research methodology, which treated learners as objects of manipulation (Tandon, 1988, p. 5). Engaging community members as participants is also done to build capacity, “increasing the likelihood that projects would be successfully implemented and remain an active part of the community’s development” (Hoare et al., 1993, p. 53).

PAR combines aspects of action research and participatory research and is an inherently political form of research (Zeichner, 2001). It is “not only a process of creating knowledge, but simultaneously, as education and development of consciousness, and of mobilization for action” (Gaventa, 1988, p. 19). Numerous lists of principles, objectives, and attributes of PAR exist in the literature (e.g., Collins, 2004; Kemmis & McTaggart, 2005; Stringer, 2007). My research has been informed by Greenwood et al.’s (1993) list of key features and Bradbury and Reason’s (2006) choice points and questions for action research (Appendix 1), as they closely mirror complexivist and Indigenous sensibilities. Greenwood et al.’s list of key features, for example, include: 1) collaboration; 2)
inclusion of local knowledge; 3) eclecticism and diversity; 4) case orientation; 5) emergent process; and 6) linking knowledge generation with social action.

3.3 Indigenous Research Methodologies

Some of the earliest encounters between Europe and Indigenous nations occurred via anthropologists, marking the beginning of a long and uneasy relationship with Western research. Indigenous peoples are arguably the most studied of the world (Rigney, 1999); numerous qualifications, careers, and patents have been derived through acquisition of Indigenous knowledge, often with little to no benefit for Indigenous peoples. This research was often undertaken through methodologies that viewed Indigenous peoples as objects of study that needed to be recorded before being lost, rather than active, knowing, feeling beings (Marker, 2006).

Decolonization is fundamental to IRM (Rigney, 1999) and implies a dual process of resisting colonization and revitalizing Indigenous ways of being. It does not infer the total rejection of Western theory, research, and knowledge but instead focuses on Indigenous concerns and worldviews, understanding theory and research from Indigenous perspectives and for Indigenous purposes (Smith, 1999, p. 39). Archibald (2008) describes this as Indigenization, a consciousness-raising process that is focused on “how Indigenous thought and action become transformative” (p. 90).

According to Smith (2005) tasks of Indigenous research include capacity building, developing researchers, and creating space for new research approaches and examinations of Indigenous knowledge (p. 92). IRMs are being enacted in international and transdisciplinary contexts (Smith, 2005), all of which critique the practice of locating problems solely within Indigenous communities, as this fails to acknowledge “issues of
historical and social processes that contribute to the marginalization of Indigenous peoples” (Ermine, 2000, p. 65). Principles and recommendations for Indigenous research generally attend to two interrelated themes: 1) honoring and enacting IKS, and 2) use of collaborative, community-based processes in all aspects of research (Martin, 2003; Menzies, 2001; Smith, 1999; Weber-Pillwax, 1999).

Indigenous knowledge embodies a relational epistemology where all is interconnected and imbued with spiritual energy. Knowledge itself is considered relational, belonging to families and communities rather than individuals (Wilson, 2001). This engenders a sense of relational accountability (Wilson, 2008) with family members, communities, and the entire web of life (Cajete, 2000). It also requires researchers to locate themselves in their research (Absolon & Willet, 2005; Steinhauer, 2001), providing an opportunity to demonstrate humility by acknowledging one’s shortcomings, areas of ignorance (Wilson, 2008, p. 134), and limitations of the research (Smith, 1999, p. 140). Indigenous knowledge is also holistic, including physical, intellectual, emotional and spiritual ways of relating (Archibald, 2008) and is best articulated in Indigenous languages (Battiste, 2008; Weber-Pillwax, 1999).

IRM require the creation of trusting and respectful relationships to facilitate community participation (Steinhauer, 2001; Wilson, 2008). Menzies (2001) suggests that maintaining these relations requires participation throughout the research process, including: 1) initiating dialogue; 2) refining the research plan in consultation with the Nation; 3) conducting research (using research teams that include community members and academics); 4) discussing, analyzing, and writing-up results with/in the community; and 5) leaving research reports, and resource packages that describe the research process,

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44 See Chapter 1 pp. ??-?? for my own attempt to locate myself in relation to this research.
data sets, and secondary literature (p. 22). The creation of respectful research relations through such collaboration also helps ensure reciprocity; that the research will be of practical benefit to the people and places involved.

3.4 Weaving PAR and IRM into Indigenous Métissage

Indigenous and non-Indigenous scholars have noted the alignment of PAR with IRM (e.g., Brown & Strega, 2005; Colorado, 1988; Hall, 2001; Kovach, 2005; Smith, 1999). Similarities include a critique of the effectiveness of positivist methodologies for complex social settings, use of emergent research processes responsive to local contexts, inclusion of local community and knowledge, and valuing story and narrative as research processes and outcomes (Brown & Strega, 2005; Colorado, 1988; Hall, 2001; Kovach, 2005, Smith, 1999). PAR and IRM embrace multiple ways of knowing and forms of knowledge (e.g., performance arts, multimedia, spoken word, etc. (Archibald, 2008; Bradbury & Reason, 2006)), drawing on local concerns and expertise to link knowledge creation to social action (Moore, 2004).

IRM remain distinct in their decolonization imperative, in being rooted in Indigenous paradigms, and in their desire for relational accountability (Kovach, 2005; Wilson, 2008). Wilson (2008) has noted PAR’s use by Indigenous scholars, but cautions that although PAR supports Indigenous research, “this support is not for external validation but rather as a complementary framework for accepting the uniqueness of an Indigenous research paradigm” (p. 16). While maintaining this uniqueness, it appears participatory and Indigenous approaches to research may share common roots; as “participatory forms of inquiry aimed at solving practical problems have existed forever
in human cultures, and have contributed to all life-supporting human activities from plant and animal husbandry to political democracy” (Reason & Bradbury, 2006b, p. 3).

Complementarities between PAR and IRM foster their weaving into a form of Indigenous Métissage (Donald, 2012), a decolonizing research sensibility that facilitates transdisciplinary and complex approaches to research by engaging the creative tensions found at the intersection of diverse (e.g., Indigenous and non-Indigenous) worldviews. Indigenous Métissage builds on the tradition of literary métissage, which expresses the dilemmas of those living in between cultures and languages (Lionnet, 1989) and animates “the egalitarian interrelations in which binary impasses are deconstructed” (p. 5).

3.4.1 Critiquing and Complementing Positivism

The onset of classical science through the Enlightenment and Scientific Revolution (Bocock, 1992) gave rise to a mechanistic mode of thought characterized by “rampant individualism, disenchantment, and the dominance of industrial reason” (Kemmis & McTaggart, 2005, p. 563) (i.e., positivism or modernity). Positivist research involves the collection of quantitative data by expert researchers who attempt to provide reliable observations by following a policy of non-interference, remaining detached from phenomena of interest. The goal of positivist research is to generate objective knowledge to inform program development, policy, etc. While a useful source of data, positivist research often ignores the complex histories, dynamics, and motivations of human communities.

Early participatory researchers were disillusioned by the often colonizing “us/them” nature of positivist research efforts and the frequent inadequacies of the

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45 See Chapter 2 for a more detailed discussion of mechanistic thought.
46 For a summary chart delineating the characteristics of traditional positivistic social science research and participatory action research, see Moore, 2004, p. 148.
interventions they created (Minkler, 2000, p. 192). Indigenous scholars’ critiques also include intellectual, emotional, and spiritual responses to experiences of colonization, including assimilation and genocide, under the reign of modernity. The capacity of PAR and IRM to address social complexity provides a potential complement to positivist research orientations, shifting research processes from those of expertise to those of emergence, and shifting research outcomes from a singular desire for objective knowledge to a triad including diverse knowledges, the creation of relationships, and transformative actions.47

3.4.2 Emergent Research Processes

PAR and IRM contrast with the positivist role of researcher as expert, shifting away from research “on” people toward research “with” people (McTaggart, 1991). Reason and Bradbury (2006b) describe action-oriented research as “an emergent, evolutionary and educational process of engaging with self, persons and communities” (p. 12). While individual control is absent in these forms of research, they are not random or chaotic (Whyte, 1989), instead relying on forms of collective or distributed control.48 Greenwood et al. (1993), for example, argue that the emergent processes of PAR are “largely controlled by local conditions” (p. 176), which complexivists Davis, Sumara, and Luce-Kapler (2008) refer to as “enabling constraints” (p. 193)

Greenwood et al. (1993) describe these emergent processes in terms of collaboration and the inclusion of local knowledge, which entail acceptance and valuing

47 For Bradbury and Reason (2006), quality PAR is defined in terms of relational praxis, reflexive-practical outcomes, plurality of knowing, and engagement in significant work (p. 346-349).
48 The use of community or Aboriginal advisory committees comprises one form of collective control. Irwin (1994) and Bishop (2005) use the Maori term whanau, which means extended family, to denote a supervisory or organizational structure for supporting research. Hoare et al. (1993) also advocate the use of community advisory committees and suggest selecting a stratified sample of adults providing age and gender balance.
of uncertainty, eclecticism and diversity. While openness and diversity among research participants can lead to conflicts that impede research, they are also rich sources of creativity. Greenwood et al., for example, relate how in one PAR project “the relative unpredictability of these open processes led the research to new insights” (p. 189). Unlike positivist research, which seeks knowledge that is generalizable across a variety of contexts, PAR and IRM often embrace a case study orientation (McTaggart, 1991) that “attempts to learn general lessons from specific cases, to operationalize concepts, to develop comparisons, and the like, from repeated case applications” (Greenwood et al., 1993, p. 179).

Quality research pursued through emergent processes depends largely on the strength of relationships with participants and/or communities. Evidence of respectful research relationships includes sincere investments in community such as taking time to visit (participants and non-participants), conversations about the purpose and ownership of the research (Kovach, 2005), and attending important cultural events, all of which “cements your membership within a community in an ongoing way and is part of how one’s credibility is continually developed and maintained” (Bishop & Glynn, 1992; cited in Smith, 1999, p. 15). Wilson (2008) has similarly described small talk as an opportunity to see how people are feeling, to express their thoughts, and to get people thinking on the same wavelength (p. 99). The presence of humor in interactions also indicates a level of respect and comfort (Archibald, 2008, p. 68).

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49 PAR and IRM advocate initiating new relations as well as building on old ones (Reason & Bradbury, 2006a; Weber-Pillwax, 1999). The use of family, relations, and friends to contact participants is as an important part of Indigenous research (Wilson, 2008).
3.4.3 Research Outcome: Diverse Knowledges

The emergent process and case study orientation of PAR and IRM also initiate a shift away from the narrow positivist focus on quantifiable, objective knowledge toward an appreciation for narrative forms of knowledge that convey nuanced depictions of the research contexts and activities of particular cases. The inclusion of my own narrative in this research has been shaped in part by autoethnography (Ellis & Bochner, 2000), a methodology that connects “the autobiographical and personal to the cultural and social” (Ellis, 2004, p. xix). As stated by Holman Jones (2005), autoethnography elicits “not only the necessity of narrative in our world but also the power of narrative to reveal and revise that world” (p. 767).

In Archibald’s *Indigenous Storywork* (2008) the time-honored tradition of storytelling is forwarded as method and methodology, and includes protocols for learning and sharing elders’ stories and also addresses the importance of personal narratives. Stories and narratives are relational forms of knowledge in their ability to convey holistic understandings and connect on emotional and spiritual levels. As Wilson (2008) noted, “when you’re relating a personal narrative, then you’re getting into a relationship with someone” (p. 115). Donald (2012) also advocated for narrative, noting that rather than following a prescribed method, Indigenous Métissage requires “careful attention to the details of the research context with the hope that a story will arise that will need to be told” (p. 12).

PAR and IRM are both receptive to extended ways of knowing (Bradbury & Reason, 2006) with IRM explicitly including spiritual knowing—dreams, fasting, ceremony, and time in nature are all acknowledged as valid sources of knowledge.
(Kovach, 2009). When dealing with spiritual knowledge researchers must exercise discretion, as IKS are governed by protocols around what can be shared, with whom, and when. Some knowledge is limited to “individuals and organizations within Indigenous communities, such as initiated men or women, or to the members of special spiritual societies” (Battiste, 2008, p. 505). This is a subject of shifting perspectives, as some elders and scholars regard the selective sharing of sacred knowledge as essential for the survival of Indigenous cultures and nations but are cautious about how it should be shared, which contexts to place it in, and who should receive such knowledge (e.g., Archibald, 2008; Kovach, 2005), while others may view removing the sacred from its traditional context as appropriation.

3.4.4 Research Outcome: Relationships

In further contrast to the positivist focus on producing objective knowledge, PAR and IRM include relationships developed through collaboration as important research outcomes. In contrast and complement to positivist approaches where knowledge is derived through distanced observation and measurement, PAR and IRM suggest that valuable knowledge is also created through engagement and developing relationships (Smith, 1999; Webber-Pillwax, 2001). The nature of the relationship (e.g., object-subject, community member) will influence the kind of knowledge (e.g., scientific fact, narrative) created, with more holistic relations (e.g., through ceremony, land) contributing more holistic forms of knowledge. The creation of relationships through research is essential for miskasowin, for fostering more relational identities. These relations are not limited only to other people, but also include the land, water, forests, animals, and spirit, and entail both physical and emotional connections.
Relationship building also results in a more equitable form of research than positivist approaches, as the establishment of networks through relationships can allow for the distribution, rather than centralization, of power and knowledge. Collaboration between the community and university-affiliated researchers allows community members access to the power of the university, and vice versa. Other groups can also be connected, providing avenues through which collective powers may address issues of common concern. For Kemmis and McTaggart (2005), the most morally, practically, and politically compelling view of PAR is that of “a practice through which people can create networks of communication” (p. 580).

3.4.5 Research Outcome: Transformations

A final significant shift from positivist research is the commitment of PAR and IRM to transformation and change. In contrast and complement to the positivist ideal of non-intervention, PAR and IRM actively seek to challenge and change the structures and realities through which people act and make meaning. While positivist research focuses on producing objective knowledge, which if applied may induce change, PAR and IRM are intentional about their influence, drawing on local needs and expertise to link knowledge generation with responsible and responsive action (Moore, 2004). Actions may address any number of issues, and transformations may take a variety of forms, both individual and systemic.

At the systemic level, PAR and IRM take aim at specific, practical problems relevant to the contexts in which the research is carried out (Stringer, 2007; Kovach, 2005). Within formal education this may include issues related to curriculum, pedagogy, and assessment, but can also include broader shifts, such as valuing Indigenous languages
or embracing a seasonal structure to the school year. PAR and IRM also address the context of academia. IRM, for example, embody a “purposeful agenda for transforming the institution of research, the deep underlying structures and taken-for-granted ways of organizing, conducting, and disseminating research and knowledge” (Smith, 2005, p. 88). As Brown and Strega (2005) note, “we push the edges of academic acceptability not because we want to be accepted within the academy but in order to transform it” (p. 2).

PAR and IRM also acknowledge the need for personal transformation in participants and researchers (Cranton, 1994; Carson & Sumara, 1997; Wilson, 2008). For Maguire (1987), “Participatory research is not only about trying to transform social structures ‘out there’ and ‘the people,’ it is about being open to transforming ourselves and our relationships with others” (cited in Moore, 2004, p. 155). Shawn Wilson, a nêhiyaw scholar, has also advocated for this personal approach: “Something that should go in the writing is how you have changed and what the whole process has done to you” (Wilson, 2008, p. 123). He continues with this imperative, “If research doesn’t change you as a person, then you haven’t done it right” (p. 135, emphasis in original).

3.5 My Research Journey

To appreciate my story of change we need to go back to my high school days, when Newtonian physics (the hallmark of mechanistic science) was a favorite subject. I was attracted to how easily one could insert numbers into an equation to obtain answers, and with the ability to check answers to ensure their correctness. My attraction to black-white and right-wrong thinking continued in undergraduate studies, where I was pursuing a degree in Physics until deciding to enter the Saskatchewan Native Teacher Education

50 Plains Cree
Program with teaching areas in Physics and Native Studies. A further aspect of the change I have experienced regards my spiritual belief, as back in high school I was also an atheist. I went to Sunday school for a short time as a child but my dad never came with us as he “couldn’t stand the hypocrisy,” and it wasn’t long until our family stopped attending.

Engagements with cultural diversity during my travels first opened me to the realities of an ambiguous and diverse world, where little, if anything, is black and white. While I still appreciate the simplicity and value of the mechanistic way of knowing, I have come to understand its limits and the need for more holistic perspectives to maintain balance. Accepting ambiguity and uncertainty prompted further shifts in my spiritual belief from atheism toward agnosticism. I no longer was a non-believer; I simply acknowledged my state of unknowingness regarding a topic that was beyond my comprehension. As described in Chapter 1, my travels also initiated a return to grad school to examine what my purpose as an educator might be in a time of human induced biospheric decline.

I first began to consider doctoral studies after a meeting with Dr. Brent Davis.51 We had met to discuss his co-authored book, *Complexity and education: Inquiries into teaching and learning* (Davis & Sumara, 2006), which I had been directed to as a frame for my M.Ed. research on education as a form of biocultural evolution (Baker, 2008). I was eager to speak with him but unsure if we would be able to meet, as he had recently taken a position at another institution. We ended up meeting the day before his departure and had a great conversation. As we were wrapping up I mentioned that he would be

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51 Dr. Davis eventually became my supervisor, and is now a committee member after taking a position at another institution.
starting at a new institution, without many grad students, and jokingly inquired into whether I should head out to work on a Ph.D. with him after my masters. He said sure, and told me to keep in touch. That was how it began.

I wanted to build on my M.Ed. topic of biocentric education (Baker, 2008) in my doctoral research and make an educational contribution of practical utility. My decision to focus on ISE evolved slowly through engagement with literature on complexity and social change; through attention to complementarities between complexity and IKS; and through the encouragement of my M.Ed. supervisor, Dr. Makere Stewart-Harawira, to connect with IKS. A significant text that shaped my doctoral research was Gregory Cajete’s (2000) *Native Science: Natural Laws of Interdependence*, which explicitly addresses Indigenous peoples’ affinity for life and connections between IKS and complexity.

### 3.5.1 Coming Home and Changing Direction

My decision to return to Saskatoon for my research was influenced by IRM’s acknowledgement of building on established relationships, my own belief in local engagement and collaboration as fundamental for maintaining health and enacting social change, and a desire for my young family to be closer to my mother and father. I returned to Saskatoon not only for my research but because it was time to come home. I had been away from Saskatoon for a number of years, and on my return invested considerable time and energy reconnecting with old acquaintances and, often through those connections, working to develop new ones.

