Becoming with/in Culturally Disruptive Pedagogies:

Teaching Science in a Pluralistic Society

by

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Territorial Acknowledgement

With humility, I acknowledge that the University of Manitoba is located on the original lands of the Anishinaabeg, Ininiwak, Anisininewuk, Dakota Oyate, and Denesuline, and the National Homeland of the Red River Métis. I recognize settler colonialism as a structure that continues to persist within our education systems, as well as the role public schools have played in occupying lands from which Indigenous peoples have been displaced and dispossessed. I also give thanks to those who have cared for the land since time immemorial and the more-than-human beings whose stories teach us how to be in relation with one another. As a racialized settler of Chinese descent, I commit to walking alongside Indigenous communities and doing the work that is necessary to honour the truth and value the strengths of Indigenous ways of knowing. There is much I still need to learn about, from and through the plants, animals, and waters of the prairies. By engaging in ongoing reflection and learning, I will continue working on becoming a better steward and Guest of these lands. Finally, I commit to being courageous in advocating for a more socially just world—a place where everyone can truly belong—in all of my personal and professional spheres of influence.

Abstract

Equity and diversity goals in Manitoba education curriculum documents (Manitoba Education and Training, 2000) are not reflected in existing Manitoba science curricula (Kim & Dionne, 2014) and may or may not be realized in science classroom practices. Science education is complicit in reproducing inequities by devaluing certain knowledge systems, reinforcing gender and sexual norms, and privileging Whiteness (Battiste, 2013; Gunckel, 2019a; Ridgeway, 2019). This study aimed to disrupt the privileging of Western Science knowledges, stereotypically masculine norms and binaries, and Whiteness embedded in school science. Through intersectional lenses of Two-Eyed Seeing, queer pedagogy and critical race theory, this critical autoethnography explored how culturally disruptive pedagogy (CDP) could inform my becoming as a middle years science educator working to enact more socially just conceptualizations of science. Following mixed and matched coding of gathered field texts (e.g., teacher journal reflections), secondary reflective vignettes were generated to create anonymized composite narratives. The findings captured moments of arising tension, disruption, self-realization and pedagogical innovation, demonstrating that these CDP tenets may form a useful framework for teachers. Disrupting existing teaching beliefs is possible; grappling with tensions is essential to the fraught process of becoming as a justice-oriented science educator. Field text analysis generated emerging themes specific to each tenet—potentially useful insights for other educators in their own contexts. This study contributes to emerging scholarly work relating to CDP in science education while responding to calls from scholars to consider the role of racially marginalized settlers in addressing reconciliation, examine racial injustices embedded in science, and explore the potential afforded through queering science.

Keywords: social justice science education, culturally disruptive pedagogy, critical autoethnography, Two-Eyed Seeing, queering science, critical race theory, anti-racist science

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Dedication

This thesis is dedicated to Kaelan and my students.

It is to them that I owe my many sleepless nights,

but also, my many moments of immeasurable joy.

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Position Statement

In an exploration of his becoming and belonging as a science educator, Roth (2015) discusses the role of identity in influencing teacher decisions. He writes, "who the person can be is a function of the unit as a whole; and because experience is continuous, who a person can be has to be viewed in a whole-life perspective" (p. 2), and that "what [he] was doing in one activity was changed by what [he] was doing in another" (p. 12). The relationships between his experiences were synergistic, not incoherent. I also take the view that my own varied experiences interact with one another to influence my science pedagogical decisions. Though most certainly an incomplete account, I begin by highlighting aspects of my lived experiences to position myself in relation to this study.

In my role as a science educator, I value pedagogical approaches that allow students to honour and celebrate who they are as a human being. This view of learning arises from the many moments in my life where I have felt different and unseen—a life where others have continually tried to tell me what I could or could not do, and who I could or could not become. Growing up as a second-generation Canadian of Chinese descent with Vietnamese cultural influences in a predominantly White[1], suburban neighbourhood has been central to my worldview. My parents were Hoa refugees who left Vietnam on a boat for open waters, eventually resettling in Canada with little more than the clothes on their backs. They viewed education as a means to survival, social mobility, and preparation for an uncertain future. Perhaps against all our natural

[1] The APA (7th edition) formatting and style guide recommends capitalizing racial and ethnic groups. Whether or not w/White should be capitalized is an evolving conversation with contested viewpoints. I capitalize *White* when referring to a racial group to make visible the powers and privileges conferred by and embedded in Whiteness, which so often is unnamed and perceived as the default, neutral identity. White persons are not racially marginalized, but neither are they unraced. However, recognizing that white supremacists have been co-opting the capitalization of White as a way of asserting their dominance over racially marginalized communities, I also choose to delegitimize *white supremacy* by using a lowercase in this context.

inclinations, my parents taught me to be as undisruptive as possible (at least publicly) in a world where some people have more power and privilege than others. My encounters with prejudice and discrimination based on my ethnicity and culture inform my conviction that science education must endeavour to be anti-racist and culturally relevant.

It is a strange tension to be glad for a place that has offered you relative safety and opportunity, while questioning whether or not you can truly belong to a place that considers you a perpetual foreigner, and then to wonder about your own role in the displacement and dispossession of others from that very same land. Perhaps it would be more fitting to identify as a second-generation settler of Chinese descent and Vietnamese cultural influences working towards becoming an increasingly better Guest on the lands of the Anishinaabeg, Ininiwak, Anisininewuk, Dakota Oyate, Denesuline, and Métis peoples. Koleszar-Green (2018) distinguishes guests from settlers, where *settler* is conceptualized as someone who might want to be a good ally and acknowledges they are on stolen lands, from a *Guest* who is reflexive as they take responsibility for and learn protocols of the land and leverages their privilege to centre others rather than themselves. While the experiences of racially marginalized settlers are diverse and not necessarily conflated with the experiences of White settlers, I too, continue to participate in, benefit from, and contribute to a nation founded on the lands of Indigenous peoples (Phung, 2011).

Functioning within the Eurocentric worldview of my K-12 schooling experiences had blinded me from recognizing colonial practices deeply entrenched in Canadian society, but subsequent education coursework has been instrumental in encouraging me to challenge dominant ways of thinking. My post-secondary science research experiences were influential in helping me become the Western Science teacher that I envisioned myself to be, but my education

graduate coursework has been equally influential in my reimagining of the science teacher that I desire to become now. While I will, no doubt, have many moments where I fall short, I am striving to dismantle my Western Science lens by acknowledging my own complicity in hegemonic science practices and settler colonialism. I aspire to continue becoming as a science educator who values coming to know the world from and through Indigenous Science lenses and is courageous in finding ways to share this learning journey with my students so that they, too, can come to know science from multiple worldviews.

Finally, my perspectives on gender equity are informed by experiences with marginalization as a girl/woman, as well as time spent advocating for greater representation of women in STEM fields through outreach work with elementary students. This work was influential in my decision to become a science educator. Further exploration in this area made me realize that focusing on the men/women gender binary in science further marginalizes those identifying as non-binary, trans, or gender diverse and reinforces heteronormativity (Knezz, 2019). This conversation is particularly salient because I teach in a community context where the predominant worldview is Eurocentric, Christian and conservative. Despite encounters with gender role stereotypes, I recognize I have privileges as a cisgender heterosexual female not afforded to others. It would be naïve to not acknowledge persistent challenges surrounding dialogue on gender diversity and sexuality. Perspectives exist on a continuum, and it is not my intention here to homogenize an entire community. I simply wish to express that finding creative ways to nudge boundaries and challenge norms will be necessary; forming partnerships with allies and those prepared to dialogue will be paramount.

In responding to Tolbert et al.'s (2018) call for science education scholars to "more explicitly identify positionality and more openly address issues of power and identity" (p. 810), I

endeavour to critically consider the ways in which gender, sexuality, race, ethnicity, culture, and settler/Guest-hood are entangled with/in my teaching and research. Power and positionality "are often disguised and underacknowledged in science education research, particularly within positivist traditions that... attempt to hide the role of the researcher" (Tolbert et al., 2018, p. 798), so the inclusion of this position statement might itself be considered a form of disruption to hegemonic science practices. Thus, as this study unfolded, I engaged in the repetition of creating something new through re-experiencing the past (Blades, 1997). I attempted, not to hide my role as the researcher in this study, but to boldly and courageously explore how researching and teaching might be synergistic forces in my becoming as a science educator.

Chapter 1: Study Context

This section orients the study by outlining the context from which this research has emerged. Beginning with an overview of social justice issues found in and perpetuated by science education, I discuss the ways in which school science reinforces Western Science perspectives, heterogendered norms, and Whiteness. Following this, I explain the purpose of the study and present the research questions explored. Finally, I consider how this study contributes to addressing gaps in the relevant science education literature and advancing more socially just approaches to science education.

Statement of the Problem

Greater attention to social justice approaches in science and related STEM fields is being called for by science education scholars (Rodriguez et al., 2022). Researchers have argued that the term social justice, as used in mainstream discourse, has detracted from the social justice origins of the term itself and thus, requires clear definition (Ridgeway, 2019; Rodriguez & Morrison, 2019). *Social justice* is "a context-dependent concept that focuses on particular, localized situation and power imbalances" (Ridgeway, 2019, p. 284) and is constituted by both equity and diversity dimensions (Rodriguez & Morrison, 2019). Social justice involves "*doing* something to challenge a social injustice. Therefore, social justice research is the enactment of the researcher's commitment to others for the purpose of challenging systems and practices that have normalized the mistreatment of groups of people" (Ridgeway, 2019, p. 285). Writing about social justice in education more generally, Sensoy and DiAngelo (2017) prefer the term *critical social justice*, which, drawing on tenets of critical theory, recognizes the stratification of social groups and understands inequality to be deeply entrenched in society. Lifelong examination of

one's personal social position and active efforts to challenge social injustice are embedded in this conceptualization.

Science pedagogy centering social justice recognizes the role of school science in reproducing inequities and assimilating students into dominant ways of knowing (Morales-Doyle, 2017). Although science is value-laden, many teachers "avoid confronting the political and social values underlying the scientific and technological practices they teach about" (Hodson, 2003, p. 654). However, as Hodson (2003) asserts,

> values are embedded in every aspect of the curriculum: content, teaching/learning methods and assessment/evaluation strategies are selected using criteria that reflect and embody particular value positions, whether teachers recognize it or not… values can be promoted as much by what is omitted from discussion as by what is included. (p. 654)

This can be illustrated, for example, by the existing Manitoba science curriculum[2], which "others" and constructs non-Western cultures as inferior to Western culture and includes limited to no incorporation of Indigenous ways of knowing science (Kim & Dionne, 2014). Despite the legitimacy, benefits, and importance of valuing multiple scientific knowledge systems (Aikenhead & Elliot, 2010; Battiste, 2013; Murray, 2016; Snively & Corsiglia, 2016), school science continues to participate in the enculturation and assimilation of students into Western Science perspectives (Snively & Corsiglia, 2016).