The emergent processes of PAR and IRM resulted in some unanticipated changes in the direction of my research. An initial shift occurred soon after my return to
Saskatoon, when I learned of a curriculum revision initiative through which IKS were to be included in the outcomes and indicators of all subject areas and grade levels in Saskatchewan. While still focusing on the transformative possibilities of ISE, this curriculum initiative prompted a shift away from my initial interest in developing culturally responsive curricula toward providing support for science teachers seeking to meet these new curriculum expectations.

A further significant change occurred through my relationship with Don Speidel, a waokiye and cultural resource person with Saskatoon Public Schools. I first met Don during a meeting with a couple of SPSD Superintendents and the Coordinator of the First Nations, Métis and Inuit Education Unit. Don popped his head in just after I had explained my research, and he was introduced as someone to whom I should also speak. When we met I offered tobacco, introduced myself and explained the intentions of my research. We connected instantly. He appreciated my sincerity and, as I later learned, had been expecting me. It wasn’t long before I was sitting in the inipi and began learning and working with him as a ceremonial helper. My research thus shifted from an anticipated process of learning about plants, medicines, and animals to a personally transformative experience that significantly deepened my understanding and appreciation of IKS.

A final shift occurred a number of months later, when I approached Don about collaborating on a research project developing and testing a professional development

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52 This research was based on a strategy employed by the Alaska Rural Systemic Initiative (AKRSI), which provides a pioneering case study of the development of flexible curricula that emerged through recognition of congruencies between traditional Indigenous knowledge systems and complexity theory (Barnhardt & Kawagley, 2003, 2005).
53 A Lakota term for a “traditional helper.”
54 A Lakota term for what is commonly referred to as the sweat lodge ceremony.
module in ISE, an offer he kindly but firmly declined. Expressing his discomfort with academia, he offered to support me however he could, and strongly encouraged me to continue my own learning journey. I understood his hesitancy but was unsure how to proceed. Don had become a close mentor and friend, and I was unwilling to explore other potential collaborators. Taking Don’s encouragement seriously, I decided to move away from a “truly collaborative” participatory project where community are involved in all aspects of the research (Tandon, 1988), instead pursuing research through my own participation in the local Indigenous education community and sharing aspects of the story of transformation this entailed. My connection with Don thus triggered both a “spiritual turn” and a “narrative turn” in my research.

3.5.2 Building Relationships

The participatory nature of my research, gaining membership in the local community through my participation in it, helped to foster relationships with elders, knowledge keepers, teachers, students, principals, superintendents, chiefs, band councilors, university faculty and many others. I became known to the community (i.e., the “seen face” (Smith, 1999)) by becoming a fixture at community events (e.g., round dances, pow wows, feasts), through random encounters in public spaces (e.g., in grocery stores, on the bus, etc.), and by hosting, attending, and volunteering with a variety of Indigenous education events (e.g., public presentations, conferences, Indigenous science fairs, etc.).

My investment in the local community as a researcher was in part demonstrated in my long-term commitment to the relations I was building, as I had come home with the intention of staying and growing roots. Community members seemed to appreciate this,

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55 As demonstrated in Don’s response, the desire and capacity (i.e., time) to build capacity by learning more about research through active and in depth participation may not be appealing to all.
and dispositions grew even more welcoming after it was acknowledged. My Indigenous ancestry also seemed to help people feel at ease, and I was sometimes introduced to elders on knowledge keepers with “he has ancestry” or “he is blood.” I had mixed feelings on this, as I am also of non-Indigenous ancestry and hadn’t grown up in an Indigenous community. On the other had, the empathetic power of my personal and emotional connections to familial experiences of colonization, which are shared among Indigenous peoples, offers an important sense of unity.

On occasions when I wanted to set up a specific meeting with someone regarding Indigenous knowledge, my request would always be accompanied with an offering of tobacco, one of four sacred medicines (tobacco, sage, cedar, and sweetgrass) on Turtle Island (North America) used to maintain reciprocity and enter into an agreement when asking for something (be it from a person, plant, or other animal). Before discussing my research these meetings were almost always preceded by general visiting and small talk, and occasionally my research would not come up at all. Nevertheless, these were always rich exchanges where I was able to learn things I wouldn’t have had I stuck to a strict research agenda or list of interview questions. My efforts to maintain reciprocity with those I met with repeatedly also included offering gifts such as food or medicines I had prepared or picked, or being of service by providing transportation, getting groceries, etc.

Important relationships were also fostered with the University of Saskatchewan and the Saskatoon Public School Division (SPSD). A particularly beneficial engagement with SPSD occurred in the role of Indigenous Knowledge Facilitator at the Brightwater Science and Environmental Centre, just outside of Saskatoon. I transitioned into the role by assisting Tracy Wilson, a Cree-Nakota-Saulteaux knowledge keeper who

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56 As a guest lecturer, sessional instructor, and guest presenter in high school classrooms.
was part of our *inipi* family, with her sessions. Subsequent experiences discussing Indigenous and Western Scientific knowledge with students around a fire in a tipi helped to develop the circle activity of *nêwo kwécimowina*.\(^{57}\) Two further community members, Barry Ahenakew and Darlene Speidel (Don’s mom), also helped to create ISE resources;\(^{58}\) important examples of what can be done when trusting relationships are developed.\(^{59}\)

I initially aimed to engage four participants but soon realized this was impractical and scaled back to two (Darlene and Barry). I decided not to include Don Speidel as a participant as I felt he had already given me enough. My initial meetings with Darlene and Barry were pre-arranged and accompanied with an offering of tobacco and an explanation of the purpose of my research. They soon became less formal, with conversations occurring over tea in their homes or in public spaces at community events. I was also able to strengthen our connections in ceremony. Darlene was often present at *inipi* and *chanupa* ceremonies led by Don, and I was able to attend two of Barry’s *pihêwisimowin*\(^{60}\) ceremonies at his home on the Atahkakoop First Nation, and also assisted him as an *oskapêwis* in a ceremony I had requested him to lead. I am sincerely grateful for the mentorship and friendship they have offered, and for allowing me to share their teachings.

My initial meeting with Barry is worthy of more discussion. I first saw Barry at the *First Nations’ Language Keepers Conference* were he was discussing *nêhiyaw* toponyms for Saskatchewan landmarks (e.g., hills, creeks, etc.). I wanted to connect but

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57 Plains Cree for “four questions.” This learning activity is elaborated on in Chapter 5.
58 These are also shared in Chapter 5: Practicing Indigenous Science Education.
59 Many others could have been included. I chose to limit it to two for pragmatic reasons of length.
60 The “Prairie Chicken Dance” ceremony.
was hesitant to approach him without an introduction, so I decided to wait. I was fairly confident he wouldn’t answer a phone call (he is a busy man) so I rehearsed a message and worked up the courage to call. He answered after two rings and, after my flustered introduction and request, said he was able to meet later that day. I was nervous when I sat down to speak with him but gained momentum as I went. Suddenly, Barry put his hand up, interrupting my excited babbling. “Did you bring any tobacco?” he asked. I had, I explained, but was so anxious I had forgotten it in my pocket. He smiled and accepted my late offering, noting that my honesty and sincerity more than offset this breach in protocol.

### 3.5.3 Ceremony, Land, and Language

A centrally important form of engagement occurred through involvement as a participant and helper in ceremony with Don Speidel. The commitment shown to the community through this involvement also helped to opened doors, and was an important part of maintaining reciprocity by giving back through service. It was an honor to become known as an *oskâpêwis,* to be asked from time to time by elders and knowledge keepers to assist with ceremonial duties. Forms of prayer and ceremony that honour life, acknowledge interrelatedness and foster humility have now become integral to my life (e.g., smudging, tobacco ties, sweat lodges, etc.). I have chosen not to write or focus explicitly on my ceremonial experiences, however, as much of what I learned is not easily expressed in academic contexts. Nevertheless, these experiences have influenced everything I have written.

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61 In the interim I also spoke to Don for advice on whether to and how to approach him.
62 Plains Cree for “helper.”
Engagement with ceremony also strengthened relations with the land, building on experiences hiking and canoeing with my father in my youth.\(^63\) The material simplicity of Indigenous ceremonial practices—the use of renewable, locally available resources for ceremonies whose physical presence is erased soon after they are completed—reflect important teachings of humility, balance, and reverence for life and land. Even preparing for ceremony, offering tobacco when gathering medicinal plants or building a sweat lodge, for example, strengthens connections with land. The land at Brightwater has become a spiritual home; a connection forged by helping and participating in numerous \(\textit{inipi}\) and \(\textit{hanblecha}\)\(^64\) ceremonies there. My family also has connections to Brightwater, as my daughter joined me there for her first \(\textit{inipi}\) and my father had one of his few ceremonial experiences there with the \textit{chanupa}.\(^65\)

A further important element of my experience has been engagement with Indigenous languages, primarily \(\textit{nêhiyawêwin}\) and, to a lesser extent, \(\textit{Lakota}\). The need to revitalize Indigenous languages has been consistently emphasized by elders and knowledge keepers, as these languages embody the knowledge and worldviews of Indigenous peoples and have arisen from the land itself, connecting the people with their places of origin. Saskatchewan is home to numerous language groups, and I chose to study \(\textit{nêhiyawêwin}\) as it is the most common language of \(\textit{mînsihk}\), because it is part of my own lineage, and to build on previous learning I had undertaken. During my doctoral research I attended further \(\textit{nêhiyawêwin}\) courses, including several land-based language

\(^{63}\) See Baker and Baker (2010).

\(^{64}\) A Lakota term for the “crying for a vision” fasting ceremony. My fasts (without food or water) were two days in duration, rather than four, a practice traditionally reserved for the initial fasts of youth during their transition to adulthood.

\(^{65}\) A Lakota term for the sacred pipe that is central to many ceremonies and was brought by White Buffalo Woman some time ago to help the people pray and overcome the coming adversities.
camps, and made many good friends along the way who continue to help me learn. My learning of *Lakota* was less formal, arising in ceremony (e.g., through prayer, ceremonial songs), through my own studies, and during conversations with Don and Darlene Speidel.66

### 3.6 Relational Research Methods

Both qualitative and quantitative research methods can be used for generating data in PAR (Minkler, 2000). Numerous research methods are also appropriate for Indigenous research, provided they honor, respect, manifest, and articulate an Indigenous worldview (Steinhauer, 2002, p. 77; Weber-Pillwax, 2001; Wilson, 2001). Examples of relevant data sources include conversations, talking circles, journal entries, anecdotes, and literature reviews (Kovach, 2009; Steinhauer, 2002). Inward knowledges (Kovach, 2009) derived through dreams, fasting, ceremony, and time in nature may also be used when appropriate. Music, dance, art, and drama have all also been suggested as possible methods for IRM (Archibald, 2008; Steinhauer, 2002; Weber-Pillwax, 2001; Wilson, 2008).

As my research in ISE shifted from a focus on participatory curriculum development toward sharing my story of *miskasowin*, my research methods and sources of data shifted as well. Rather than engaging community members in a participatory research project, my experience as a participant and eventually a member of the community became the data on which this dissertation is based. The relational orientation of my research, in terms of both building community relationships and fostering

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66 See Chapter 5 for how discussions with Darlene helped identify the Lakota concept of *taku skay skay* as an Indigenous equivalent to the complexivist concept of emergence.
miskasowin, led to methods reflecting these goals. Primary methods employed include conversation (Kovach, 2009; Herda, 1999) and anecdotal narrative (van Manen, 1989).

3.6.1 Conversation

Conversation has been advocated for in the PAR and IRM literature as a research method that fosters knowledge sharing, relationship building, and transformative learning (Herda, 1999; Kovach, 2009). It also fosters mutually beneficial research relations, as all involved may contribute ideas and ask questions. Describing IRM, Kovach (2009) has articulated how the two-way communication of conversation “shows respect for the participant’s story and allows research participants greater control over what they wish to address with respect to the research” (p. 124). The shared control of conversations helps ensure reciprocity, that the research will address the objectives of both participants and researchers. Conversation is also important for processes of relationship building, which, while requiring more time than structured interviews, are critical for researchers seeking to learn with and from elders and knowledge keepers (p. 125).

Herda’s (1999) work in PAR draws on critical hermeneutics (Gadamer, 1975; Ricoeur, 1995) to theorize conversation as a process of cross-cultural communication that fosters shared understandings and catalyzes personal change. Differences encountered are considered “not as a problem to be solved but as an invitation to consider the boundaries and limits of one’s own understanding” (Smith, 1991, p. 203). For Gadamer (1992),

When something other or different is understood, then we must also concede something, yield—in certain limits—to the truth of the other…

To understand someone else is to see the justice, the truth, of their position. And this is what transforms us. (p. 152)
For Herda (1999), conversations are a means of connecting, mediating conflicts, and co-generating new narratives that open possibilities for mutually preferable forms of social organization (p. 10).

Herda (1999) and Kovach (2009) suggest developing and sharing lists of topics and questions prior to conducting conversations. These constraints ensure those in conversation remain focused and “do not talk at cross purposes” (Gadamer, 1975, p. 330). My initial list of topics\(^\text{67}\) was broad, and I remained open to conversations taking unexpectedly fruitful turns, which they did. My conversations with Darlene and Barry were quite different. Darlene and I explored a range of topics before focusing in on one, while Barry focused solely on sharing traditional stories. Reflecting the value of both establishing topics and remaining open, my conversations with Darlene eventually focused on one of my listed topics (concepts for integrating IKS and science), while my conversations with Barry did not (traditional storytelling). I also conversed with many elders and knowledge keepers not formally involved with the research, through which I learned a great deal yet are not reported on here, as I did not offer them tobacco nor ask permission to share their understandings in this work.

### 3.6.2 Anecdotal Narrative

Anecdote\(^\text{68}\) is a method of relating short stories of relevant research experiences that provide examples of concrete, lived experience and illustrate a concept, topic or issue.

Anecdote honours the Indigenous use of story as a means of keeping and sharing

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\(^{67}\) This list included participants’ views of and experiences with formal education, Indigenous worldview and complexity thinking, tensions between cultural traditions and school curricula (e.g., sacred knowledge, language), key topics and concepts for integrating IKS and science, ideas for professional development, and reflections on Indigenous research in urban contexts.

\(^{68}\) Derived from Greek for “things unpublished” and French for “secret or private stories” (www.etymonline.com).
knowledge; for many Indigenous scholars, “woven throughout the varied forms of our writing – analytical, reflective, expository – there will be story, for our story is who we are” (Kovach, 2009, p. 4). It is also a pedagogical tool used instinctively by educators; “among teachers, and also among parents, anecdote is the natural way by which particular concerns of educating and living with children are brought to awareness” (van Manen, 1989, p. 232). The decision to focus this research on my journey of miskasowin meant the instructive power of anecdote would be relied on throughout my writing.

Van Manen (1989) draws on hermeneutic phenomenology to describe anecdote as a method aligned with the conversational and relational orientation of this research. Using conversation in a broad sense to denote how our worldviews shape perceptions and experiences of relatedness, van Manen positions anecdote as a device for understanding “the phenomenon of conversational relation which every human being maintains with his or her world,” and notes that “the human being not only stands in a certain conversational relation to the world—the human being really is this relation” (p. 249, emphases in original). Hence, anecdotes are employed here to share interpretations of my lived experience, illustrating how my worldview has shaped perceptions of relatedness and resulting actions, and how this research has catalyzed changes in both.

Pragmatically speaking, anecdote provides a complement to abstract, theoretical discourse through the provision of concrete examples (van Manen, 1989). It is especially useful for research involving IKS, as it also provides a means of accounting orally transmitted teachings from elders and knowledge keepers. Of particular importance to this research, anecdote can be used as a “methodological device to describe something indirectly when this phenomenon resists direct description” (p. 243). The transformative
process of *miskasowin* is a complex and multifaceted phenomenon of fostering relational worldviews and identities, and is inherently difficult to define. Anecdotes, therefore, provide a means of articulating my experience of *miskasowin* without attempting to delimit its boundaries within a prescribed definition.

### 3.7 Challenges of Indigenous Métissage

The decolonizing orientation of Indigenous Métissage positions it as an important methodological approach for those wishing to draw on both Indigenous and non-Indigenous knowledges in catalyzing transformation and change. The departure from more conventional methodologies, however, may also lead to a number of challenges, some of which are particular to this weaving of PAR and IRM. Challenges that I encountered in my research include those of needing to satisfy both institutional and Indigenous expectations for ethical research, those inherent to emergent and relational research processes, and those associated with the systemic and individually transformative nature of this work.

#### 3.7.1 Indigenous and Institutional Ethics

A unique challenge faced by researchers employing Indigenous Métissage involves satisfying the expectations for ethical research of both Institutional Review Boards (IRBs) and Indigenous communities (Absolon & Willet, 2005; Weber-Pillwax, 1999). This is also an opportunity to strengthen the research by making it accessible and relevant to a broader audience. Due to a dearth of policy regarding Indigenous research when I began my research, I initially relied solely on the IRM literature (e.g., Smith, 1999; 69)

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69 The *Tri-Council Policy Statement* (TCPS) (1998) governing the Canadian Institutes of Health Research, Natural Science and Engineering Research Council of Canada, and Social Sciences and Humanities Research Council of Canada, for example, included guidelines but no policy for research involving Aboriginal peoples.
Steinhauer, 2002) for guidance. During the course of my research, however, a number of policies emerged. The University of Saskatchewan released a draft of Recommendations for Ethical Research with Indigenous Peoples (2008) and, as reported by Battiste (2008), the Universities of Auckland and South Australia have established Indigenous ethics committees to review all research with Indigenous communities. The Tri-Council Policy Statement (Second Edition) (TCPS2) (2010) that governs federally funded research in Canada also now includes twenty-two articles on research with Indigenous peoples (p. 109-138) that were developed in consultation with Indigenous scholars.\footnote{The TCPS2 cites reciprocity as a basis for mutually beneficial research relationships (p. 109), noting the import of “collective rights, interests, and responsibilities that also serve the welfare of individuals” (p. 113). It acknowledges the primacy of “ethical guidance provided by Aboriginal peoples” (p. 109) and will continue to evolve in consultation with Canada’s Indigenous peoples.}

These policies provide important guidance on Indigenous research to IRBs, and in some cases also describe relational processes for gaining approval from Indigenous communities (e.g., TCPS2, 2010). Means of achieving this include applying to a local Indigenous research ethics committee,\footnote{For example, Kaupapa Maori provides seven culturally based values to guide research activities in New Zealand’s Indigenous communities (Bishop, 2005) and the Mi’kmaw Ethics Watch (2000) has developed protocols through which all research is reviewed.} negotiating a research agreement with an Indigenous community organization,\footnote{Examples include a Tribal or Band Council, a Métis local, an urban community organization, etc. Published guidelines for research within organizations or Indigenous communities (e.g., Pidgeon & Hardy Cox, 2002) can serve as a starting place for ethical guidance.} or establishing an advisory committee from the local community (Smith, 1999). The nature and context of the research will shape the form of approval pursued, and in my research, which was performed in a context without a local Indigenous research ethics committee in operation, approval was attained through broad community engagement and relationship building but particularly through the guidance of an informal advisory committee comprised of Don Speidel and my participants, Darlene Speidel and Barry Ahenakew.
Wilson’s (2008) concept of “relational accountability,” which considers ethics with regard to impacts on all of one’s relations, including our non-human relatives, comprises a further important way in which my use of Indigenous Métissage aligns with an Indigenous understanding of ethical research. As explained by Smith (2005):

...research ethics is at a very basic level about establishing, maintaining, and nurturing reciprocal and respectful relationships, not just among people as individuals but also with people as individuals, as collectives, and as members of communities, and with humans who live in and with other entities in the environment. (p. 97)

In my research, relational accountability is manifested through my primary desire to catalyze change toward more equitable and sustainable ways of living through fostering the development of more relational worldviews and identities.