Western Science, which has historically aligned itself with traditional and stereotypical notions of masculinity (e.g., reason and cognition) in opposition to femininity (e.g., emotion and embodiment) (Brickhouse, 2001), is also complicit in reinforcing heterogendered norms that

[2] It should be noted that the Manitoba science curriculum is in the process of being renewed. At the time of the completion of this thesis, the renewed science curriculum draft, which contains significantly greater reference to Indigenous Science perspectives, is being piloted and has not yet been formally implemented.

privilege heterosexuality and gender binaries (Gunckel, 2019a). In school science, for example, rather than centering embodied inquiry experiences that evoke feelings of desire and wonder, teachers tend to view science knowledge as facts to be transmitted to students who are then assessed through testing (Gilbert & Gray, 2019; Gunckel, 2009). The way gender and sexuality are portrayed in science texts and resources is another way these norms are perpetuated in science classrooms (Bazzul & Sykes, 2011; Gunckel, 2019a; Snyder & Broadway, 2004). For example, the biology textbook analyzed by Bazzul and Sykes (2011) reinforces heteronormativity by depicting only heterosexual couples in images that alluded to a romantic relationship (e.g., a heterosexual couple was used as a visual for hormonal effects). The textbook also reinforces sex and gender binaries by attaching sex to specific hormone levels, conflating sex and gender by using the terms "male" and "boy" interchangeably and applying rigid anatomical categories to male and female bodies. Science teachers' pedagogical moves in the classroom (e.g., using same-sex groupings, disregarding student emotions) also contribute to reinforcing heterogendered norms (Letts, 1999). Additionally, students have reported that they rarely encounter positive representation of 2SLGBTQIA+ topics in science classes (Kosciw et al., 2020).

Oppressive systems of racial injustice are also embedded in science classrooms and curricula (Lodge, 2021; Ridgeway, 2019). As Ridgeway (2019) writes, "science education is imbued with whiteness; it is the mechanism that marginalizes groups" (p. 290). This can take the form of inaccurate and racist scientific claims or overrepresentation of White, European scientists' contributions (Ash & Wiggans, 2018). Although humans share 99.9% of the same DNA sequence, variations in phenotype or intelligence have been attributed to racial differences in order to legitimize the oppression of racially marginalized communities (Ash & Wiggans,

2018; Sheth, 2019). Experiments comparing anatomical differences (e.g., skull size) have been used to categorize certain groups of people as inferior (Battiste, 2013). Additionally, Greek physician Hippocrates has traditionally been positioned as the father of medicine while the earlier contributions of Imhotep (ruler, physician, and scientist in Ancient Egypt) to medicine have largely been omitted and ignored (Ash & Wiggans, 2018).

The pervasiveness of Whiteness in science education can discourage racially marginalized students from seeing themselves as science learners, especially when students have limited to no exposure to science role models who are also members of racially marginalized groups (Mensah, 2019). In addition to a lack of racially diverse representation, science also positions White norms and values as the standard to which all science learners must aspire (King et al., 2023; Madkins & Morton, 2021). The privileging of Eurocentric science perspectives over Indigenous science perspectives, for example, can create cultural dissonance for Indigenous students (Battiste, 2013). Additionally, racially marginalized learners whose linguistic and scientific discourse patterns differ from White norms may experience negative science learning experiences (Madkins & Morton, 2021). Science educators may also hold deficit views of racially marginalized learners (Madkins & Morton, 2021; Sparks, 2018). Without challenging white supremacy, which Sensoy and DiAngelo (2017) define as the "pervasiveness, magnitude, and normalcy of White privilege, dominance, and assumed superiority" (p. 143), science education will continue to center Whiteness, reinforce colourblindness and perpetuate racial discrimination (Ridgeway, 2019).

Mueller and Bentley (2006) suggest that,

> as science educators, we might embrace an education *for* and *of* pluralistic life in terms of aligning theory, research and practice. Teachers of science must take into account their

> students' culture (and gender), voices, community, and Earth's environments before planning and enacting curriculum. (p. 333)

They describe *landscapes of pluralism* as a representation of diverse cultures and ways of knowing. Here, their use of the term culture includes social identifications such as race and ethnicity, but also gender, class, and religious background. Like the authors, I acknowledge the intersectionality and importance of all these social group memberships, but will focus on race, ethnicity, and gender in this research study. In considering landscapes of pluralism, it is necessary to recognize that while cultural pluralism aims to promote diversity and appreciation of different norms and identities, it can also make invisible the oppressive power structures that reinforce the values of the dominant group (Hodson, 1999). Thus, in considering pluralism, I refer to the diverse ways of knowing and being that exist and *should* be equally valued, but that in our current societal reality are *not*. In this study, my goal is not to explore ways to assimilate students into mainstream science, but to interrogate how hegemonic science practices perpetuate injustices and detract from realizing a world that embodies the original spirit of pluralism.

Purpose of the Study

Science education scholars need to gaze inward to reflect on their own role in perpetuating and dismantling social injustices in science education (Rodriguez & Morrison, 2019). Through a critical qualitative lens, this study aims to disrupt hegemonic science norms that privilege Western Science perspectives, traditionally binary, cis-gendered, heterosexual, masculine norms, and Whiteness. To better understand how science educators can support students in conceptualizing science more equitably in a pluralistic society, this critical autoethnography (Boylorn & Orbe, 2021b) explores how I, as a middle school science teacher in

rural southern Manitoba, can draw on various theoretical lenses to both inform and transform my science teaching practices.

Research Questions

This critical autoethnography explored the following central and sub questions:

How can culturally disruptive pedagogies inform my becoming as a middle years science educator working to enact more socially just conceptualizations of science in a pluralistic society?

i. How can I, as a racialized settler/Guest, engage in teaching practices that honour coming to know science from both Indigenous and Western perspectives?
ii. How can I enact science pedagogies that support gender equity in the science classroom?
iii. How can my teaching practices honour students' ethnoracial diversity in the science classroom?

Rationale and Significance of the Study

According to Manitoba Education and Early Childhood Learning's (2022, November) draft *Framework for Learning*, schooling should:

> ensure that every Manitoban is valued and authentically represented in an equitable, socially just, anti-oppressive education system [where] learners are prepared to reach their full potential and to live The Good Life in which they have hope, belonging, meaning, and purpose… it means honouring and respecting Indigenous ways of knowing, being and doing with a commitment to and understanding of Truth and Reconciliation. (pp. 1-2)

Additionally, *Mamàhtawisiwin: The Wonder We Are Born With—An Indigenous Education Policy Framework* (Manitoba Education and Early Childhood Learning, 2022), which responds

to the Truth and Reconciliation Commission's Calls to Action relating to education, emphasizes the role of teachers in helping students understand Indigenous worldviews and values in culturally safe, inclusive environments by, for instance, "find[ing] ways to incorporate Indigenous ways of knowing into curriculum (e.g., science activities from both Euro-Western and Indigenous perspectives)" (p. 25).

The Manitoba science curriculum in its current form fails to live up to the goals of the *Framework for Learning* and *Mamàhtawisiwin*. Although one of the general learning outcomes in the *Grades 5-8 Science: Manitoba Curriculum Framework of Outcomes* (Manitoba Education and Training, 2000) is to "identify and appreciate contributions made by women and men from many societies and cultural backgrounds towards increasing our understanding of the world and in bringing about technological innovations" (p. 2.6), the remaining content of the document does little to support this learning outcome. In addition to using language that reinforces heterogendered norms and binaries (e.g., making references to contributions "by women and men" (p. 3.62), all the scientists provided as examples to include were White, European men (e.g., Robert Hooke, Anton van Leeuwenhoek, Matthias Schleiden, and Theodore Schwann as contributors to cell biology). In a specific learning outcome about human health, the science curriculum lists "unhealthy eating and physical inactivity [as factors that] may lead to diabetes or heart disease" (p. 3.14). Here, poor individual lifestyle choices are positioned as the cause for disease without consideration and acknowledgement of how discrimination (for example, based on race and/or gender) influences well-being and access to healthcare (Public Health Agency of Canada, 2023).

Although the *Grades 5-8 Science: Manitoba Curriculum Framework of Outcomes* (Manitoba Education and Training, 2000) makes one mention of "traditional knowledge" (p.

3.21) in a specific learning outcome about predicting weather patterns, the document makes no explicit use of the terms *Indigenous*, *First Nations*, *Inuit*, or *Métis*. By omitting other science perspectives, such as Indigenous Sciences, the existing Manitoba science curriculum continues to reinforce Western Science as universal. For example, in learning outcomes relating to living things, there is an emphasis on classification and identifying characteristics of living things from a Western Science lens (e.g., made of cells, can reproduce, produces wastes) without any mention of what constitutes a living thing from Indigenous Science worldviews (i.e., that living things have spirit or energy and are interconnected).

Similar observations have been made by Kim and Dionne (2014), who, in their examination of all the grades seven and eight Canadian science curriculum documents, found that many of the provincial documents, including Manitoba, have placed a low priority on honouring Indigenous knowledges or other ways of knowing science. Zarry (2002) has also noted that the *Kindergarten to Grade 4 Science: Manitoba Framework of Outcomes*, like its grades 5 to 8 counterpart, has similarly identified appreciating diverse contributions to science as a general learning outcome, but "unfortunately when examining the actual curricula, the specific identification of individuals or cultural groups and their contributions in science is minimal" (p. 5). Following an analysis of *Manitoba Senior 1 Science: A Foundation for Implementation*, Ragoub (2024) similarly concluded that the curriculum document is overwhelmingly "colonial and Western Eurocentric, validating the contributions of Western European cultures, and mentioning only male scientists" (pp. 125-126) despite making references to the importance of incorporating cultural diversity.