3.7.2 Relational Research Processes

The emergent and relationally oriented processes of Indigenous Métissage also posed challenges. Relational research can be problematic with regard to IRB expectations such as informed consent, which may be difficult to obtain when the research direction may be unknown and will be decided on through an emergent process (Nolen & Putten, 2007). I was able to circumvent this in my research by utilizing a two-stage approach. My initial application explicitly stated that it covered only a first stage of meeting with potential participants without collecting data, and that a further application would be made once a suitable direction for the research had been identified.73 While my applications were approved without amendment and this adaptive approach to ethics is becoming more

73 I was also willing to submit further amendments should the research have continued to change.
common and in some cases even encouraged, the composition and nature of IRBs can vary greatly and such approaches may not always be so easily approved.

The diversity inherent to communities can also present challenges in the form of divides between community members. In many communities, building relationships with certain community members may inadvertently alienate you from others. Saskatoon is no exception, and community politics played a small but notable role in my research. My willingness to connect broadly across the community as a volunteer and ceremonial helper, along with the support of my participants, helped to lessen any significant frictions that may have arisen, and in some cases even helped to begin bridging these divides. As one example of an issue encountered, although Barry Ahenakew encouraged me to share sacred stories in print, there is some debate around this practice. It has been humbling to accept that my research may not be appreciated or supported by all, and to listen and respond respectfully to concerns voiced while relying on the guidance and support of my advisors.

A final challenge of Indigenous Métissage regards the time required to engage in relational research. The process of engaging broadly with the community and meeting with members to discuss needs requires time to navigate the schedules of participants, to develop trusting relationships, and to seek out opportunities for collaboration. These time constraints make it difficult to produce frequent publications, and the transformative nature of such research can pose further complications (Moore, 2004). Bradbury and Reason (2006) also note the poor fit of funding agreements with the sustained length of

74 While present in all communities, in some cases these politics and divides can be exacerbated in Indigenous communities due to the historical and ongoing trauma of colonization.
75 The type of transformative and self-reflexive processes inherent to PAR and (especially) IRM can require amounts of time and energy that would seem ‘exorbitant’ within traditional research schedules (Moore, 2004).
many relationally oriented research projects (p. 12). For these reasons, Moore (2004) echoes Stoecker and Bonacich’s (1992) notion that “doing PAR is antithetical to climbing the ladder of professional success” (p. 153). Of special significance to my research, issues of timeliness are especially challenging for grad students with limited experience, with often limited financial support, and frequently tighter timelines (Moore, 2004).

3.7.3 Systemic and Individual Change
A final set of challenges encountered stem from the transformative nature of Indigenous Métissage. My research aims to catalyze individual and systemic change toward more equitable and sustainable ways of living among teachers, students, and administrators, but is also part of a wider movement toward change within academia and other socio-cultural institutions. For IRBs and institutions that privilege positivist research, PAR and IRM may be viewed as lacking rigour and objectivity, and possibly even as threatening to the established hierarchy of knowledge. Smith (2005), for example, noted that use of IRMs “can be perceived as threatening, destabilizing, and privileging of indigeneity over the interests and experiences of other diverse groups” (p. 91). Weber-Pillwax (1999) has similarly cautioned that, “some degree of opposition and criticism is predictable from those who perceive such a force of change as a threat to their established authority and control” (p. 35).

I am pleased to report that in my experience overt opposition was not encountered. If anything, my research was sometimes met with a sense of indifference, which itself may be a more subtle form of resistance. While challenges related to systemic change were not significantly encountered, those of individual change most certainly were. As noted earlier, for researchers engaging PAR or IRM not only can the
research change and shift, so will you – personal change can and should be expected (Carson & Sumara, 1997; Wilson, 2008). The creation of new relationships itself can be transformative, depending on the nature and strength of the connections. Change may also result from the time and energy put into relationships with community members and participants, leaving less for pre-existing, non-research related relations.

The personal changes I experienced through this research were palpable, and constitute by far the greatest challenges I encountered. The changes toward miskasowin in my identity and worldview were gradual, and perhaps therefore less challenging. Yet on occasion I would encounter a situation where old habits confronted my emerging understandings and beliefs. New spiritual practices, such as smudging and helping at ceremonies, were difficult to explain to old friends, and slowly my friendships began to change. My decision to abstain from alcohol, an expectation of oskapêwisak and an acknowledgement of the impact of alcoholism in my own and other Indigenous families, also shifted my social network. I also experienced professional changes with regard to my philosophy and practice of teaching and research. Occasionally challenging the ideas and assumptions of my peers, and sometimes even second-guessing myself, I have begun embracing slower, more personal, and more process and land-based practices.

Undoubtedly the largest and most difficult shift experienced through my research was the breakdown of my family. A combination of time away, changes in my spiritual belief, and my own personal failings, contributed to the dissolution of my marriage. It is difficult to write about something so personal and emotional, yet I feel it is important to share the magnitude of the changes that can ensue, and that I underwent through this research. The depth to which I pursued and maintained the relationships created through my research may be unique, and therefore somewhat of an outlier with respect to PAR and IRM research.

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76 The depth to which I pursued and maintained the relationships created through my research may be unique, and therefore somewhat of an outlier with respect to PAR and IRM research.
research. I believe it is equally important to convey that these changes were my decisions. Sometimes we have to hurt in order to heal. In connecting with ceremony I had found something I had been searching for, a place where I belonged and a way of living that strengthened relations and honored life. While difficult and regretfully hurtful to some I care for deeply, including myself, it has been a healthy change in my ongoing process of learning to walk in balance. In this respect, dealing with loss is an important yet under examined aspect of transformative learning and research. We always need to let go of something, to varying degrees and in different ways, to make room for the new.

3.8 Research Reflections

As a process of knowledge creation and dissemination, academic research, like formal education, is an inherently epistemological and political endeavor that can be used for purposes of social change or stasis. As explained by Tandon (1988):

Control over knowledge production systems, dissemination and use of knowledge, and access to knowledge historically have been used in different societies to continue the systems of domination of the few against the many, to preserve the status quo, and to undermine the forces of social transformation. (p. 6)

By embracing IKS and weaving PAR and IRM into an Indigenous Métissage, “Research, like schooling” becomes a way “to reclaim languages, histories, and knowledge, to find solutions to the negative impacts of colonialism and to give voice to an alternative way of knowing and of being” (Smith, 2005, p. 91).

PAR and IRM draw on the power of connections between people, communities, and their ecologies, to identify and address problems and create guiding forces for
change. In today’s era of interconnected global crises (Baker, 2008), when the scope of problems daunts comprehension, the potential for IRM and PAR to enact local changes with global ramifications remains, for me, reason for hope. Much as IRM act as a force for decolonization, both IRM and PAR help to balance top-down bureaucracy and expertise with bottom-up collaboration, knowledge, and local (even individual) transformations. Hence, IRM and PAR are not meant to replace more positivist forms of research, but to complement them. Rather than the positivist goal of proof, I view the goal of Indigenous Métissage as persuasion, weaving stories within which we can see ourselves and witness our need for change. As Indigenous storyteller Thomas King kindly reminds us, “Want a different ethic? Tell a different story” (2003, p. 163).

I am hopeful that the shifts in my research focus; from curriculum development, to professional development, to personal narrative; will amplify its transformative impact, as this work now addresses the systemic level of classroom practice, the community level of student achievement and experience in science education, and the personal level by sharing my story with other educators. The most significant transformational element of my research has undoubtedly been my own process of personal change. Returning home to reconnect with my home community by building relationships with people, the academy, the land, and the spiritual world through prayer and ceremony, have all contributed to my ongoing process of miskasowin, of attempting to understand who and what I am, including the small place I occupy in the grander scheme of relations. This experience didn’t go as “planned” but has become a solid foundation and preparation for a lifetime of further teaching, learning, and research in ISE.
Chapter 4: Conceptualizing Indigenous Science Education

4.1 Conceptualizing Indigenous Science Education

ISE is a relatively new arena of educational research and practice, and there is no single, correct, way to conceptualize it (Michell et al., 2008). My understandings are themselves evolving, based on ongoing experiences with ISE in Saskatoon, Saskatchewan. At present I view ISE as characterized by the respectful inclusion of IKS in curricula, pedagogy, and assessment, which may range from the inclusion of IKS in a few lessons to entire science courses or programs developed and taught from an Indigenous paradigm. Thus, it is the meaningful presence of IKS that differentiates ISE from conventional science education.

While not suggesting IKS as simplistic add-ons to established curricula (i.e., tokenism), educators will be starting from different places, many with little or no familiarity with IKS, and few with the capacity to teach from Indigenous paradigms. There is a pressing need to support educators where they are, and to consider the enhancement of their capacity to respectfully include IKS with confidence and sincerity as a personal and ongoing process, even if it begins with a single lesson.

My view of ISE as a transformative practice of miskasowin is rooted in a desire to foster more equitable and sustainable ways of living through formal education. Numerous scholars have described how the mechanistic worldview of the Scientific Revolution has contributed to the emergence of today’s humanitarian and ecological crises, particularly through notions of individualism, certainty, and control (Abram, 1996; Capra, 1996), each of which has informed colonial thinking and practice. The need to decolonize and shift toward more holistic frames that might balance the dominance of mechanistic thought and remediate these crises is also being recognized. Complexity and IKS provide
two such frames, and their inclusion in formal science education, a site of socially mandated enculturation, comprises one means of catalyzing this shift.

With regard to the context of Saskatoon, the recent inclusion of IKS in science curricula in Saskatchewan has left many teachers scrambling to attain the aptitudes and knowledge to respectfully engage in this work. For the many science teachers unfamiliar with Indigenous peoples and knowledges, the notion of including IKS and worldviews in their work can be daunting. I have heard numerous teachers express their frustration and reluctance with regard to meeting these new curriculum expectations with few resources and little support. Fortunately, many teachers I encountered expressed this hesitancy in terms of respect for Indigenous peoples and knowledges and fear of breaching protocols. While susceptible to being employed as excuses by those who resist the inclusion of IKS for other reasons,77 these are genuine concerns. This conceptualization of ISE and the examples of ISE in practice in Chapter 5 are offered as resources for the personal and professional development of teachers interested in ISE but unsure of how to begin.

In this chapter I retrace the path of my own coming to understand ISE as a holistic approach to teaching that balances the predominantly mechanistic orientation of school science. I begin by reviewing the purposes of ISE and introduce miskasowin as a possible goal of ISE, before connecting ISE with three prominent educational discourses, those of transformative, culturally responsive, and place-based education. I conclude by reviewing four key realizations that led to my interest in ISE and discussing bridging, two-eyed seeing, and weaving as metaphors for ISE.

77 There are also many teachers those who resist the inclusion of IKS for other reasons, based largely on an ignorance of the importance of this work (e.g., ignorance of Canada’s colonial legacy) and an all too common racism toward Indigenous peoples. These teachers require a more foundational form of PD covering the history of colonialism in Canada and anti-oppressive/anti-racist education. Similarly, it should not be assumed that teachers already interested in ISE would not also benefit from these forms of PD.
4.2 The Purposes of Indigenous Science Education

Given the marginalization of Indigenous peoples and knowledge systems within formal education and the position of science as the hallmark of knowledge in Western societies, ISE comprises a critical venue for dialogue on the politics of knowledge. Key questions here include “Whose knowledge is of most worth?” “What should be taught in schools?” and “How should it be taught?” and responses will vary with one’s views of the purposes of education itself. While equity and sustainability have largely informed my views on ISE, often these aims are considered in isolation, with equity-oriented work exacerbating issues of sustainability, and vice versa. Taking the goals of equity and sustainability as complementary and interdependent; whether through holistic Indigenous views of kinship or complexivist understanding of the interrelatedness of economic, ecological, and other systems; may help to foster more effective policies, programs, and practices for our individual and collective health and well-being.

The primary motivation for most work in ISE has been equity, with a focus on improving the retention and achievement of Indigenous peoples in science programs and increasing our representation in scientific careers (Aikenhead, 2006; Michell et al., 2008). The failure of schools to meet Indigenous learners’ needs is most pronounced in science education (Canadian Council on Learning, 2007) where classrooms can often comprise foreign, sometimes even hostile, environments (Aikenhead, 2001). Differences in worldview, the dearth of science in residential schools, and a perception of science among Indigenous communities as a tool of the oppressor (through past support of racist practices, connections to government and industry (James, 2001)) have all contributed to

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78 As a couple of examples, efforts addressing poverty may employ unsustainable forms of economic development, and sustainability education may ignore issues of poverty that limit who can participate.
this reality. Issues of sovereignty and identity are also pertinent here. With few
Indigenous peoples pursuing careers in science, our ability to inform decisions related to
health, employment, resource management, and education in our communities is grossly
diminished, thus limiting the efforts toward sovereignty. The respectful inclusion of IKS
in schools can also help to strengthen our sense of identity as Indigenous peoples,
meeting a desire shared widely among many communities while also contributing to
improved academic achievement.

This focus on equity is clearly warranted, but can leave the impression that ISE is
only for the benefit of, and thus only for, Indigenous peoples. Through a relational lens,
however, goals of cultural and socio-economic revitalization in Indigenous communities
will contribute to the creation of a healthier society that is beneficial for everyone. The
respectful inclusion of IKS similarly provides opportunities for all to learn with and about
Indigenous peoples and knowledge systems, thus positioning ISE as part of the broader
contemporary movement toward reconciliation between Indigenous and non-Indigenous
populations. In my view, while these equity-oriented purposes are critical they must also
be balanced with those of sustainability, with the dire need for reconciliation between
humanity and the rest of the natural world in order to meet the needs of generations to
come.79 It is in terms of both equity and sustainability that I view the holistic, non-
mechanistic frames of IKS and complexity as powerful sources of transformation toward
miskasowin, deepening our individual and collective sense of relationship, respect, and
reverence for the human and non-human worlds.

79 It is not my ambition to simply encourage and facilitate the training of Indigenous peoples in Eurocentric
science so that they may more effectively participate in an unsustainable, exploitative economic system.
4.3 Transformative, Culturally Responsive, and Place-Based

My views on ISE have also been informed by theories of transformative learning (O’Sullivan, 1999), culturally responsive education (CRE) (Gay, 2000; Castango & Brayboy, 2008), and place-based education (PBE) (Gruenewald, 2003; Sobel, 2004). I was drawn to these approaches as means of increasing student achievement (Gay, 2000; Sobel, 2004) while catalyzing change toward equity and sustainability\(^80\) (Gruenewald, 2003), a potent mix for influencing policy makers in today’s standards-driven climate of accountability. Educators are increasingly embracing these pedagogical approaches, and their confluence constitutes a way of conceptualizing ISE with which some teachers may already be familiar. While these approaches do not specifically address the inclusion of IKS, their critical and relational orientation are consonant with IKS and complexity and position them as a helpful way for educators to begin conceptualizing ISE.

4.3.1 Transformative Learning

Identifying *miskasowin* as a goal of ISE positions it as a form of transformative learning (Mezirow, 1978; O’Sullivan, 1999), which seeks to facilitate deep, structural shifts in basic premises of thought, feelings, and actions (Transformative Learning Centre, 2004). The notion of identifying a “disorienting dilemma” capable of triggering a “perspective transformation” was introduced by Mezirow (1978),\(^81\) who described one’s perspective as a process where “habitual ways of thinking, feeling and acting become articulated in a

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\(^{80}\) The work of the Alaska Rural Systemic Initiative, which drew on CRE and PBE principles, presents a compelling example of effective educational change (Barnhardt & Kawagley, 2003). Extensive community collaboration and participation led to the development of pedagogies, curricula, and assessment tailored to fit the cultural contexts in which they were situated, resulting in increased retention, achievement, and students pursuing college education (p. 63).

specific point of view” (1997, p. 5-6). The ethics of pursuing transformative learning in schools is important as, while schools invariably influence learners’ perspectives, one may question whether teachers have the right to explicitly shape students’ views and beliefs. For me, being intentional about the perspectives we are fostering is preferable to unconsciously perpetuating the status quo. The initiation of perspective transformations should also be provided as an opportunity rather than a requirement. Hence, while a course may be set up to provide this opportunity, a student’s success (or failure) in attaining this perspective should not be reflected in their grade.

In response to contemporary humanitarian, ecological, and economic crises, transformative learning has been directed to the broad development of socio-ecological consciousness (e.g., Cajete, 2004; O’Sullivan, 1999), which bears strong resemblance to miskasowin as an aim of ISE. In Mezirow’s (1978) terms, it is believed the disorienting dilemmas of these crises may trigger the emergence of more socially and ecologically oriented forms of thinking, points of view, and actions. Within ISE, the marginalization of Indigenous peoples through colonial practices and policies (e.g., Residential Schools, the Indian Act) contributes an additional dilemma that may trigger transformations by fostering appreciation for the revitalization of IKS. Importantly, all of these dilemmas suggest a need for change toward holism and relationality, which positions IKS and CS as perspectives that can be drawn on as sources of transformation. As just one example, Cranton (2006) has noted how the potentially traumatic experience of encountering dilemmas and being changed by them means that transformative learning “depends to a large extent on establishing meaningful, genuine relationships with students” (p. 5), a theme that is echoed throughout the literature on CRE and PBE.
4.3.2 Culturally Responsive Education

Culturally responsive education (CRE)\(^82\) is an approach to teaching and learning that facilitates critical consciousness, engenders respect for diversity and acknowledges the importance of building relationships with and drawing from the culture, knowledge, and language of students, teachers, and the local community. It is a means of attending to prominent educational issues and a pledge to respond to needs of students, their families, and their communities. Here I outline two key elements of CRE that are pertinent to ISE:

1) the development of a critical consciousness (including shifting from views of cultural deficits to valuing diversity), and
2) establishing relationships to promote collaboration and community engagement (Bartolomé, 1994; Gay, 2000, 2002b; Phuntsog, 1999; Villegas, 1988; Wlodkowski & Ginsberg, 1994).