While the purpose of this research study is not to analyze science curriculum documents, they do guide my science teaching. Thus, this research study endeavours to realize a science

education that is better aligned with the purported goals of Manitoba Education, while contributing to a reconceptualized reimagining of science education as one that participates in the creating of a more socially just and equitable world (Galamba & Matthews, 2021; Hodson, 2003). Currently, the Manitoba science curriculum for grades K-10 is in the process of being renewed and the released draft documents do show some promise with respect to addressing the aforementioned critiques. The draft curriculum, for example, no longer uses gender binary reinforcing terms like *men* and *women* when referring to the contributions of scientists. Indigenous Science perspectives are also mentioned more explicitly. “Indigenous People within the Natural World” (Manitoba Education and Early Childhood Learning, 2024, p. 1) is now one of the five overarching general learning outcomes. There are encouragements to “[i]nvite an Elder or a Knowledge Keeper to share Indigenous Teachings” (Manitoba Education and Early Childhood Learning, 2024, p. 9) and incorporate content such as “Indigenous traditional uses of rocks and minerals… [and] traditional teachings related to water and land” (Manitoba Education and Early Childhood Learning, 2024, p. 8). Additionally, science learners are invited to “seek equitable solutions to scientific issues which support diversity, inclusivity, and human rights” (Manitoba Education and Early Childhood Learning, 2024, p. 4).

Interrogating hegemonic practices in science education can be challenging for many educators who, like me, are also products of a system that has reinforced the values and norms of the dominant culture. Although teachers may resist change because of school pressures (e.g., curriculum documents, classroom management), viewing existing practices as already effective, or a lack of desire to challenge the status quo, it is making ideological changes to values and beliefs that is particularly difficult (Rodriguez, 2001). This critical autoethnographic study allows me to both center my voice as a racially marginalized female science educator and

document how the journey of grappling with Indigenous ways of knowing, queering science, and anti-racist science pedagogies unfolds. This study explores the process of how a teacher can engage with the complex and difficult work of (un)learning different ways of knowing science while figuring out how to realize these understandings in the science classroom context.

Navigating justice-oriented science pedagogy in the school landscape can be challenging. When grappling with racism, gender inequity and colonization, one needs to get comfortable with being uncomfortable—a feeling that many educators would much rather avoid (Parhar & Sensoy, 2011). Discourse on gender and sexuality in schools is often considered a controversial topic (Gunckel, 2009), and it can be challenging for teachers, students, and communities to confront race and racism in education systems (Battiste, 2013). Science teachers interested in enacting more equitable science education practices might encounter not only resistance from students and the broader community but also experience opposition from colleagues who are not ready to face their own fears of change (Chrona, 2022). This lack of support can be incredibly isolating for science educators trying to do important equity work (Burke, 2023).

This research study is significant because it is about growing forward even in the face of continued resistance. It is about finding ways to advance equity and social justice in science education while navigating the complexities of school systems. It is about gathering courage, having hope, and facing your own fears so that others, too, might one day come to realize and understand why this work is so important for our students and communities. Culturally disruptive pedagogy may be a way to do so, and insights from this study could support other educators on their own justice-oriented science journeys. Other science teachers may be able to transfer, to their own teaching contexts, insights from this research that resonate with them.

This study also addresses gaps in the science education research literature. While it builds on the literature of culturally relevant pedagogy (Ladson-Billings, 1995), culturally disruptive pedagogy itself is an emerging concept and the studies utilizing this concept have primarily been in ethnic studies or multicultural courses (San Pedro, 2018; San Pedro et al., 2020). To the best of my knowledge, there is currently a very limited number of research studies exploring the application of culturally disruptive pedagogy to science education in schools (Litts et al., 2020b; Yan, 2023; Yan et al., 2021). My research study contributes to the emerging literature on science education and culturally disruptive pedagogy.

This study also responds to the call from scholars to use multiple theoretical and intersectional lenses in research to address complex systems (Brickhouse, 2001; Lemke, 2011; Marco-Bujosa, 2022). According to McGuire and Denis (2019), more research exploring the role of racially marginalized settlers in reconciliation is needed and one of the theoretical frames in this study is Two-Eyed Seeing, which seeks to value both Indigenous and Western Sciences (Hatcher et al., 2009). This study also explores critical race theory and racism, which scholars argue requires greater attention in science education (Sheth, 2019; Walls, 2022; Watkins, 2022). Additionally, this study explores the queering of science, which according to Fifield and Letts (2019) is an emerging field in science education as related work is primarily focused on "the experiences of gender and sexual minorities, without pursuing queering" (p. 24) as a theoretical framework.

Summary

Dismantling entrenched hegemonic views and practices embedded in science education will require us to recognize the diverse intersectional identities of humanity. As Ridgeway (2019) writes, "in order to maintain critical conversations within science education, attention

should focus on how to disrupt power dynamics and privilege which operate to maintain inequities" (p. 290). However, critical examination of current science education discourse within school contexts will not be without its challenges as these conversations require the recognition of science and schooling as inherently political and value laden (Hodson, 2003; Morales-Doyle, 2017). School science has long had a reputation for being inaccessible and perceived as exclusive (Knezz, 2019). This study, however, hopes to (re)center the voices of those on the margins who may not have been able to feel like they belong to science (Battiste, 2013; Knezz, 2019; Mensah, 2019). As a critical autoethnography, my voice as a racially marginalized female science educator is at the forefront of this study. Furthermore, this (re)centering of marginalized voices takes place through connecting my stories and experiences to those of diverse scholars in wider cultural contexts through citational justice (Mott & Cockayne, 2017, as cited in Bratman & DeLince, 2022).

Being "a numerical minority" (Ridgeway, 2019, p. 291), albeit optimistically becoming less so over the last decade, it can be challenging for equity scholars to "bring their voices and concerns to the forefront of this field" (p. 291). Additionally, this work can be "difficult and emotionally draining… if you are working for social justice, you will encounter those who will seek to silence you, to 'place' you, and to intimidate you" (Rodriguez, 2001, p. 285). Despite this, I hope to contribute to discourse on justice-oriented science practices by centering my own learning and voice through/with critical autoethnography. Although ministries of education may have equity and diversity goals, these are not always realized in science resources and practices. This study seeks to disrupt Western Science perspectives, hetero/cisnormativity, and Whiteness through the exploration of teaching with/in intersectional lenses that value multiple ways of knowing. This research contributes to the emerging literature on culturally disruptive pedagogy

along with other critical frameworks, as well as the conceptualization of how science educators might be able to understand science as a vehicle for social change.

This section outlined the purpose, research questions, rationale and significance of this research study, as well as the problems in science education from which this project has emerged. Next, I review the literature relevant to this study, followed by an outline of the methodological framework used to answer my research questions.

Chapter 2: Literature Review

This section provides an overview of literature related to culturally disruptive pedagogy and its tenets while also introducing the theoretical frameworks underpinning this research study. Because scholarly work relating to culturally disruptive pedagogy and its application to science education is still emerging, I introduce literature relating to Two-Eyed Seeing, queer theory, as well as critical race theory and anti-racist pedagogy while explicating how these theories work to support the culturally disruptive pedagogy tenets. In addition to providing an explanation of each theory, scholarly work relating to each lens is synthesized to demonstrate how they fit within the culturally disruptive pedagogical framework of disruptions, tensions, self-realizations, and pedagogical innovations involved in a justice-oriented approach to science education. Finally, an explanation of how each theoretical framework is mobilized in this research study is provided.

Defining Culturally Disruptive Pedagogy

The term *culturally disruptive pedagogy (CDP)* was first used in San Pedro's (2018) ethnographic study exploring the experiences of a White student in a high school ethnic studies course on Native American literature. CDP builds on previous pedagogies aimed at addressing the cultural diversity of students. Ladson-Billings (1995) originally conceptualized *culturally relevant pedagogy* as a theoretical framework encouraging learners to develop sociopolitical consciousness and cultural competence while maintaining high expectations for student achievement. With greater focus on teacher-enacted pedagogy, Gay (2010) later described *culturally responsive pedagogy* as a model where teachers used understandings of students' diverse knowledges and realities to make curricular decisions and foster classroom climates conducive to learning. *Culturally sustaining pedagogy* expanded the concept by seeking to perpetuate students' cultures and memberships in communities beyond just race or ethnicity

(Paris, 2012), and *culturally revitalizing pedagogy* has been applied to discourse surrounding Indigenous peoples and decolonization (McCarty & Lee, 2014).

Culturally disruptive pedagogy extends previous scholarship by recognizing and seeking to disrupt the privileges afforded to those whose realities are centred by dominant cultural norms, especially those associated with Whiteness (San Pedro, 2018). It is important to note, that *Whiteness* does not only refer to having physically light skin, but also to those afforded privileges because of their skin colour, as well as the structural practices that reinforce and perpetuate that privilege (Lindner, 2018). CDP is not about assimilating diverse students so they can be successful within the dominant culture, but rather, creating spaces and opportunities for learners to dialogue with multiple truths and learn from the lived realities of others. It is in these *sacred truth spaces*, as San Pedro (2018) describes them, that different truths interact and have the potential to influence our understandings. The *zones of contact* where individuals grapple with the truths of others and work to make sense of potentially conflicting ideologies create ruptures that can allow for the disruption of existing understandings and identities (Bakhtin, 1981; San Pedro, 2018).

San Pedro (2018) describes three foundational tenets of culturally disruptive pedagogy: tensions, disruptions, and self-discoveries. Tensions are created when people are faced with new and unfamiliar circumstances or ideologies. This might manifest, for example, in the form of resistance and defensiveness when existing worldviews are challenged (San Pedro, 2018), or feelings of inadequacy stemming from the disconnection between where you are and where you want to go (Litts et al., 2020b). Disruption takes place when existing understandings are changed —an undertaking that is not always easy or straightforward. It is important to:

> acknowledge this process as painful, and as necessary, to see that our liberation is tied together. It may mean seeing the humanity in those who have long dehumanized us by easing others' eyes while adjusting to a new reality inclusive of a more complete story of us. (San Pedro, 2018, p. 1208)

In a classroom setting, disruption might involve desiring to teach differently and taking steps toward implementing unfamiliar pedagogies to reach new goals (Litts et al., 2020b; San Pedro et al., 2020). Finally, self-discovery, also referred to by Litts et al. (2020b) as self-realization, involves the realization and acceptance of new knowledges, as well as the integration of new ideologies with pre-existing ones (Litts et al., 2020b; San Pedro, 2018). For this study, my preferred term is self-realization as it connotes a process of coming to know rather than an existing insight that was simply waiting to be found.