CRE considers the sociohistorical and political dimensions of education and critiques “societal norms, values, mores, and institutions that produce and maintain social inequities” (Ladson-Billings, 1995, p. 162). This requires teachers to become aware of “sociopolitical and economic realities that shape their lives and their capacity to recreate them” (Bartolomé, 1994, p. 195), which for ISE includes colonialism and Eurocentric science’s contributions to the marginalization of Indigenous peoples. This also requires critically examining one’s values and attitudes and shifting from views of cultural deficits to valuing the knowledge and experience all students bring to their learning. The cultural deficit view holds students’ lack of familiarity with dominant culture as a primary cause

\(^{82}\) The United Nations Education, Scientific, and Cultural Organization defines culture as the “distinctive spiritual, material, intellectual and emotional features of society or a social group, and encompasses, in addition to art and literature, lifestyles, ways of living together, value systems, traditions and beliefs.” www.unesco.org
of low achievement (Demmert & Towner, 2003)\textsuperscript{83} and ascribes responsibility to the marginalized, rather than systems that perpetuate inequities (Smith, 1999, p. 91).\textsuperscript{84} While culturally appropriate instruction has shown to increase achievement,\textsuperscript{85} it may not address sources of inequities and the need for systemic change (Bartolomé, 1994; Villegas, 1988). The shift away from deficit views also encourages the development of high expectations for all students, which is a crucial element of effective pedagogy (Bishop & Glynn, 1999; Dukepoo, 2001; McKinley, 1996).

Shifting from views of deficit to diversity is also part of decolonization, where difference, rather than a source of confrontation requiring neutralization (Stotsky, 1999), becomes a source of creative potential (Cochran-Smith, 2001). This view is echoed in complexity thinking (Davis & Sumara, 2006), where diversity is a source of possibilities needed for evolution and continued survival in dynamic environments. Valuing diversity across all aspects of school life requires the development of healthy, trusting relationships among educators, learners, and the school community, and that schools address local challenges and problems through the inclusion of the local knowledges and languages. This can be challenging in any context, especially so in multicultural communities. For many ISE practitioners, especially those just starting out, it will be important to approach this as part of an ongoing process, slowly learning protocol, building relationships, and gaining confidence in engaging the community in one’s teaching.

\textsuperscript{83} A study by Aikenhead & Huntley (1999), for example, found many teachers blamed Aboriginal students disinterest in science on deficits (lack of language skills (vocabulary), discipline, family support, etc.).
\textsuperscript{84} Deficit thinking has also contributed to disproportionate special education diagnoses among minority students, as evaluations using dominant cultural norms and values are the standards against which all students are measured (Gay, 2000, 2002a; Klingner et al., 2005; Villegas & Lucas, 2002).
\textsuperscript{85} See, for example, Au, 1979 & 1980; and Ignas, 2004.
4.3.3 Place-Based Education

Noting that our sense of place is increasingly “indoor space” and that our “minds are increasingly shaped by electronic stimuli” (p. 163), Orr (2004) portends the need to “rediscover and rehabit our places and regions, finding in them sources of food, livelihood, energy, healing, recreation, and celebration” (p. 147). Place-based education (PBE) addresses this need for reinhabitation by dissolving boundaries between schools and their environs and engaging local people, places and concerns. Lists of characteristics and attributes of PBE generally attend to two prominent themes of relevance to ISE: 1) an expanding focus from local to global, and 2) the centrality of experiential, land-based learning (Smith, 2002; Sobel, 2004; Woodhouse & Knapp, 2000).

Woodhouse (2001) cites Comenius, a seventeenth-century philosopher of education, in stating a core precept of PBE; “Knowledge of the nearest things should be acquired first, then that of those farther and farther off” (cited in Sobel, 2004, p. 4). This emphasis is shared in ISE, as a “primary focus must be to integrate local knowledges” (Michell et al., 2008, p. 5). IKS are inherently local, and their inclusion honours the protocol of acknowledging the peoples of the place in which one is learning. This does exclude the knowledges of others, but grounds PBE in local knowledge and concerns. Smith (2002), for example, has advised that students’ questions and local concerns “play a central role in deciding what is studied” and that teachers “act as experienced guides, co-learners, and brokers of community resources and learning possibilities. (p. 593).

Experiential, land-based learning, which Sobel (2004) describes as hands-on or real world learning, is a further precept of PBE (Woodhouse & Knapp, 2002). Through experiential learning students become knowledge creators, rather than consumers of
knowledge created by others (Smith, 2002). Experience is a deep form of learning that teaches students about “things that cannot be known or said about a mountain, or a forest, or a river—things too subtle or too powerful to be caught in the net of science, language, and intellect” (Orr, 2004, p. 96). Experiential learning also fits with the holism of ISE, as developing a sense of place occurs via “intimate, experiential knowledge associated with values and emotions” (Chinn, 2006, p. 399). Land-based learning further complements Indigenous teachings that regard okâwimâw askî as a foundational source of knowledge that provides for all of our needs.

The kinds of relationships developed through PBE depend, in part, on the attributes given to place. In addition to describing place as local, experiential, and land-based, ISE takes a holistic perspective of place that “entails physical, emotional, and spiritual characteristics” (Michell et al., 2008, p. 27). Cajete (2000a) has described how Western discourse frequently describes places “by their physical features and not as a reflection of a creative, living force” (p. 182). Deloria and Wildcat (2001) similarly describe Indigenous reality in terms of two foundational experiential dimensions, place and power (p. 2), “power being the living energy that inhabits and/or composes the universe, and place being the relationship of things to each other” (p. 22-23). This understanding of power is mirrored in the complexivist concept of emergence, which suggests a universe that is active or alive. Hence, “the universe [and place] is personal and, therefore, must be approached in a personal manner” (p. 23). ISE thus aims to foster personal relationships with place by positioning learners as coexisting with our human and non-human relatives in the natural world.  

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86 PBE sometimes belies the seriousness of ecological problems by focusing on the creation of caring relationships with local people and places. It does so “out of the realization that love—love of nature, love
4.3 Key Realizations for ISE

In addition to the influence of transformative learning, CRE and PBE, my experience of coming to understand ISE is rooted in four realizations that took place during graduate studies, after my travels had alerted me to the existence, viability, and importance of diverse cultures and worldviews. In roughly chronological order these include: 1) that science, knowledge, and science education are all socially constructed, culturally-based phenomena (Maddock, 1981); 2) that Indigenous peoples have robust knowledge systems, much of which satisfies criteria of Eurocentric science (Waldram, 1986); 3) that there are many culturally distinct forms of science, including Indigenous science (Ogawa, 1995); and 4) that Eurocentric science alone may be insufficient for meeting the challenges of the 21st century (Mohawk, 2010).

When I first became interested in ISE and mentioned Indigenous Science to my supervisor he replied with a wry smile, “Wait, isn’t that an oxymoron?” His sarcasm reflected the common notion that IKS are non-scientific, an idea based in an acultural view of science where the quest for objectivity is believed to largely eliminate issues of personal belief and social interaction from knowledge production. Understanding science as socially constructed and culturally situated (Maddock, 1981), however, is foundational to ISE. My studies in the philosophy of science, where I learned how science is subject to paradigm shifts (Kuhn, 1980), how it is oriented toward falsification more than proof

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87 See Bennett’s (1986) Developmental Model of Intercultural Sensitivity, which spans from ethnocentric to ethnopluralistic though stages of denial, defense, minimization, acceptance, adaptation, and integration. While reaching the stage of acceptance is crucial to any kind of cross-cultural work, I do not address it here explicitly as it was not part of my own experience. See Aikenhead et al., 2012 for more.

88 At the time the comment was made my supervisor was Dr. Brent Davis, who after a change of institutions has become a committee member.
(Popper, 1959/2002), and how it involves complex social processes and accidents as much as the scientific method (Feyerabend, 1975; Fleck, 1979), challenged my preceding view of science as a straightforward matter of collecting evidence and conducting experiments, thus adding to the edifice of scientific knowledge. These observations allowed me to think about science as adaptive and dynamic, and challenged my prior view of scientific knowledge as objective truth, which was implicitly taught through my school science experiences (Aikenhead & Ogawa, 2007).

A second important realization regards acknowledging the existence and contemporary relevance of IKS. While viewing knowledge production as a social and cultural process was a contributing factor here, it was my M.Ed. supervisor, Dr. Makere Stewart-Harawira, who recognized congruencies between IKS and my work on biocentric complexity (Baker, 2008) and first encouraged me to explore IKS. Initially I was hesitant, I had little understanding of IKS and their potential importance, and was unsure of how to begin finding out. When I began reading work on the topic, however, the similarities and relevance quickly became apparent. I was somewhat troubled by this realization, as it confirmed biases and racism toward my Indigenous ancestors I had internalized through my schooling and other forms of socialization. I also felt reticence that my learning of IKS first came from books rather than elders or knowledge keepers, yet acknowledge this as having contributed to the deeper relationships and learning I have since pursued.

A third realization, that there are many culturally distinct forms of science, including Indigenous Science, occurred during doctoral studies. Ogawa (1995) termed

89 Waldram (1986), for example, has noted that within IKS, “the extensive observation, processing and sharing of information over extremely long periods of time represent a system of knowledge generation and verification which is inherently scientific” (p. 118).

90 I share this experience with students to exemplify the need to examine our internalized beliefs and biases.
this a “multi-science perspective” and acknowledged that there are a number of culturally based knowledges at play in contemporary science education, which continues to largely reflect ideas and ideals from Eurocentric Science (ES). This realization is crucial for ISE, as “the definition of science is a de facto ‘gatekeeping’ device for determining what can be included in a school science curriculum” and it also suggests that “Western or modern science is just one of many sciences that need to be addressed in the science classroom” (Snively & Corsiglia, 2001, p. 6). Indigenous Science is an unfamiliar concept for many (Michell et al., 2008) and the ethics and efficacy of terming IKS science remain a matter of debate91 (El-Hani & Souza de Ferreria Bandeira, 2008; Gorelick, 2014). The intent here is not to validate IKS, which have sustained and guided Indigenous peoples for millennia, including through recent attempts at physical and cultural genocide, and thus require no external validation. Instead, I view Indigenous Science as synonymous with IKS (Cajete, 2000b) and as a political statement affirming the power and need for the respectful inclusion of IKS in science education.

The fourth realization, that ES may be insufficient for the challenges of the 21st century, emerged with an awareness of how mechanistic thought and classical science have contributed to the origin and perpetuation of humanitarian and ecological crises. The focus of ES on the quantitative and measureable and the related ideals of certainty and truth attenuate the desire to engage with other perspectives that may offer unique and valuable insights. The focus of ES on generating objective knowledge also renders it a tool that can be directed toward whatever purposes society chooses, which at present is

91 This debate typically revolves around negative perceptions of science among some Indigenous peoples and a desire to maintain science as a Eurocentric endeavor among others.
largely inequitable and unsustainable economic growth.\textsuperscript{92} A related issue is the absence of values and ethics guiding the application of ES, which may have been erased with the onset of the mechanistic worldview. As noted by Havel (1994), while we may know more about the universe than our ancestors, “it increasingly seems they knew something more essential about it than we do, something that escapes us” (p. F8). Perhaps the “essential” missing knowledge to which Havel refers results from the desacralization that occurred through mechanistic science, rendering the universe static and impersonal. IKS and complexity offer two lenses that may help reinscribe an active, intelligent, living universe, and thus foster more ethically relational ontologies and ways of being.

4.4 Metaphors for Indigenous Science Education

My progression through these realizations is useful in framing three primary metaphors for ISE I encountered in this research, those of bridging (Aikenhead, 2001; Aikenhead & Michell, 2011), 2) two-eyed seeing (Hatcher et al., 2009), and 3) weaving (Kimmerer, 2002; Snively & Williams, 2008). While these metaphors are unpacked and theorized to varying degrees in the literature and are sometimes used interchangeably, I interpret them here as distinct ways for educators to approach ISE and as varying in their suitability for transformative learning and miskasowin. While the metaphors are presented in a linear progression, each one is acknowledged as a useful means of respectfully including IKS in science education. Which is most appropriate is contextual, depending on the knowledge and comfort of the teacher, students, and others involved. I begin by briefly addressing

\textsuperscript{92} At present, the socio-economic elite largely control processes of ES for their own purposes, most often these include the generation of profit and the maintenance of their positions of societal control. Even the health sciences, which produce important technologies and pharmaceuticals, are governed by economics, with social benefits only accruing when a suitably large profit can be made.
the historical (and still prevalent) exclusion of IKS from science education before discussing the metaphors of bridging, two-eyed seeing, and weaving.

### 4.4.1 Exclusion

The categorical exclusion of IKS from science education, and from formal education more generally, is aligned with a failure to recognize the culturally situated nature of all knowledge and the existence and contemporary relevance of IKS.\(^\text{93}\) Science education poses a unique case as one of the last disciplines to address the inclusion of IKS, a result of attributing scientific knowledge solely to Euro-Western peoples and viewing IKS as non-scientific, primitive, or archaic. Snively and Corsiglia (2001) cited Elkana (1981) in noting the profusion of comparative studies of art, religion, ethics, and politics, and the absence of similarly comparative studies in science (p. 7). Hence, even when the socio-cultural nature of science and the existence of IKS are acknowledged, the view that IKS are non-scientific and therefore irrelevant to science education may persist, an attitude I encountered on occasional after introducing my research to teachers and administrators.

### 4.4.2 Bridging

The bridging metaphor, which positions IKS and ES as separate but parallel knowledge systems, is an important beginning place for educators interested in ISE. The literature on bridging often describes teachers as culture brokers that help students navigate border crossings between their home cultures and the subculture of school science (Aikenhead, 1996; 2001; Phalen, Davidson, & Cao, 1991). As the culture of school science can be equally foreign to Indigenous and non-Indigenous students, the inclusion of relevant cultural perspectives is viewed as an important means of improving science education for all (Ogawa, 1995). The bridging metaphor responds to a body of research indicating that

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\(^{93}\) This could apply to a Ministry of Education, school division, an individual school, or a teacher, etc.
cultural difference is “associated with greater student disengagement, disconnectedness, and alienation” (Chinn, 2006, p. 369) and that links strategies attending to these cultural differences with improved achievement (Battiste, 2002; Chinn, 2002; Sutherland, 2005).

The work of Barnhardt and Kawagley (2005) (Figure 3), among others (e.g., Aikenhead & Michell, 2011; Knudtson and Suzuki, 2006), exemplifies bridging in addressing both similarities and differences between IKS and ES. Jegede (1995) has described the process of teaching across cultural difference as “collateral learning,” where a learner “constructs, with minimal interference and interaction, Western and traditional meanings of a simple concept” (p. 117). Examples of this might include teaching Indigenous and Eurocentric scientific classification systems of elements (e.g., fire, earth, air and water vs. the periodic table of the elements) and organisms/species (e.g., those that crawl, four-leggeds, two-leggeds, etc. vs. Linnean taxonomy), with both acknowledged as functional for their respective worldviews and the purposes they serve.

Barnhardt and Kawagley (2003) suggest that teachers employing such strategies “should start with what the student and community know and are using in everyday life”:

...when describing an eddy along the river for placing a fishing net, it should be explained initially in the indigenous way of understanding, pointing out the currents, the movement of debris and sediment in the water, the likely path of the fish, the condition of the river bank, upstream conditions affecting water levels, the impact of passing boats etc. Once the students understand the significance of the knowledge being presented, it can then be explained in western terms, such as flow, velocity, resistance, turgidity, sonar readings, tide tables, etc. (p. 2)
While acknowledging students’ local knowledge and allowing them to build on it is good pedagogy, the ultimate goal here is to enable students to successfully border cross, to understand both knowledge systems and to be able to move smoothly between them.

A second type of bridging makes use of “natural bridges” or areas of overlap that exist between IKS and ES, (e.g., the “Common Ground” in Barnhardt and Kawagley’s (2005) Venn diagram (Figure 3)). These natural bridges highlight elements of IKS that fit within the paradigm of ES. Similarities posed by natural bridges such as Traditional Ecological Knowledge\textsuperscript{95} (TEK), a term that refers to Indigenous peoples’ knowledge of

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\textsuperscript{94} A hearty \textit{kinanâskomitin} (thank you) to Dr. Brent Davis for permission to use this diagram.

\textsuperscript{95} TEK has also been variously defined as synonymous with IKS (e.g., Pierotti, 2011) and as a branch of Indigenous Science (Snively & Corsiglia, 2001).
the physical aspects of nature (e.g., plants, animals, stars, etc.), are hence more easily embraced as suitable for inclusion via bridging by science educators.

The ease with which these examples (the eddy, classification systems, and TEK) fit with ES and enable border crossings make them useful starting places for ISE, yet also portend potential limits of the bridging metaphor. The example of TEK is instructive. For Snively and Corsiglia (2001), TEK refers to elements of IKS deemed useful by botanists, biologists, geologists, ecologists, and medical anthropologists, “often with an eye toward the incorporation of indigenous knowledge into the western scientific tradition” (p. 116). McGregor (2000) also noted how interest in TEK often originates among non-Indigenous scientists, and thus perpetuates “the same pattern of ‘discovery’ and investigation that has characterized colonial history in North America” (p. 439). All too often research results, which can include considerable financial gains, do little to benefit the communities where it took place (Cajete, 2000b; Smith, 1999). As an element of Western discourse, TEK also carries little of the spiritual elements that are inherent to IKS.

There is no such thing as a perfect metaphor, and all metaphors are subject to interpretation and can be enacted in a variety of ways. At issue here is that bridging can lead to the assimilation, rather than respectful inclusion, of IKS in school science. As bridging is focused on cultural difference it may not address broader contexts of inequity (Bartolomé’s, 1994) including the historical, colonial, power imbalances between IKS, which have been marginalized in school science, and ES, which is its foundation. This may lead to the replication of one-way transmission where bridges are used to enculturate Indigenous students to the norms and assumptions of ES, hence the need for teachers to embrace critical socio-historical consciousness (Ladson-Billings, 1995). Focusing only
on aspects of IKS that fit within the ES paradigm can also be assimilative, as this negates a fuller, holistic understanding of IKS. McGregor’s (2000) suggestion of adopting a “co-existence” model based on “equality, mutual respect, support, and co-operation” (p. 454) and the use of complexity as a natural bridge that more closely emulating the holism of IKS (and is elaborated on in Chapter Five) are two possible means of limiting the bridging metaphor’s assimilative potential.