Building on San Pedro's (2018) work, Litts et al. (2020b) added pedagogical innovation as a fourth component of culturally disruptive pedagogy. Results from their analysis of two case studies demonstrated that pedagogical innovations resulted from the teacher participants' engagement with culturally disruptive research. The study followed two grade six teachers as they worked collaboratively with stakeholders (e.g., researchers, curriculum designers) to create culturally situated student experiences. The authors observed the teachers expanding their teaching practices by "engaging cultural knowledge holders and expanding the teaching network" (Litts et al., 2020b, p. 775, Figure 2) and "using perspective-taking to integrate content and cultural competence skills" (Litts et al., 2020b, p. 778, Figure 3). Culturally disruptive pedagogy led to a shift from individualistic to collectivistic teaching approaches, the centering of diverse perspectives and cultures in classroom pedagogical practices, as well as shifting to learning both life skills and academic skills simultaneously in the classroom. The tenets of

culturally disruptive pedagogy are understood by Litts et al. (2020b) as cyclical and iterative. As self-realizations are realized and pedagogical innovations are applied, further disruptions take place as new tensions continue to emerge.

Culturally Disruptive Pedagogy and Science Education

Work with culturally disruptive pedagogy as defined by San Pedro (2018) is still emerging. For instance, San Pedro et al. (2020) extend the CDP conversation by applying ideas to a multicultural and equity studies graduate level university course to disrupt top-down knowledge transfer pedagogies. Scholarly work that explicitly uses the term CDP is in its infancy, but there *have* been other studies describing related concepts. For example, Mills (1997) uses *disruptive pedagogy* to describe how teachers and students in an Australian high school advocated for social justice. Although Mills' study emphasizes the disruption of sexism and teacher-student power dynamics, both studies illustrate the disruption of hegemonic norms in school settings. In efforts to address the Truth and Reconciliation of Canada's (2015) calls to action, Nolan (2020) employs the term *culturally responsive disrupting pedagogy* (CRdP) as a lens for analysing research literature in mathematics education, with the eventual goal of exploring CRdP in different educational contexts. Here, Nolan aims to disrupt the dominant Euro-Western lens entrenched in the teaching of mathematics in Canadian schools.

Although there exists science education literature built on the foundational idea of culturally responsive/relevant pedagogy (e.g., Brown, 2017; Johnson, 2011; Laughter & Adams, 2012), science education scholarship utilizing CDP as a framework is currently undertheorized. Drawing from a larger design-based implementation research study, Litts and colleagues have highlighted case studies in several papers that illustrate how culturally disruptive research and pedagogy can take place in middle school science classrooms. One case study involving a grade

six teacher (Litts et al., 2020b) illustrates how the culturally disruptive pedagogical tenets can frame educators' learning processes when weaving diverse science perspectives into their teaching. Notably, efforts were made to avoid tokenizing Indigenous Science knowledges in the classroom, which is consistent with recommendations from other scholars (Aikenhead & Elliot, 2010). Additional case studies also demonstrate how educators can disrupt Western Science notions of an acultural science by embedding science understandings within cultural storytelling, restorying learners' relationships with/in nature through place-based learning and reaching beyond standard prescribed science curricula (Yan, 2023; Yan et al., 2021; Litts et al., 2020a).

I intend to contribute to ongoing work in science education research involving culturally disruptive pedagogy by using the four tenets (tensions, disruptions, self-realizations, pedagogical innovations) as conceptualized by San Pedro (2018) and expanded upon by Litts et al. (2020b) to inform my becoming as a science educator. This study seeks to disrupt hegemonic science norms privileging Western Science perspectives, traditionally cis-heteronormative masculine norms, and Whiteness. Responding to calls for researchers to carry out research involving multiple theoretical frameworks that attend to intersectionality (Brickhouse, 2001; Lemke, 2011; Marco-Bujosa, 2022), I leveraged ideas stemming from critical race theory, Two-Eyed Seeing, and queer theory. I will now address the tensions that arise from these theoretical lenses, what they aim to disrupt, any self-realizations emerging from researchers or participants in the literature, as well as relevant pedagogical strategies that have been used in science classroom settings.

Two-Eyed Seeing: Integrating Indigenous and Western Sciences

What Is Being Disrupted?

A dilemma faced by science education in Canada is the continued emphasis on Western Science perspectives as the single universal way of making sense of the natural world. As Cajete

(1986) writes, “the teaching of science from only one cultural perspective and in the partialistic manner that dominates science education continues to be the central dilemma of science education today” (p. 221). Science and how we come to know nature is socially constructed, and although Western Science attempts to present itself as an objective knowledge system, it is neither acultural nor unbiased. Our constructions of scientific knowledges and understandings of nature are derived from our values, beliefs, and languages (Battiste, 2013). Snively and Corsiglia (2016) assert that “when Western Science is taught without acknowledging Indigenous Science, this can be construed as assimilative science education” (p. 80). The legitimacy of Indigenous Science perspectives and importance of valuing multiple scientific knowledge systems has been recognized both globally (as mentioned by Battiste, 2013) and by other science education scholars in Canada (Aikenhead & Elliot, 2010; Murray, 2016; Snively & Corsiglia, 2016).