The bridging metaphor’s portrayal of IKS and ES as adjacent monoliths, with teachers as “culture brokers” (Aikenhead, 1999) helping students bridge the gap, suggests a constructivist approach to learning that builds on students’ prior knowledge. While effective pedagogically, this is not a transformative approach to learning and may be of limited use for fostering miskasowin. Viewing IKS and ES as separate monoliths negates awareness of their dynamic and adaptive nature and consideration of complementarities and mutually beneficial possibilities. While the bridging metaphor may suggest IKS and ES are separated by a wide chasm, it is important to acknowledge they remain connected by the land below—there are similarities between these knowledge systems because they are rooted in the same physical world. By embracing a fuller understanding of IKS and acknowledging the interdependence of IKS and ES it may be possible for the bridging metaphor to move closer toward a transformative practice.

At minimum the bridging metaphor requires teachers to acknowledge the socio-cultural nature of science and the contemporary relevance of IKS, becoming conversant and comfortable enough with IKS (via professional development on colonial history, working with elders, etc.) to facilitate border crossings to ES. While limited in capacity for transformative learning and miskasowin, bridging is an important beginning point for
ISE practitioners and is preferable than the historic practice of excluding IKS from school science when care is taken to avoid an assimilative approach. The relative newness of ISE and the accessibility of the bridging metaphor for new ISE practitioners suggest that many teachers will be amenable to this approach. It is also important to acknowledge that the bridging of IKS and ES is not an end in itself, but should be viewed as a step in an ongoing process of learning. The familiarity with IKS gained through bridging should facilitate meaningful engagement and learning with elders and knowledge keepers, foundational sources of IKS, and help educators to embrace other ISE metaphors.

4.4.3 Two-Eyed Seeing

A second metaphor for ISE is that of two-eyed seeing\(^\text{96}\) (Hatcher et al., 2009), which departs from bridging’s focus on cultural difference, instead viewing the relationship between IKS and ES as complementary and giving rise, in a very literal sense, to new, emergent dimensions of understanding. This ‘both/and’ view reflects Waters’ (2004) depiction of Indigenous languages as embodying an ontology of nondiscrete, nonbinary dualism. Hence, perhaps unsurprisingly, two-eyed seeing was developed collaboratively by academics and elders, who described it as a process of “learning to see from one eye with the strengths of Indigenous ways of knowing and from the other eye with the strengths of Western ways of knowing and to use both of these eyes together” (p. 146). This view is echoed by Urion (1999), an Indigenous scholar who believed that in cross-cultural education, “It is not a ‘translation’ of one world view to another that is required, but access to the multidimensionality provided by two pairs of eyes” (p. 11).

\(^{96}\) Two-eyed seeing is similar to the notion of “walking in two worlds” (Cajete, 2000a), although walking can be done in each world separately, rather than the simultaneity of two-eyed seeing.
In addition to recognizing the socio-cultural nature of ES and the contemporary relevance of IKS, educators seeking to embrace two-eyed seeing also need to embrace a “multi-science perspective” (Ogawa, 1995) that acknowledges IKS as its own form of science (i.e., Indigenous Science) and provides impetus to include the holism of IKS in school science. As described by Hatcher et al. (2009), a guiding principle of two-eyed seeing is to let “the Indigenous Sciences sense of the whole ‘to dance with’ the Western sense of the parts” (p. 146) in the co-creation of new mutually informed understandings. Acknowledging the limitations of ES (and all knowledge systems, including IKS), such as the aforementioned desacralization of the universe, is helpful in determining why the strategy of two-eyed seeing might be pursued. Two-eyed seeing, for instance, “teaches that everything is physical and spiritual... Western Science sees objects, but Indigenous languages teach us to see subjects” (p. 146).

Urion (1999) cites Archibald’s (1980) Coyote story on literacy and orality as an example of the complementarity entailed by two-eyed seeing: “she and Coyote remove nothing from ‘literacy’ – there is no essential opposition, the literacy – a valued thing – does not deny the legitimacy of the oral medium” (p. 10). The example of the eddy as a form of bridging can also exemplify two-eyed seeing when one is careful “to illustrate how the modern explanation adds to the traditional understanding (and vice versa)” (Barnhardt & Kawagley, 2003, p. 2). Including Indigenous and complexivist notions of eddies as emergent manifestations of an active, living universe, noting their similarity to the structures of some plants, spider webs, and galaxies, and that all can be considered living entities, further exemplifies two-eyed seeing by embracing the holism of IKS.
The goal here is not for students to believe the alternate knowledge system (whether ES or IKS) but to understand it, see its value, and consider it as a possibility for altering or broadening one’s perspective (Faye, 2001; Snively & Corsiglia, 2000). In viewing IKS and ES as complementary and allowing the entirety of IKS (as Indigenous Science) to be respectfully included in school science, two-eyed seeing can position IKS and ES (via complexity science) as capable of contributing to transformative learning and miskasowin, contrasting and complementing the positivist, mechanistic worldview that presently informs school science (Aikenhead & Ogawa, 2007). While two-eyed seeing does not deny cultural difference, and for some new to ISE understanding distinctions between IKS and ES through bridging will be an important way to limit their potential conflation, it shifts focus to the benefits of understanding both. The maintenance of critical socio-historical consciousness (Ladson-Billings, 1995) and identification of disorienting dilemmas (Mezirow, 1978) are both still required in two-eyed seeing to provide impetus and direction for transformative learning.

4.4.4 Weaving

The third metaphor for ISE, weaving (Kimmerer, 2002; Snively & Williams, 2008), is more often used to describe a general “bringing together” (Bartlett et al., 2012) of IKS and ES than it is an explicit theory or practice of ISE. For me, weaving IKS and ES through ISE will allow teachers and students to draw on the best from these knowledge systems and co-create new knowledges and practices that contribute to transformative learning and miskasowin. Issues of appropriation are clearly at play here, as through the creation of new knowledge there is a danger of IKS being subsumed into ES given their historical power imbalance. It is likely that teachers will need to spend time becoming
adept and comfortable with IKS and ES, possibly through bridging and two-eyed seeing, before embracing weaving. A further reason for hesitance may be that teachers rarely see themselves as creators of new knowledge, but rather as transmitters of the established knowledge reflected in curricula.

As there are few explicit examples of weaving in ISE, I will share a couple of examples of weaving from sustainability science research, where the creation of new knowledge is the norm. In one project the weaving consisted of a broad combination of Indigenous “protocols of stewardship and caretaking with scientific inquiry as part of the approaches of particular Indigenous nations to sustainability” (White et al., 2015, p. 2). In another project, which was pursued with the Nisga’a people who live in the Nass Valley in Northwestern British Columbia, the weaving of Nisga’a fish wheel technology with statistical methods and modern materials effectively mitigated inaccuracies of electronic fish counters and improved the management of important salmon fisheries (Corsiglia & Snively, 1995). While these examples constitute different forms of and approaches to weaving, they clearly demonstrate the possibility and effectiveness of respectfully combining IKS and ES.

My desire to embrace weaving as a metaphor for ISE may be worthy of consideration, as not all may be amenable to this approach. I believe my location as a person of diverse, Métis97 ancestry with a combination of international cross-cultural experience, graduate level study, and experience with the Indigenous education and ceremonial communities in Saskatoon, has contributed to my comfort with cross-cultural work and the processes involved, including weaving.98 These experiences also fuelled my

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97 My existence as a person of mixed, Métis ancestry is itself a product of weaving.
98 While comfortable, I also approach this work with some hesitancy and a great deal of respect.
desire for this work, as the ethic of care I was raised with was broadened and affirmed through them, informing my view of weaving as a natural process (Said, 1982/2000) and an ethical imperative for today’s context of crises. The lens of complexity, whose Latin root *pleatere*[^99] means, “to weave, braid, twine, entwine,” has also informed my view of weaving as the emergence of an additional layer of complexity and a process of cultural evolution. The selection process will follow, but simply by being presented as a doctoral dissertation this work has met an important step in its acceptance and legitimacy, at least in the world of academia.

My intent is not to suggest that weaving will be immediately achievable by the average teacher or student, but that it is possible, and that it may be a goal worthy of aspiration. As expressed by Faye (2001), an instructor of a course on Indigenous Science for university science students:

> I understand that the work I do has to be incremental, that many of my students must first become comfortable with a scientific worldview rooted in holism before they can believe that the earth is *alive.* (p. 273)

Presently, many teachers are beginning to walk in two worlds (Cajete, 2000a), see with two eyes (Hatcher et al., 2009), and create bridges between IKS and ES (Aikenhead, 2001). While I am hopeful it will be possible to subsequently begin weaving together teachings from both knowledge systems, I am certain that in some cases this is already happening, although at present undocumented by academia. I am still learning to weave, and am also very early in my own process of learning ISE. The process will not be an easy one, and ISE is only one of many venues in which such work needs to occur.

4.5 Chapter Summary

Before moving on to Chapter 5: Practicing Indigenous Science Education, I would like to briefly review this chapter, where I presented ISE as a holistic approach to teaching that contrasts, complements, and balances the predominantly mechanistic orientation of school science. In this chapter I also reviewed the purposes of ISE, which include diverse issues of equity (e.g., educational achievement, socio-economic health, sovereignty), and argued for sustainability as a further important purpose, introducing *miskasowin* as an overarching purpose of ISE that addresses issues of both equity and sustainability. I also described ISE in relation to prominent discourses on transformative, culturally responsive, and place-based education.

I concluded the chapter by reviewing a series of personal realizations that led to my interest in ISE (i.e., socio-cultural nature of science, existence and relevance of IKS, multi-science perspective (i.e., Indigenous Science), and limitations of ES) and discussed the benefits, limitation, and complications of bridging, two-eyed seeing, and weaving as a series of prominent metaphors for ISE. The following chapter articulates my own vision of ISE in practice in terms of a “slow pedagogy of relations,” discussing implications for professional development, articulating *miskasowin* as a process of learning to relate, positioning complexity as a path to ISE, and presenting four pedagogical examples that arose during my research.
Chapter 5: Practicing Indigenous Science Education

5.1 Toward a Slow Pedagogy of Relations

In this chapter I articulate my practice of Indigenous Science Education in terms of a slow pedagogy of relations, an idea that was offered by my supervisor, Dr. Cynthia Nicol, after I described how my research had impacted my teaching during one of our numerous phone conversations. I hadn’t consciously decided to pursue slow pedagogy (Payne & Wattchow, 2009), and was somewhat caught off guard when she suggested it. In today’s world, and especially in education, the term slow has a variety of negative connotations, most of which indicate an inability to keep up. On reflection, however, I recalled my experiences in the hanblecha, where I spent a few days on the land in isolation, praying and sacrificing for those things I was seeking. One of the first things I noticed, and that I began to look forward to each spring, was how different the pace of life was without my phone, computer, or other trappings of modern life; and with just the wind, sun, moon, stars, plants, insects, and other animals to guide me. Perhaps it is not so much that my pedagogy is slow, as it is that the world is moving too fast.

For me, this slow pedagogy of relations foregrounds connections to land, language, and life, and prioritizes story and ceremony as important avenues for learning. Land includes experience and relationship building with earth, water, air, fire, plants, and animals in their natural environments. Language refers to the transformative, rather than translational, inclusion of Indigenous languages (more on this below), and life refers to implicitly and explicitly fostering respect and reverence for life and broadening ES views of life as organism to encompass more holistic understandings of living systems and an

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100 This one occurred on Nov. 14, 2014.
animate universe. The use of story in ISE can include the telling of traditional Indigenous stories (e.g., creation stories), viewing science itself as a form of narrative (e.g., the Big Bang as a scientific creation story), and having students reflect on and express how IKS and ES have influenced their storied understandings of themselves and the universe. The presence of ceremony in ISE is an important way to honour the spiritual beliefs of IKS but should be pursued with respect and guidance from the local community.

This slow, relational pedagogy has resulted from my experience of coming to understand ISE, and I encourage others to develop approaches based on their own unique experiences, skills, and gifts. Before describing my journey toward this pedagogy by articulating miskasowin in terms of learning to relate, offering complexity as a path to ISE, and sharing examples of learning activities developed through my research, I will share a few ideas about the kind of professional development that is needed to prepare and support teachers beginning the process of becoming effective ISE practitioners.

5.2 Foundational Professional Development for ISE

The average teacher should not be expected to simply begin practicing ISE, as this work presents important divergences from the past, homogenizing goals of formal education, and many teachers will have received little support regarding Indigenous education, let alone ISE. There is a pressing need for professional development and improved teacher education programming in Indigenous education that addresses foundational knowledge regarding local peoples’ histories and worldviews (Ignas, 2004; Michell et al., 2011). This is especially so in Saskatchewan, where Indigenous content, perspectives, and ways of knowing have been included in curricula. While some programming may be broadly applicable (e.g., Indian Act policies and impacts, strategies for curriculum, pedagogy, and
evaluation), much of it will be contextual, based on the knowledge, needs, and desires of
the community.\textsuperscript{101}

Some of this includes the names of local Indigenous peoples (both common and
in their own languages) and other issues of terminology (e.g., Aboriginal, Indigenous,
etc.); myths and misconceptions (e.g., taxation, funding, etc.); worldviews (e.g., holism,
language, protocols, approaches to learning);\textsuperscript{102} anti-racist and anti-oppressive education
(e.g., white privilege, color blindness); and colonization and its contemporary impacts
(e.g., the Indian Act, reserve system). Educators must also be aware of the historically
assimilative orientation of schooling as a form of cultural genocide (Duran & Duran,
1995; Hampton, 1995). In Saskatchewan, Treaty education is also an important part of
this programming, and was mandated by the Ministry of Education in 2007. With regard
to ISE, the realizations described in Chapter Four (i.e., socio-cultural nature of science,
existence and relevance of IKS, multi-science perspective (i.e., Indigenous Science), and
limitations of ES) and attending to the diversity of ES present in mechanistic and
complexity sciences would be important elements.

While classroom and workshop style professional development are important for
supporting ISE, this work also requires the development of respectful relationships with
the local community. The support of parents and community is beneficial in all forms of
education, and this is especially pertinent in Indigenous education due to the historically
traumatic experience of schooling for many Indigenous peoples. Developing relationships
with community members also honours the relationality of Indigenous worldviews and

\textsuperscript{101} It should be noted that not all Indigenous communities (or community members) want IKS in their
schools (Aikenhead & Huntley, 1999).

\textsuperscript{102} A few examples from a conversation with Darlene Speidel: awareness of cultural norms around eye
contact (looking others in the eye can be a sign of disrespect), disciplining in private, and extended family
structures (e.g., not being surprised if a grandparent, aunt, or uncle show up at parent-teacher interviews).
may be viewed as an attempt toward reconciliation; as a sign of respect for the people of
the place in which we live and work. These community connections may also help to
foster relationships with elders and knowledge keepers\textsuperscript{103} who can support the learning of
students, teachers, and others, perhaps through in-depth cultural immersion experiences
(e.g., culture camps) which have been cited as effective means of providing the skills,
knowledges, and aptitudes needed for ISE (Aikenhead et al., 2013; Chinn, 2006).

5.3 \textit{miskasowin} as “Learning to Relate”

In identifying \textit{miskasowin} as a purpose of ISE, contributing to the purposes of equity and
sustainability by fostering the development of more holistic worldviews and identities, I
would like to further articulate it here as a process of \textit{learning to relate}. The notion of
learning to relate is well suited to this work, as the verb \textit{relate} has a number of relevant
and interconnected meanings,\textsuperscript{104} each of which is addressed and reflected in my
description of complexity as a path to ISE and the learning activities that follow. The
meanings of relate that are instructive for ISE as a process of fostering \textit{miskasowin} are
connected to notions of intersubjectivity, biophysical interconnectedness, kinship, and
storytelling.

First, relate can be used to denote the act of connecting in thought or meaning,
creating mental links and schema amongst ideas or phenomena. This form of relating is
thus a process of knowledge creation pivotal to both learning and research, one that is
capable of \textit{fostering intersubjective understandings} when connections are made across
diverse cultures and worldviews. The acknowledgement of uncertainty common to IKS
and complexity, combined with the understanding that diverse perspectives are needed to

\textsuperscript{103} While there is no replacement for what can be learned through spending time with elders and knowledge keepers, other venues (e.g., websites, books, etc.) may help to prepare teachers for these encounters.

\textsuperscript{104} Retrieved and adapted from www.dictionary.com, April 2, 2011.
address the myriad of interconnected crises we face, make this an important aspect of learning to relate. There is no single, correct, path toward miskasowin, rather a variety of knowledge systems may offer understandings that will contribute to a diverse array of relationally-oriented worldviews and identities.

Next, the notion of being related (or more provocatively, “having relations”) connotes both physical and ancestral connections (e.g., among people, plants, animals, earth, ecosystems, etc.). In this sense, relate implies our biophysical interconnectedness to and complicity with the complex web of cycles and systems that shape local and global realities impacting present and future generations. It also implies a sense of kinship with all those we consider relatives. Through IKS and some interpretations of the complexivist concept of emergence (i.e., those that highlight our common (cosmic) evolutionary roots and acknowledge physical existence as a manifestation of spiritual energy or quantum flux (Little Bear, 2000)), this includes all of creation. It is in this sense that relate also refers to the establishment of sympathetic relationships that entail emotional and spiritual connections and are associated with feelings of respect, responsibility, care, and love.

Finally, relate can refer to the act of telling or communicating an idea or story, which is a fundamental way of sharing one’s experience, fostering intersubjectivity, and establishing and nurturing relationships. This telling can occur in a variety of forms, such as sculpting, painting, song, drama, and dance. Through this research I have learned the importance and power of sharing stories; of both telling one’s own and listening to and learning from others. Accordingly, in this work I have chosen to share the story of my research to provide an example for others interested in pursuing ISE as an approach to
fostering understandings of our interrelatedness and inspiring a deeper and more holistic sense of kinship with creation.

5.4 Complexity as a Path to Indigenous Science Education

A key issue for ISE is that it not only requires the inclusion of new content but also entails the teaching of what for many is an unfamiliar worldview. For this reason it is important to provide tools for educators that will enable bridges to be built with IKS, slowly fostering the confidence and capacity to introduce these worldviews to students and to embrace the possibilities of two-eyed seeing and weaving. A number of scholars have noted congruencies between the complexity sciences and IKS (e.g., Barnhardt & Kawagley, 2003; Cajete, 2000; Peat, 1994; Urion, 1999) through their mutual attention to dynamic, interconnected systems. In Figure 4 (Complexity as a Path to ISE), I explicate these similarities as a path for science educators to connect with IKS, taking concepts from complexity and Plains Cree and positioning them in contrast and complement to the mechanistic paradigm from which school science is predominantly taught.

Connections made between terms in complexity and Plains Cree reflect the notion that languages express and embody worldviews, and that the revitalization of “indigenous histories, knowledges, experiences, and identity is inextricably linked to our languages” (McKinley, 2005, p. 232). This sentiment is also emphasized by elders and knowledge keepers, who further stress the importance of language for maintaining a healthy sense of self, an idea supported by research that correlates language retention with lower youth suicide rates in Indigenous communities (Hallet et al., 2007). The inclusion of Indigenous languages is also meant to initiate transformative learning, drawing on areas of similarity between IKS and complexity to catalyze change, rather than simply translate Indigenous
languages into familiar Western understandings. As noted by McKinley (2005), when “language is used to only name objects [it] does nothing for the revitalization of language and continues to separate culture and language” (p. 233).

<table>
<thead>
<tr>
<th>Mechanistic Science</th>
<th>School Science</th>
<th>Complexity Science</th>
<th>Indigenous Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reductionist</td>
<td>Ecology</td>
<td>Nestedness</td>
<td>miyo wîcêhtowin</td>
</tr>
<tr>
<td>Static</td>
<td>Evolution</td>
<td>Emergence</td>
<td>wâhkôhtowin</td>
</tr>
<tr>
<td>Certainty</td>
<td>Quantum Physics</td>
<td>Uncertainty</td>
<td>tapahtêyimisowin</td>
</tr>
<tr>
<td>Linearity</td>
<td></td>
<td>Nonlinearity (e.g., fractals, cycles, circles)</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td>Co-existence</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4: Complexity as a Path to Indigenous Science Education

In this example I have used Plains Cree, one of many Indigenous languages spoken in Saskatoon, in order to honour some of the local people of this place and also because of my desire to learn it for reasons expressed above. Figure 4 could (and should) be recreated and expanded on with additional concepts and languages, and, as with the teaching of ISE in general, be approached as an ongoing process. In this rendition, the complexivist concepts of nestedness, emergence and the acknowledgement of uncertainty are linked with the teaching of ecology, evolution and quantum physics, and then to Plains Cree concepts of miyo wîcêhtowin (good relations), wâhkôhtowin (kinship) and tapehtêyimisowin (humility). Overall, the shift to complement and balance mechanistic thought is described as prompting movements from linear to nonlinear thinking, and from aspirations of control to those of co-existence.
The column on the left of Figure 4 contains attributes of the mechanistic view of science that arose during the Scientific Revolution that, while not necessarily portraying contemporary scientists’ views, remain popular concepts that influence the teaching of science in schools today. This mechanistic caricature of science perceives reality through the metaphor of the machine (e.g., an analogue clock) and as such is reductionist (with identifiable parts), assumes the universe is static (i.e., matter moves when acted on by an external force), and is knowable with a high degree of certainty. The accuracy with which reality is knowable in this paradigm has led to beliefs in certainty and linear thinking, as the behaviors of these systems can be accurately known and predicted into the future. This assumption of certainty has also led to the possibility of, and desire for, control.

This belief in certainty created an oppressive hierarchy of knowledge systems, with those that more accurately describe the mechanistic paradigm at the top. From this perspective comes the assertion that those atop the hierarchy have the right, and perhaps even the responsibility, to exercise control over those with lesser knowledges, possibly even for their own good. This paternalistic attitude is inherent to a mechanistic view of science, and has had disastrous consequences for the world’s Indigenous peoples and the rest of the natural world, as this desire for control is pervasive and includes land, water, plants, and animals. While the seductive nature of certainty in the mechanistic paradigm is cause for concern, it remains a valuable tool of human ingenuity, provided it is balanced with the presence of more holistic and relational epistemologies. Complexity and IKS provide useful conceptual frames to help provide such balance.
5.4.1 Nestedness, Ecology, and miyo wîcêhtowin

The complexivist concept of nestedness may be contrasted with the reductionism of the mechanistic paradigm, and describes complex systems as being “simultaneously autonomous unities, collectives of autonomous unities, and subsystems within grander unities” (Davis & Sumara, 2006, p. 90). Living organisms are one example of nestedness, as an organism is at once an autonomous unity, a collective of autonomous unities (e.g., genes, cells and organs), and part of a subsystem within grander unities (e.g., communities, societies, and ecosystems). The concept of nestedness is inherent in the teaching of ecology, which is focused on the dynamic relationships that exist among organisms, between organisms and their environments, and with a variety of systems and cycles (e.g., nutrient systems, water cycles, etc.).

Nestedness is partially reflected in the Indigenous perspective of holism (Archibald, 2008; Armstrong, 2000), which has been articulated in terms of “concentric rings of relationship” (Cajete, 2000b, p. 277) among the individual, family, clan, community, land, and the broader living world. The Plains Cree concept and value of miyo wîcêhtowin (good relations) reflects this inherently relational reality, and stresses the importance of maintaining healthy relationships among these diverse spheres of existence. In our industrialized and globalizing world, the concepts of nestedness and miyo wîcêhtowin may expand the ecological focus on organisms, environments, and geophysical systems to include other nested social systems impacting the physical world, such as economic systems and educational systems, among others. In this way, science teachers may connect their teaching with any number of issues relevant to their students’ lives with a focus on the meaning and process of maintaining good relations.

105 Indigenous holism also attends to the physical, mental, emotional and spiritual elements of existence.
5.4.2 Emergence, Evolution, and wâhkôhtowin

While nestendess describes connections of the present, emergence speaks to historical relations of common evolutionary origins. As described by Davis and Sumara (2006), emergence refers to how “agents that need not have much in common—much less be oriented by a common goal—can join into collectives that seem to have clear purposes” (p. 83). Complex systems like ant colonies and brains arise and maintain a coherent unity not through centralized control but through the nature of the relationships among their parts (Johnson, 2001). Emergence connotes the “inherent creativity” of nature (Doll, 1993) and is also referred to as “self-organization” (Johnson, 2001).

Kauffman (1995) similarly describes emergence as “order for free,” noting that it provides an important supplement to Darwin’s theory of evolution by natural selection, positing that selection operates on naturally emergent patterns rather than random mutations. For Kauffman, this initiates a shift in scientific perceptions of life on Earth from “we the accidental” to “we the expected” and amounts to nothing less than the “reinvention of the sacred.” The view of the universe as emergent and active, rather than static and inert (as the mechanistic paradigm holds), mirrors the Indigenous view of the cosmos as animate and imbued with spirit. Emergence also supports the Plains Cree concept and value of wâhkôhtowin, referring to a sense of kinship that extends beyond blood relatives to include all of creation (e.g., animals, plants, rivers, mountains, earth, moon, etc.). Cosmic evolutionary theory as portrayed through the Big Bang necessarily entails human connections with creation. The concept of emergence provides a means of a deepening one’s personal sense of kinship with creation, as entailed in wâhkôhtowin, viewing all elements of creation, including us, as naturally emergent phenomena.
Justice (2008), a Cherokee scholar, has noted the verb-oriented nature of Indigenous kinship, it “is about life and living,” it is “something we do, actively, thoughtfully, respectfully” (p. 148).

5.4.3 Uncertainty, Quantum Physics, and tapahtêyimisowin

Quantum physics reveals a limit of reductionist analysis by suggesting that fundamental particles of matter can only be described in terms of probabilities within fields of energy (Capra, 1982). Heisenberg’s “uncertainty principle” states that the location and velocity of a subatomic particle can never be specified with certainty, as the act of observation itself alters these variables. Quantum physics thus acknowledges uncertainty, marking an important shift away from mechanistic thought common to complexity and Indigenous knowledge. Complexity further recognizes uncertainty at the level of everyday human experience. Since complex systems can behave in novel and unpredictable ways, when assuming the ubiquity of complexity “the limited and provisional nature of all understanding has to be recognized” (Richardson & Cilliers, 2001, p. 8).

Indigenous knowledge is closely attuned to local places, and thus “makes no claims to universality” (Castellano, 2000, p. 25). Rather than recording exact, objective measurements of the natural world, Indigenous knowledges emerged through millennia of adaptation and co-evolution with the dynamic, shifting patterns of nature. A further acknowledgement of uncertainty is evident in the idea of the “Great Mystery” (Cajete, 2000b), a term used in reference to the Creator that signifies tapahtêyimisowin—a sense of humility with respect to the place of humanity in creation. Acknowledging uncertainty disrupts the hierarchy of knowledge systems described above, initiating shifts away from

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106 Subatomic particles have also been observed influencing one another over great distances, indicating a high degree of interconnectivity (Bohm, 1980).
linear thought and aspirations of control toward forms of non-linear thought and co-existence that value diversity, expect change and adaptation, and embrace multiple possibilities.

5.4.4 Toward Nonlinearity and Co-existence

Taken together, the congruencies between complexity and IKS identified and expressed in Figure 4 are intended to prompt shifts away from the linear thought and belief in certainty of mechanistic science toward nonlinearity and an appreciation of the need for co-existence. The notions of relationality embodied in these terms are also intended to help catalyze more equitable and sustainable ways of living by fostering miskasowin through ISE, and can be used to enable bridging, two-eyed seeing, and weaving IKS and ES, depending on the nature of the teachers and students involved. Again, the concepts are not necessarily meant to be believed and internalized, but are offered as opportunities for students to encounter these ideas, and they can take what fits and makes sense to them. If we don’t teach these things in schools students may have few other opportunities to encounter them, and, at least in my opinion, they are valuable for responding to the crisis of perception underlying today’s humanitarian and ecological crises.

5.5 ISE Activities and Resources

The following activities and resources emerged through my experiences teaching ISE and in conversation with elders and knowledge keepers, and include nêwo kwécimowina, a set of questions for a talking circle; okâwîmâw askî, a way of teaching about Mother Earth with early learners; taku skan skan, a Lakota concept that helps to connect concepts of emergence, spiritual energy, and quantum physics; and kînîkâtos âtayohkêwin, a sacred part of the creation story of the Plains Cree that predates the more commonly told story of
the flood. Each is connected in various ways to my slow pedagogy of relations’ focus on land, language, life, story, and ceremony, and an understanding of miskasowin as a process of learning to relate that deepens awareness of intersubjectivity, biophysical interconnectedness, and kinship.

5.5.1 nêwo kwêcimowina

nêwo kwêcimowina (Four Questions) is a talking circle activity that helps build relationships and introduces similarities and differences between IKS and ES. Talking circles are effective pedagogical practices that offer a more egalitarian complement to the typical classroom structure, as there is no front or back to a circle and everyone can see one another, rather than only the teacher. I often start my classes with a quick “check-in” circle to give students an opportunity to share how they are feeling and what is going on in their lives, if they so choose. While this takes time (hence the slowness), the majority of students have responded they appreciate these circles as a way for to get to know each other and to create a welcoming atmosphere. Circles can also be used to introduce aspects of IKS, including the notion that nature is a teacher, rather than only a resource. As the circle is found in the moon, sun, and Earth, in the shapes of animals’ homes, and in the power of the swirling wind, Indigenous peoples have recognized its importance and learned to construct homes and conduct ceremonies in a similar fashion.

The nêwo kwêcimowina activity was developed through work as an Indigenous Knowledge Facilitator with grades six to eight students at the Brightwater Science and Environmental Learning Centre. I would meet with small groups of students for an hour, where I would introduce myself, show them the ceremonial grounds, and then discuss connections between IKS and ES around a fire in a tipi. Relationship building is central
to my pedagogy, and I would always ask the students to introduce themselves, sometimes leaving little time to discuss IKS and ES. I eventually learned to weave this discussion into a set of four questions the students could respond to while introducing themselves:

1. What is your name?
2. Where are you from?
3. Who are your ancestors?
4. How are you unique?

Before the students responded to each question I would address it from perspectives of both IKS and ES, noting how the diversity of our beliefs and worldviews are reflected in our answers to these questions, and asking students to reflect on the degree to which each question is connected to their own sense of identity.

On the topic of naming, I note how both IKS and ES employ names (e.g., the elements or plant and animal classification) but that in IKS names can change with time and location, reflecting the idea that all is in flux, rather than static. For example, in many Indigenous traditions a person’s name can change to reflect achievements, attributes, or be adopted from relatives who have passed to the spirit world. I also note how people’s names often have deeper meanings, and ask if they know the meaning of theirs and if it has influenced how they view themselves.\textsuperscript{107} When addressing “Where are you from?” I discuss how the places we spend our time influence our worldviews, and how Indigenous people’s relationship with the natural world has contributed to worldviews and beliefs focused on relationships and cycles, rather than the linear worldview of Western society, and compare winter counts (cyclical) with the calendar (linear) to demonstrate this.

\textsuperscript{107} Jeff, for example, means ‘peacemaker.’
With respect to “Who are your ancestors?” I discuss the Indigenous reverence for “those who have come before” as reflected in the Lakota term *tuŋka shila*, which means grandfather (and includes grandmothers) and is used to appeal to the ancestors in prayer and ceremony. I note a similar view in ES, in that we carry our ancestors in the DNA in our cells. So from both IKS and ES, those ancestors are with us, either standing behind or functioning within our cells, at all times. I sometimes also note our common ancestry by asking, “What percentage of your school has Indigenous ancestry?” The answer is one hundred percent, as we all have ancestors that lived close to the land in ways that revered the sacredness of life. An interesting observation is that very few students have a sense of their ancestry, of who their great grandparents are and where they came from. Perhaps an important first step in fostering *miskasowin* would be to help students learn more about their own familial relations.

The final question “How are you unique?” is an opportunity for students to let the other participants know about anything they would like, and is often quite humorous. The question emphasizes that regardless of where we come from or who our ancestors are, we are all unique. Diversity exists across divergent responses to these questions as well as within similar answers (e.g., two students from the same place or with similar ancestries can be completely different people). Each of these questions can be adapted to suit the grade level or particular subjects being taught. For example, the question “Who are your ancestors?” could be rephrased to “Who are your relatives?” after a unit on emergence and evolution to elicit responses that might include other species or natural phenomenon. The questions can also be revisited throughout the year to assess changes to students’ understandings. In sum, *nēwo kwēcimowina* is an activity that helps establish a sense of
community, encourages students to consider their interrelatedness, and provides ongoing opportunities for students to personalize their learning.

5.5.2  okâwîmâw askî

Unlike nêwo kwêcimowina, which evolved over a period of time, the okâwîmâw askî (Mother Earth) activity was a more spontaneous crystallization of ideas I had developed while working at Brightwater. When discussing the tipi I would note how the materials traditionally used to make tipis all came from the Earth, which led to discussion of how all that we need and use comes from the Earth, with the exception of sunlight. Hence, Mother Earth, Father Sky, Grandmother Moon, and Grandfather Sun embody an animate universe and provide all that is needed for life. The okâwîmâw askî activity crystallized while I was sharing connections between IKS and ES with youth at the University of Saskatchewan’s annual graduation powwow. A number of tipis had been set up around the arena, with people sharing different crafts, stories, and teachings inside them.

Toward the end of the day when things had slowed down and I was preparing to leave, an international group of parents, toddlers, and babies filed in and sat down around me. Once they were settled I welcomed the group, “tatawâw êkwa kitâtamisktinâwâw kahkiyaw,”108 acknowledged the Plains Cree as one of the First Peoples of the land we were sitting on, and introduced myself. I had never worked with such a diverse group before, and was unsure of how to proceed. I decided to speak with them about where we were, which, among other things, was on the ground. I spoke of the importance of connections to land among Indigenous peoples, running my fingers along the grass and digging them into the dirt. Many of the kids looked down and did the same. “In Cree, we call this askî, which means dirt, or earth. Can you say that?” “askî,” the collective softly

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108 Plains Cree for “Welcome and warm greetings to you all.”
responded. “We also call this okâwîmâw askî,” I continued, rubbing my hands around me on the ground, “which means Mother Earth.” The parents and their children gazed down and rubbed their hands on the earth. “okâwîmâw askî,” they slowly replied.

What happened next was almost magical. One of the toddlers, maybe three or four years old, quietly asked, “Why do you call it Mother Earth?” I was just about to respond when another toddler spoke up, “Because she takes care of us.” We all sat for a moment before I affirmed her suggestion, “That’s right, she does. In a lot of ways, the Earth cares for us just like our mothers do.” “Can you tell me some ways your mom cares for you?” I asked the group. “She feeds me,” someone said, “And she helps me get dressed,” another responded. “Yes, those are great examples! And just like your moms, the Earth feeds all of us and provides the plants and materials we need for our clothes, too. Anything else?” “My mom takes care of me when I’m sick” another toddler offered. “Yes,” I continued, “and Mother Earth provides us with medicine too. Did you know that most of the world’s medicines originally come from plants?” Before anyone could respond a little girl piped up, “And I like to take care of my mom when she’s sick too, because I love her.” She looked up at her mom, and gave her a big hug.

I was stunned. “That’s wonderful,” I said. “I think you’re right, we all like to take care of things we love. But what about Mother Earth, do you think she ever gets sick?” I asked. It was at this point that the parents began to jump in, citing climate change, species loss, and pollution as different ways that Mother Earth was suffering, nodding across the tipi at one another in agreement. “Why?” another toddler asked, “Why is Mother Earth sick? And how can we help her?” “Well, there are lots of reasons,” I replied, “but one is that we are living out of balance, I think we might be taking too much from Mother Earth
without giving back. Amongst the Plains Cree it was always taught that we have to give back when we take something. Maybe some of us have forgotten that.” Again, the parents nodded at each other, and began to speak with each other and their children about things they were doing and that they could do to help Mother Earth. As the session wrapped up I thanked the group, especially the children, for coming to speak with me and for all that they brought to the conversation. I shook hands with each of them as they filed out, and many of the parents smiled and thanked me for the experience.

While this example of the okāwîmâw askî activity relied on the participants as much as it did on me, it is a good example of what can happen when a repertoire of IKS is built up that can be drawn upon as needed. I had no idea where the discussion would go when it began but my previous work and experience listening to and learning from elders and knowledge keepers helped me connect the group’s comments with elements of IKS with which I was familiar. While one of the strengths of this activity is that it can be done with early learners, which is crucial given the influence of early learning on one’s beliefs and values later in life, it can also be adapted for use with older groups. Working with high school biology students, for example, the Gaia Hypothesis (Lovelock, 2000), which considers the Earth a living organism, could be introduced, as could the idea that organic life is an emergent phenomenon that has arisen with the Earth’s myriad systems (e.g., climate, hydrological, nitrogen, etc.), positioning the Earth as a mother to all life.

5.5.3 Taku skaŋ skaŋ

My conversations with Darlene Speidel covered a broad array of topics, far too many to report on here. I have chosen to focus on connections between the Lakota language and

109 This section is drawn from notes taken during conversations held at Darlene’s kitchen table on December 30, 2014 and April 12, 2015.
the complexivist concept of emergence because of my interest in biocentric complexity (Baker, 2008) and my belief that the idea of an animate universe is an important avenue for fostering miskasowin. When I asked Darlene if there were Lakota terms that reflected emergence (i.e., the idea that the universe is inherently creative, rather than static and inert), a few thoughtful moments passed before she replied, “Maybe taku skaŋ skaŋ?” When I asked what it meant she provided its translation, “That which moves, moves,” noting that the repetition of skaŋ emphasizes the term, in this case movement. I was intrigued; the phrase suggests that movement occurs of its own volition, rather than requiring a mover, and that all things are in motion, all the time.

Darlene explained that there are different levels of language in Lakota, and that the translation she had given was the common meaning of taku skaŋ skaŋ used in day-to-day life. In its wakan (sacred) form, the phrase describes an animate universe in which everything is in constant motion and where creation is an ongoing process. She continued with a focus on skaŋ, which in common usage refers to movement but through wakan language refers to a life-giving energy, an essence that fuels the motion and vibration of all existence, including atoms and molecules. She then introduced tuaŋ, another term that is connected to emergence, that in common usage means, “to give birth to” and in wakan language describes a spiritual essence that is infused, along with skaŋ, in all things. It is tuaŋ, this spiritual essence, which gives birth to action and manifests the life energy of skaŋ into growth and development.

Tuaŋ is also personal, and conceptualizes the power that personalizes the Indigenous connection to nature, as described in Deloria and Wildcat’s (2001) phrase, “power plus place produce personality” (p. 21). We each carry tuaŋ, it is imprinted on our
belongings and objects through physical connections and through thoughts and prayers. Making a commitment, for example, ignites the tuy within us, which will burn until the task is completed. For this reason we must be careful with our words, with what we ask for and agree to. Tuy needs rest and our energy will be drained if it is left lit, leading to ill health or other forms of misfortune in our own lives or among our family. While I realize skay and tuy are two aspects of a far more complex Lakota understanding of an animate, spiritual existence, in my understanding they comprise interdependent sources of energy and order through which creation has emerged and are sustained. They exemplify the idea that “Indigenous sciences are underlain by the understanding that all physical bodies and minds are connected and expressions of a deeper spiritual essence” (Sheridan & Longboat, 2006, cited in Hatcher et al., 2009, p. 143).

For practitioners of ISE, skay and tuy are concepts that may prove useful in introducing Indigenous spiritual beliefs, an aspect of IKS that can be an awkward fit with the ES focus of school science on descriptions and explanations of the physical world. It may be helpful to point out that ES does not deny spirit, only its capacity to be quantified (Haverkort & Burgoa, 2010). As ES focuses only on the physical aspects of reality, it cannot dispute or disprove the reality of metaphysical phenomena; the spiritual realm simply lies beyond the purview of its gaze. With regard to ISE and the stated goal of miskasowin, rather than focusing on the challenge of respectfully including Indigenous spirituality in school science, perhaps we might start looking at it as an opportunity to infuse spiritual and emotional relationality into science education in recognition of their relevance and necessity for achieving a more balanced and harmonious existence.
5.5.4 *kînikatos âtayohkêwin*

The final resource offered is the sacred story of *kînikatos*, as told to me by Barry Ahenakew, who has allowed me to share it in print. This is the first time that this story has been written and published and, given the often appropriative nature of research–Indigenous relations, serves as an example of what can happen when trusting, respectful relations are established. I am sincerely grateful to Barry for allowing me to share it with ISE instructors in the hope that it will be used in a good way. The story of *kînikatos* tells of the power and perils of intelligence and technological innovation and the repercussions of *pâstâhowin* (breaking natural law). It is part of a much longer *nēhiyaw* creation story that tells of two periods of creation and destruction that predate the present.

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*kînikatos âtayohkêwin*¹¹¹

*kayâs*. A long time ago, before the waters ended the second world of people, a man was born who was blessed with *nipwâhkêwin*, the gift of cleverness and ingenuity. At the time, the People were struggling. *kisê manito* (Creator) had taken their ability to communicate with their animal brothers and sisters at the end of the first world of people, and they were living a hard life, taking shelter in caves and hollows and using rocks and sticks to try to provide for themselves. The man blessed with *nipwâhkêwin* noticed how the sharp edges of broken rocks could be used to cut, and he began to create and invent, fashioning wood and stone tools that helped

¹¹⁰ Barry has shared another story with me, *niyanamis* and the Wooden Boat People, for publication in a report for another project (Baker & Ewert-Bauer, 2014), for which I am also grateful. ¹¹¹ “The Sacred Story of *kînikatos*.” The story shared here is an abridged version of the fuller story, which I am continuing to work on with Barry’s daughter, Sekwan Ahenakew.
make life easier for the People again. Among his inventions were the 
câpihcicikanis (spear), the asinîy mohkomân (stone blade), the pakamakan
(club), the ahcâpî (bow), the piskokask (blunt arrow), and atos (arrow).
Through his inventions he earned the name kînikatos\textsuperscript{112} (sharp arrowhead).

\textit{kînikatos’} blessing was passed on to his children, who carried on
his passion for inventing, and the gift of nipwâhkêwin became amplified
within each successive generation. Over many generations, \textit{kînikatos’}
ancestors learned to harness the powers of special stones (crystals), air,
and water, and used this knowledge to fly, to transmit sounds and images
long distances, and to create bombs and other weapons. With these new
technologies \textit{kînikatos’} ancestors were able to travel great distances and
became very powerful, in some cases abusing this new power. In their
travels they came across another People living on an island in an inland
sea to the West. The power given to \textit{kînikatos’} ancestors had resulted in
arrogance in some, and it wasn’t long before altercations began. With their
dominant technology \textit{kînikatos’} people killed many of the island dwellers.

\textit{kisê manito} was disappointed, and disapproved of this behavior as
it violated the laws that had been given to the People, through which they
could live good lives. This violence, death, and destruction were too great
a pâtâhowin (breaking of nêhiyaw law) to leave unpunished. \textit{kisê manito}
decided again to end the world, shaking it and telling his Thunderbirds to

\textsuperscript{112} \textit{kînikatos} is also sometimes referred to as cîpokayó (pointed arrowhead).
make it rain, causing a flood and destroying the People and the technology they had been blessed with, bringing an end to the second world of People.

This story has numerous connections to school science, including physics (e.g., projectile motion, force, mass, etc.) and geology (e.g., properties of rocks, evidence of interglacial lake in North America). It is also appropriate for lessons on technology, which is sometimes considered synonymous with ES but is a distinct and interdependent pursuit (Aikenhead & Michell, 2011). With respect to ISE, the story could be used to introduce technologies used in Indigenous societies and to discuss the benefits and limitations of those in the story and those used today. Helping students learn about the limitations and abuses of technology may help disrupt ideas that technology is purely of benefit to human societies. Teaching that all peoples (and even some other animals) use technology may also disrupt the notion that technology separates some human groups from others, and humans from other animals. Lastly, the story may also lead to discussion of the degree to which contemporary technologies have entwined themselves in our lives, and the degree to which they improve or limit our capacity to live well with one another.

The story of kînikatos thus serves as an instructive parable on the power provided by ES and technology, and of the relative lack of wisdom guiding its use. It also provides an opportunity to consider the relevance of Indigenous teachings regarding appropriate behavior, sometimes referred to as “natural laws” that were given by the Creator to guide human actions. nêhiyaw law (McAdam, 2015), for example, provides guidance regarding physical and verbal offenses against our human and non-human relatives, with physical transgressions against other humans termed pâstâhowin. While these teachings were
passed on through the oral tradition; in stories, songs, ceremonies, and dances, etc.; the interruptions forced on Indigenous peoples through colonization have resulted in a departure from this and prompted some knowledge to be recorded in written form. While this practice is still a matter of debate among Indigenous peoples, it was for this reason that Barry chose to allow some of the oral history to be recorded here.

The use of narratives in school science is a further area in which the story of kînikatos may be useful for ISE. While creation stories are often viewed as part of IKS, they also allow students to consider ES as a form of narrative, telling particular kinds of stories about the world and how it works. The Big Bang, for example, can be considered a creation story in ES, with Swimme’s The Universe Story (1994) offering a complexivist narrative of the emergence of the cosmos and life on Earth. A useful activity for fostering miskasowin might be to ask students to consider how creation stories situate people in relation to the world and universe, thus impacting the narratives through which we make sense of and live out our lives.113 While contradictions with the standard account of ES (Erickson, 2005) may cause hesitancy with regard to embracing Indigenous stories in school science, stories do not need to be taken literally to be taken seriously and to be instructive (Thompson, 1981). The ability for stories to connect with us in personal and emotional ways makes them important avenues for miskasowin, in complement to the positivism of ES, and therefore essential to the practice of ISE.

5.6 Evaluation in ISE

Strategies for evaluating student learning in ISE are not as well attended to in the literature. Aikenhead et al. (2012), however, provide a useful summary of culturally valid

113 See King (2003) for an example of a comparison between Christian and Indigenous creation stories.
assessment for science education (p. 82–106) that differentiates between assessment of scientific knowledge (e.g., ES and IKS), knowledge about science (e.g., socio-cultural phenomena, holistic, etc.), and processes of coming to know (i.e., participation in cultural immersion for IKS). While noting specific strategies will be highly context-dependent, Aikenhead et al. strongly advocate for the use of portfolios in culturally valid assessment as this “nurtures students’ responsible autonomy in the classroom, strengthens students’ collaborative relationships with their teacher, and encourages students to develop a capacity for self-assessment” (p. 93, emphasis in original). Portfolios also provide students opportunities to showcase their own gifts and knowledge base, allowing the knowledge they bring to the classroom to be assessed as part of their learning.

Discussing strategies for evaluating student learning begs the question of the aims and purposes of education itself. When educators focus solely on student achievement we perpetuate the dominant goals of society, which at present include creating a labor force to compete in the global economy and providing opportunities for maximum individual financial gain (Orr, 2004). While economics are important, especially considering the poverty many Indigenous peoples are subjected to, focusing solely on finances blinds us to other important aspects of holistic health. Teachers must therefore articulate their own goals for ISE and tailor their teaching and evaluation accordingly. Adopting equity and sustainability as goals of education shifts focus from purely economic indicators and may include measures of the health of students, teachers, schools, and communities in local and global contexts, as well as other measures of planetary health including biodiversity, pollution, and climate change. This approach more closely mirrors an Indigenous view of
assessment where “competency has an equivocal relationship to survival or extinction” and “survival is the ultimate measure” (Kawagley & Barnhardt, 1988, p. 2).

5.6 Chapter Summary

In this chapter I have attempted to describe the slow, relational pedagogy that emerged from my experience of coming to understand ISE. Acknowledging articulations of ISE as personal, ongoing processes, I encourage others to develop approaches to ISE based on their own unique experiences, skills, and gifts. I also discussed the need for professional development that will support teachers interested in ISE, noting the pressing need for programming addressing foundational knowledge on local histories and worldviews, a process that invariably requires local engagement and relationship building.

I also articulated miskasowin in terms of learning to relate (fostering a deeper sense of intersubjectivity, biophysical interconnections, kinship, and sharing stories) and offered complexity as a path to ISE by connecting complexivist concepts of nestedness, emergence, and uncertainty with topics from school science (ecology, evolution, and quantum physics) and related nêhiyaw terminology (miyo wicēhtowin, wâhkôhtowin, and tapahtēyimisowin). I concluded the chapter by sharing four examples of learning activities that arose through my research. In the next and final chapter I discuss the centrality of identity, story and ceremony in my research; provide recommendations for teaching and research in ISE, and identify important directions for future research.
Chapter 6: Closing Reflections

6.1 Wrapping Up

This research has been an unexpected adventure, complete with twists, turns, tragedies and triumphs. It has been closely interwoven with my personal life, and it feels almost surreal that this part of my journey is coming to a close. My research set out to explore the transformative possibilities of ISE, weaving PAR and IRM into a form of Indigenous Métissage (Donald, 2012); decolonizing and Indigenizing school science through the respectful inclusion of complexity and IKS. I knew I would be impacted, and possibly even changed to some degree through this research, but had no idea how much. Based on my research experience I can say, without question, that ISE can be transformative.

In this final chapter I offer a brief research summary; discuss identity, story and ceremony as aspects of the personal change I experienced through this research; share some recommendations for teaching and research in ISE; and list directions for future research in ISE before offering a few words to conclude this work.

6.2 Research Summary

There is growing acknowledgement that contemporary humanitarian and ecological crises are manifestations of a single crisis, a “crisis of perception” (Capra, 1996, p. 4) regarding the modes of thought, perception, and values guiding Western societies. The mechanistic worldview that arose during the Scientific Revolution and Enlightenment gave rise to a mode of thought that delegitimized all things non-Western114 (Taylor, 1991) and was characterized by “rampant individualism, disenchantment, and the dominance of industrial reason” (Kemmis & McTaggart, 2005, p. 563), thus separating

114 And/or appropriation of things deemed useful.
humans from the natural world and inspiring aspirations of perfect knowledge and control. Core ideas regarding reductionism and linearity have also informed European colonial aspirations and institutions of formal education, and continue to predominantly shape science education in K–12 schools.

This research explored the transformative possibilities of ISE for catalyzing the emergence of more equitable and sustainable ways of living, and positioned IKS and the complexity sciences as means of complementing the mechanistic tendencies of school science and as agents of change toward *miskasowin*. Positioning IKS as transformative signals an important shift away from deficit views of Indigenous peoples (i.e., as sources of problems) to one that acknowledges our ongoing and potential contributions. The complexity sciences were presented as a way for teachers to connect ES with ISE, as they more closely resemble the holism of IKS through their attention to dynamic, nonlinear, irreducible, systems and their acknowledgement of uncertainty, inviting consideration of the spiritual and emotional domains of human existence.

On a more personal note, pursing this research through a relational and adaptive methodology of Indigenous Métissage (Donald, 2012) has allowed me to come home and reconnect, provided an opportunity for me to engage with ceremony, and led to a shift in my research toward sharing my own story of change. Through this research I have been building relationships and learning with members of my home community, reclaiming an important part of my cultural heritage, and continuing my journey of holistic personal and professional development. In sharing the story of the changes experienced through this research, notably my appreciation for story and engagement with ceremony, I hope to
support other interested educators to navigate the adventures that lie ahead in their own explorations of ISE.

6.3 Identity, Story, and Ceremony

My research began with a desire to understand how my work as a science educator might contribute to the resolution of humanitarian and ecological crises. This led me to consider the efficacy of fostering more relational worldviews and identities, what I have described here as *miskasowin*, as a means of working toward this goal. Drawing on complexity and respectfully engaging IKS during this research in ISE, I developed a new appreciation for spirituality and narrative as important elements that informed my own process of learning to relate. Interestingly, all three of these factors—identity, story and ceremony—are linked to an acknowledgement of uncertainty.

My diverse ancestry and experiences travelling have prompted reflection on my relations to diverse people and places, and led to changes in the way I identified myself and viewed the world. I now embrace some uncertainty regarding my identity, and lack a strong, singular sense of self. While similar to identity confusion in some ways, this may also simply be part of the process of *miskasowin*. Perhaps before we can foster relational worldviews and identities we must trouble and begin to let go of those we know. Further, acknowledging uncertainty does not entail a total incoherence or loss of self, only a sense of fluidity and an acceptance that how we presently understand ourselves may not be conducive to fostering the emergence of equitable and sustainable ways of living.

*Story and ceremony, two foundational elements of IKS, are also connected to uncertainty, and comprise important ways of engaging with and expressing it (Mohawk, 2010). Notably, it may be more common for Indigenous peoples to express uncertainty in*
terms of mystery, as in the “Great Mystery” (a common synonym for Creator), shifting focus from something lacking (i.e., not being certain of a knowledge claim) to something accepted as a natural part of creation (i.e., that some things are unknowable). In my view, a little mystery (or uncertainty) is good for us, as it keeps us humble and lessens our tendency to dominate and oppress based in the truth of our own beliefs. Both story and ceremony have impacted the way I approach teaching and research, and have also influenced the way I view the world.

6.3.1 Identity

The intensity of the changes I experienced through this research sprang in part from my interest in pursuing them, and should not be expected of all teaching and research in ISE. Work in ISE, however, especially as I have conceptualized it, will likely require personal change in the form of decolonization (i.e., developing critical consciousness) and may also lead to Indigenization, to varying degrees, through engagement with IKS. A central result of this research has been my own process of learning to relate. A variety of factors (e.g., ancestry, upbringing, travels, education, etc.) that predated this research, and other life events not typically relevant to research, such as the birth of my daughter, have also influenced my journey of miskasowin. It has not been without challenges, not the least of which is the emotional toll of learning to relate. Assuming a kinship relation with creation, for example, personalizes the varied crises unfolding on our planet, which is challenging to conceptualize, and can be overwhelming to experience.

I wish to acknowledge and honor all of my ancestors in this work, but due to the nature of my research, my residence in the province of Saskatchewan, and my nascent understandings of IKS, a primary focus has been on my growing sense of Indigeneity. I
am presently in the midst of what Smith (1999), citing Fanon (1990), described as the second of three phases through which Indigenous intellectuals’ progress in their journey back over the line. It is a “period of disturbance” that emphasizes the need for “intellectuals to remember who they actually are, a time for remembering the past” (p. 70). While Indigenization has heightened my awareness of what it means to be a person of Indigenous ancestry, I realize that I still reside, and likely always will, in a space in between Indigenous and non-Indigenous realities.

Being ḥpihtawikosisân, a “half-son” living between worlds, has its strengths and limitations. While I can walk with varying degrees of ease in both worlds, I sometimes feel caught between seemingly conflicting impulses: the rational and intuitive, the human and more-than-human, the present and future. I have come to realize, however, that it is in these spaces of contradiction that sources of creativity and possibility arise. As Cajete (2000a) noted, being torn between different ways of living and looking at life “is a place of great confusion, but it can also be a place of great compassion and clarity” (p. 189). Holman Jones (2005) has similarly urged us to, “Recognize the power of the in-between. Recognize the power of having it ‘both ways’” (p. 784, emphasis in original). While living between worlds and worldviews can be confusing, it also provides access to the richness of intersubjectivity, prompting shifts from ‘either/or’ to ‘both/and’ thinking and engaging with the “radical possibilities that exist in these in-betweens” (p. 784).

6.3.2 Story

A deeper appreciation for narrative and story, which are foundational to IKS, is another important aspect of the change that occurred. Sharing and listening to stories, whether personal, fictional, or traditional, can also foster intersubjectivity, providing access to and
familiarity with perspectives, experiences, and worldviews that may differ from one’s own. I now understand science and stories not as antithetical, but as complementary. Stories and narratives can help to balance the scientific focus on facts and measurement, opening a respectful space for the inclusion of IKS and contextualizing science in personally relevant ways. Living the world through stories, those I’ve heard, those I’ve learned, and those I tell, has deeply impacted nitâcimowin, the story through which I make sense of the world and act out my life.

Scientific narratives (the stories that science tells, or that we construct from scientific knowledge) and their impact on kitâcimowinawaw (our stories) have become central to my pedagogical commitment to transformative learning. As Berry (1988) suggested, “It’s all a question of story. We are in trouble just now because we do not have a good story. We are in between stories. The old story, the account of how we fit into it, is no longer effective” (p. 123). Perhaps IKS and complexity may help to co-author new stories arising from the borderlands between worldviews and knowledge systems. It is border areas in ecosystems, for example, where diversity, abundance, and possibilities for new growth occur. Similarly, “borderland stories speak in several ways—as histories complete in themselves, as historical dialogues with the potential for mutual enlightenment, and as forecasts for phenomena yet to come” (Brooks, 2002, p. 184). Stories from in between need not be stories of what is (e.g., ES) but may be stories of what might become.

My research makes no assertions of Truth or provisions of proof, but instead is offered as a story focused on persuasion, connecting on human and emotional levels, regarding the efficacy of fostering relational worldviews and identities as a response to

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115 “My story” in nêhiyawêwin (Plains Cree).
global humanitarian and ecological crises. Acknowledging the need to change our story amounts to a paradigm shift of sorts, and suggests that many efforts will be ineffective until we learn to embrace a new story, or stories, that situate us in deeply relational ways with people, plants, animals, the planet, and the cosmos. While I offer my story as an example for those working to respectfully include IKS in science education, hoping they may find something of use for their own journey, I acknowledge I am an inexperienced storyteller, and that I am only learning how to write, teach, make meaning, and research in this way.

6.3.3 Ceremony

My engagement with ceremony is a further major change that occurred through my research. I was unaware that ceremony was something I had been missing and seeking until I was invited to participate. The settings, natural pace, and calm atmosphere were immediately appealing, and my comfort grew as I learned about the role of ceremonies in humbly honouring our relatives and respectfully engaging in natural cycles of renewal. Experiences in ceremony also helped me expand my awareness of our biophysical and socio-cultural interconnectedness to include a spiritual dimension. While I had begun considering a deeper concept of kinship through the complexivist notion of emergent evolution, ceremony helped me make sense of Indigenous views of kinship, where interrelatedness is rooted in the idea that all elements of creation are expressions of spiritual energy, an understanding that draws more parallels with quantum physics than evolution.

Ceremony allowed me to experience the reality of something that exists beyond the physical realm. While my own experiences helped me come to this understanding,
through participating and helping in ceremony I have also heard some compelling stories, far too many to ignore. My commitment to leading a spiritual life has wavered to some degree over the duration of this research, but the impact of these experiences is evident in the fact that prayer, smudging, and song are part of my daily practice, and I draw on them when needed (prior to this research I would pray only out of desperation). To me, prayer is a form of meditation, connecting, giving thanks, focusing, asking, and putting out intentions. Coming from a background in ES, I have to admit I do not know how prayer or ceremony work, but whether one employs a spiritual or psychological lens does not change the positive impact these practices have had on my life.

Listening to the prayers of others in the inipi has also been transformative, as I learned first hand of the realities facing many families and community members, and of the importance and power of these healing traditions. I also learned about the strength and resilience of Indigenous peoples and ceremonies in the face of attempted genocide. While ceremonies were outlawed under the Indian Act until from the late 1800s until 1951, and many were lost during this time, they are coming back. The people I have met attending ceremony have consistently been humble and healthy, or at least seeking health. Even for me, as an Indigenous person of privilege, the spiritual family that I belong to has been an amazing source of community support, and along with the ceremonies and my spiritual beliefs were instrumental in helping me cope with the sudden passing of my father, which marked yet another transformative moment during this research.
6.4 Recommendations for Teaching and Research in ISE

This summary of recommendations for teaching and research in ISE is based on my conceptualization of ISE as a process of catalyzing more equitable and sustainable ways of living through *miskasowin*. While many of the recommendations will be applicable anywhere, they were developed primarily for educators (teachers and faculty), policy makers, and researchers in Saskatchewan, where a rapidly growing demographic of young Indigenous peoples and new science curricula and textbooks that respectfully include IKS have heightened the need for professional development and improved teacher education programs. I have arranged my recommendations, which in general suggest slower, more personal, and relational processes, as follows: 1) preparing teachers for ISE, 2) decolonizing and Indigenizing pedagogies for ISE, and 3) Indigenous Métissage in ISE research.

6.4.1 Preparing Educators for ISE

Becoming an effective teacher in ISE will require preparation similar to that needed for any work in Indigenous education, such as understanding the ongoing impacts of colonial policies and practices, and learning about (and with) local Indigenous peoples, histories, and the holistic nature of our worldviews and knowledges. Building relationships in the community, which may include or lead toward relationships with elders and knowledge keepers, is a fundamental aspect of this learning, and opportunities for this engagement (e.g., culture camps, local language courses, community events, etc.) should be made available to learners as frequently as possible. Preparation for these experiences with respect to protocols, expectations, and other issues such as potential voyeurism and
dealing with vulnerabilities (of community members and students) will help to ensure positive learning experiences.

The focus on transformation and miskasowin within ISE also necessitates an awareness of humanitarian and ecological crises, a part of our shared context that, along with colonization, constitutes the disorienting dilemma required to prompt transformative learning (Mezirow, 1978). The four realizations that grounded my views of ISE,\(^\text{116}\) which include an awareness of colonization and contemporary crises’ rootedness in mechanistic science,\(^\text{117}\) may also help ISE instructors appreciate the utility of respectfully including IKS in science education. Further, teaching ISE requires a critical self-awareness of one’s views on the purposes of education (and their fit with miskasowin), one’s own learning in IKS\(^\text{118}\) and journey toward miskasowin (i.e., areas of strength and weakness), and of the possibility for personal change via decolonization and Indigenization and the emotional responses this can entail. This preparation can take some time, and it is advised to approach it, like ISE in general, as an ongoing developmental process.

### 6.4.2 Decolonizing and Indigenizing Pedagogies in ISE

In discussing pedagogical strategies for ISE I return to the notion of a slow pedagogy of relations, which infers taking the time needed to allow relational approaches to unfold. Building respectful relationships with students, teachers, elders, knowledge keepers, and other community members is a foundational and time-consuming part of creating quality learning opportunities in ISE. Making time to visit, sharing your stories, and listening to

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\(^{116}\) I.e., acknowledging: 1) the socio-cultural nature of all knowledge; 2) the existence and relevance of IKS; 3) a multi-science perspective; (Ogawa, 1995); and 4) the limits of ES for today’s crises.

\(^{117}\) Via assertions of certain knowledge and the desacralization and separation of humanity from creation.

\(^{118}\) Being honest and humble about your own learning journey is also important. Try not to worry about whether you know enough. Be aware of what you know and what you need to learn, and be comfortable with who you are and why you do this work, even if others are not. An open and honest heart is often enough for respectful relations to be established.
others are all part of this, as is being of service and following protocols, as this honours and shows gratitude for knowledge that is shared, whether by an elder or a student. The work required to arrange opportunities for students to build relationships with and learn from the land (e.g., transportation, food, equipment, etc.), often through the guidance and teachings of elders, knowledge keepers, and scientists, is also a time-consuming yet crucial element of this approach to ISE.

My slow pedagogy of relations can be considered a kind of “pedagogical Métissage” woven from Indigenous and non-Indigenous views on teaching, and I would recommend that others also weave ISE pedagogies based on their own interests and the ideas discussed here (and elsewhere), adapting and broadening one’s pedagogical repertoire toward more holistic and relational approaches. Basic elements of effective pedagogy such as having high expectations, engaging in hands-on, experiential learning activities relevant to students and the local community, and drawing on students’ own knowledges, should all be maintained when teaching ISE. Engaging with the community (through learning with elders and knowledge keepers or via community service learning projects), connecting with land, embracing Indigenous languages, and fostering reverence for life have all been mentioned as ways to decolonize and Indigenize pedagogy that can be employed in any subject area.

With respect to ISE, one recommendation would be to engage pre-service and practicing teachers in discussions on the metaphors for teaching ISE presented earlier (i.e., bridging, two-eyed seeing, and weaving). Engaging in discussion on how teachers would choose a metaphor for their ISE teaching, for example, may prompt reflection on the purposes of education, on their views and understandings of ES and IKS, and on the

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119 i.e., from transformative learning, culturally responsive education, place-based education, and IKS.
need to choose a developmentally appropriate metaphor for their students. While these metaphors are intended to provide clarity on distinct approaches to and results of ISE, teachers may also point out other possibilities or limitations based on their experience. An additional important recommendation for ISE is to explicitly teach about mechanistic science, complexity science, and the Indigenous sciences, including the relative strengths and weaknesses of each, emphasizing that these sciences complement one another and that they provide more together than on their own. Connections made between prominent complexivist and *nêhiyaw* concepts that suggest holism and interrelatedness in Figure 4 (p. 104), for example, could also be adapted to local Indigenous languages and shared with students.

Two further recommendations for ISE pertain to story and ceremony. Providing forums for story sharing in ISE activities (e.g., sharing circles, online discussion forums, traditional stories) and assignments (e.g., journals, narrative accounts of science, etc.) complements the often reductionist nature of school science, honours a fundamental way of sharing knowledge in IKS, and helps to build respectful relationships in the classroom. In my experience, showing vulnerability by sharing part of my story has helped to create spaces where students felt comfortable sharing their stories as well. I would also advocate for the inclusion of voluntary ceremonial activities that provide opportunities for students to learn about and experience the spiritual dimensions of IKS.¹²⁰ This is a contextual endeavor that will require support from school administration and should be pursued with the guidance and support of a ceremonial leader from the community who will be able to

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¹²⁰ With respect to the inclusion of spiritual and ceremonial activities, I have encountered opinions from Indigenous colleagues who believe they have no place in colonial institutions of education. I share the views of others, however, such as Don Speidel, who believe that they are a necessary part of decolonizing and Indigenizing, provided they are respectfully conducted.
share knowledge regarding protocols and expectations for participation. It will likely be the first experience with Indigenous ceremonies for many students, and may open a door to further participation and potential transformation, as it did for me.

A final recommendation for ISE regards carefully considering the purposes of education. Taking *miskasowin*, the fostering of relational worldviews and identities, as a goal of ISE appears to stand in opposition to dominant societal goals, and may thus be dismissed by administrators and policymakers. One of the four Broad Areas of Learning that inform Saskatchewan’s (2009) science curriculum, however, states that students will “develop and strengthen their personal identity as they explore connections between their own understanding of the natural and constructed world and perspectives of others, including scientific and Indigenous perspectives” (Ministry of Education, p. 4). The close similarity of this to *miskasowin*, where identities and worldviews are developed through ES and IKS, is further strengthened in the goals this Broad Area of Learning is intended to meet, which include: 1) relating to and understanding; 2) self concept development; 3) positive lifestyle; and 4) spiritual development (p. 4). Teachers wishing to engage ISE for *miskasowin* therefore do not need to justify their pursuit of *miskasowin* through ISE, as this kind of work is an expectation of all science teachers in Saskatchewan.

### 6.4.3 Indigenous Métissage in ISE Research

Similar to my recommendation for teachers to draw on Indigenous and non-Indigenous views of learning in developing their own “pedagogical Métissage” for ISE, I advocate for scholars to weave their own braids of Indigenous Métissage (Donald, 2012) in ISE research. Faced with the challenges of the twenty-first century, it is imperative that we draw on all resources available in response, including the creative possibilities that can
arise from the respectful weaving of Indigenous and non-Indigenous methodologies into diverse forms of Indigenous Métissage. For me, Indigenous Métissage expresses the growing desire among academic communities to “move beyond the binaries found within Indigenous-settler relations” and “construct new, mutual forms of dialogue, research, theory, and action” (Kovach, 2009, p. 12).

As an âpihtawikosisân (Métis) scholar trained in Western qualitative research and engaged in an ongoing process of learning and living IKS, Indigenous Métissage has emerged as a natural fit for my research. While my Indigenous ancestry contributed to an interest in IRM and helped with processes of relationship building in the Indigenous community, it was acknowledging the need to balance the mechanistic worldview with more relational and holistic perspectives that ultimately drove my desire to engage with IKS and IRM. Thus, I believe that IRM and Indigenous Métissage are accessible to any, regardless of ancestry, who acknowledge this need and are willing to commit to the processes of learning and relationship building that are required.

6.5 Directions for Future Research

My experience pursuing this research, while challenging, has also been life changing, rewarding, and humbling, and has inspired me to continue to explore the transformative possibilities of ISE. My future research will also be conducted through varied forms of Indigenous Métissage (Donald, 2012), engaging with scholarship from Indigenous and non-Indigenous scholarship, seeking guidance from academics, elders, and knowledge keepers, and through participation in ceremony. I have come to appreciate the strengths of both ES and IKS, as each has significantly shaped who I am today, and I hope to continue to learn and grow by interweaving and living between them.
The roles of story and ceremony in ISE, two key transformative elements of my research experience, are both areas in need of further research. I would like to explore the literature on how story (and narrative) and ceremony (and spirituality) have been engaged in transformative learning (e.g., Dei, 2002; Johnson, 2003; Shahjahan, 2004) and science education (e.g., Gough, 1993; Martin & Brouwer, 1991; Norris et al., 2005) and examine how students are able to engage story and ceremony to make meanings relevant to ISE and miskasowin. Policies prohibiting religious instruction in schools, offering cultural and spiritual teachings as credit courses, and dealing with the sense of loss and trauma that can accompany transformative learning are related areas of interest. I also aim to engage educators in research on the utility of the some of the conceptual tools developed in this research, elaborating on them (e.g., blending concepts of bridging, two-eyed seeing, and weaving to create more powerful metaphors for ISE (Fauconnier & Turner, 2002)) or developing practical ways to enact them with students.

Early childhood education and anti-racism/anti-oppressive education are also areas of research relevant to ISE that are of interest. Beliefs about the world that comprise worldviews and eventually shape our identities are formed very early in life, and I am interested in exploring whether early learners may more readily embrace miskasowin (i.e., that reductionist notions of self as individual are learned rather than innate). My interest in anti-racism/anti-oppressive education is rooted in experience as an Indigenous person of privilege, the prevalence of racism in formal education and Canadian society, and my awareness of its absence from scholarship on ISE. As science was used to justify racism, it is a topic of great relevance to science education, particularly to ISE. St. Denis (2004) has also questioned the primacy of cultural difference in the achievement of
Indigenous students’, and I would like to explore a both/and approach through ISE, where issues of cultural difference and racism are both addressed while attempting to improve achievement and foster *miskasowin*.

A final implication for future research regards teachers’ knowledge of contemporary science. While my research has focused on connecting science educators with IKS, I am also interested in science teachers’ understandings of the complexity sciences (i.e., ecology, evolution, quantum physics). Recognizing and utilizing the deep compatibilities that exist between ES and IKS through ISE will also require that science teachers have adequate understandings of ES. I am particularly interested in research on teachers’ understandings of evolution with regard to impacts on teaching ISE. Numerous studies have identified evolution as a content area where misconceptions abound (Eick, 2000; Ha et al., 2015; Nehm & Schonfeld, 2007; Rutledge & Mitchell, 2002). The centrality of evolutionary theory for understanding contemporary science in general; and complexity thinking, *wâhkôhtowin*, and *miskasowin* more specifically; also renders it an important concept for identifying resonances in scientific thinking across culturally based knowledge systems.

6.6 *êkosi pitamâ*... (That’s it for now...)

In sharing the story of this exploratory research in ISE I have sought to substantively contribute to the literature on Indigenous education and science education. The detailed, personal account of the relational research processes I employed, including some of the twists and turns that occurred, was offered as an instructive example from which other researchers may draw on. The review and synthesis of literature on ISE through the lens of my experience provided a unique conceptualization of ISE as a process of fostering...
miskasowin and responding to humanitarian and ecological crises in their local and global manifestations. My articulation of the complexity sciences as a path to ISE contributed an elaboration of similarities between complexity and IKS that have been broadly touched on but rarely delved into, and that will be of benefit to others teaching and researching in ISE. I hope this research will also contribute to broader discourse on the importance of intercultural communication, understanding, and collaboration in today’s age of crisis.

Despite these contributions I still retain feelings of trepidation in putting these ideas forward. Notions of equity, sustainability, slowness, and relationality seem at odds with the pressures of academia and the trends toward standardization, accountability and economic efficiency in formal education more generally. While this climate may not be conducive to the kind of work I am forwarding, especially for graduate students and untenured faculty, I am confident that the pendulum will once again swing away from the mechanistic side, and am hopeful my research may even nudge it a little in that direction. As Mehl-Madrona (2008) noted, “Life is a chemical imbalance, equilibrium is death” (Apr. 11). In a living universe change is the norm, and an inability to adapt can be fatal. Regardless of how much we may try to fix and finalize our understandings and beliefs about the world, they will always need to change, and today’s context is no exception.

kinanâskomitin for reading. Please feel free to take what is useful for you, for where you are and what you need. Leave the rest, it will still be here should you need it later. As there is no word for good-bye in the cyclical worldview of the nêhiyaw I leave you with kîhtwam ka-wâpamitin (I will see you again). ūkosi pitamâ.
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http://tlc.oise.utoronto.ca/index.htm


Appendix

Appendix 1

Issues as choice-points and questions for quality in action research

Is the action research:

• Explicit in developing a praxis of relational-participation?

• Guided by reflexive concern for practical outcomes?

• Inclusive of a plurality of knowing?
  – Ensuring conceptual-theoretical integrity?
  – Embracing ways of knowing beyond the intellect?
  – Intentionally choosing appropriate research methods?

• Worthy of the term significant?

• Emerging towards a new and enduring infrastructure?

( Bradbury and Reason, 2006, p. 350)