When science is taught solely from dominant Eurocentric perspectives, Indigenous learners may experience cultural dissonance that impacts science achievement and engagement (Battiste, 2013). Thus, finding ways to honour and learn through diverse science worldviews is critical, and Aikenhead and Elliot (2010) highlight many examples of cross-cultural science teaching that have demonstrated successes and benefits for Indigenous students. They further argue, that despite teachers’ efforts in conventional school science classes to enculturate students to Western Science ways of thinking and behaving, most science learners struggle to connect with a science identity and become increasingly disengaged from school science anyways. This is consistent with other authors who have noted students’ feelings of disconnect from who scientists are and what they do (Hsu & Roth, 2010) and declining interest in science over the course of their K-12 education (Turner & Peck, 2010). Ultimately, “a decolonizing curriculum is about improving the scientific literacy of all students” (Aikenhead & Elliot, 2010, p. 334).

What Is Two-Eyed Seeing?

In efforts to disrupt the dominance of Western Science perspectives in the current school science landscape, I utilize the guiding principle of Two-Eyed Seeing to inform my science teaching practices. Two-Eyed Seeing was initially brought forth by Elder Albert Marshall of the Mi'kmaq Nation in Atlantic Canada and means "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" (Hatcher et al., 2009, p. 146). Learners do not need to abandon their existing worldviews; learning through Two-Eyed Seeing is to value multiple science knowledge systems simultaneously and having the wisdom of knowing when to apply each perspective. This principle is a key aspect of Integrative Science, which was originally created as a post-secondary program at Cape Breton University. The aims of the program were to increase Mi'kmaw students' interest in science and to improve the retention of Mi'kmaw students studying in science-related programs (Bartlett et al., 2012). Though not without its challenges (e.g., administrative issues, faculty recruitment, allocation of funds for the program), the Integrative Science program experienced a number of successes, which included an increase in Mi'kmaw students graduating with science-related degrees, subsequent employment in key sectors (e.g., healthcare, education, natural resource management), and more student recipients of research grants (Bartlett et al., 2012).

What Are the Tensions?

A key tension that Two-Eyed seeing attempts to address is the challenge of making sense of different cultural concepts through the lens of an existing worldview since "cultural modes of perception and understanding are deeply embedded and self-perpetuating" (Hatcher et al., 2009, p. 145). Hatcher et al. (2009) continue,

> Indigenous Sciences contain deep and subtle wisdom, which Mother Earth needs, but that is difficult for those with a Western culture to practice authentically because they generally do not have the underlying beliefs, values, and cultural connections to nature and each other. Many cultural concepts simply are not transferable to other cultures. Indigenous Sciences cannot be practiced within Western ontological assumptions and experiences. (p. 145)

Science educators will need to grapple with differences between Indigenous and Western worldviews. Indigenous Sciences are deeply connected to spirituality, are learned through living and experiencing (e.g., through stories, community, ceremonies, the land), and involve emphasizing wholeness and balance. On the other hand, Western Sciences are generally considered to not be spiritual, often learned through accessing texts, and emphasize parts and compartmentalization of science disciplines (Bartlett et al., 2007; Hatcher et al., 2009). Spirituality in school classrooms requires particular attention (Hatcher et al., 2009). One will need to be cognizant that public schools are secular and may also be in community contexts with religious traditions. Although spirituality and religion are *not* the same concept, it is prudent to remember that students and families may not interpret the two ideas as such.

There are other tensions that educators will need to navigate when guided by Two-Eyed Seeing in their science classrooms. For instance, whether students have an Indigenous or Western lens, teachers need to take into consideration that many students may lack a connection with nature due to the greater presence of technology in their lives (Bartlett et al., 2007). Educators may also find it challenging to locate science resources emphasizing a wholistic approach to learning. While tempting to make up knowledge or access readily available sources, teachers must ensure authentic resources are used when developing science lessons, including

consultation with Elders and Knowledge Keepers where possible—remembering to consult with an appropriate community member based on the topic of interest, as it should not be assumed that all Elders and Knowledge Keepers have expertise in all areas (Bartlett et al., 2012; Hatcher et al., 2009). Authentic resources are those that centre Indigenous voices, address ideas significant to Indigenous cultures, and incorporate features of traditional storytelling (Chrona, 2022). Finally, science educators need to remember that learning takes patience and time (First Nations Education Steering Committee, 2016) and is a life-long process always unfinished (Bartlett et al., 2012). The journey to make sense of and implement Two-Eyed Seeing and transform teaching practices is not something done quickly, easily or without critical reflection.

What Self-Realizations Have Been Made in the Field?

At the time when Two-Eyed Seeing was initially used to guide the development of the Integrative Science program, there was no previous post-secondary program on which to model it (Bartlett et al., 2007). Since the advent of the program, several key lessons—or self-realizations—have emerged. In addition to being guided by Two-Eyed Seeing, Bartlett et al. (2012) emphasize the importance of co-learning, where teachers, students, Elders and Knowledge Keepers, and other knowledgeable stakeholders develop understanding together as Indigenous ways of knowing science and Western Sciences are constructed alongside one another. Learners (and I include teachers as learners here) need to be reflexive by continually examining their personal positions and be able to weave different science worldviews. Where appropriate, educators should represent ideas visually by using pictures or charts. They identified advocating for a more inclusive view of what science is and encouraging everyone to "grow forward" (p. 334) in creative ways when taking action as important lessons emerging from their Integrative Science journey.

In Michie et al. (2018), the authors of each case study also reflect on their experiences with applying Two-Eyed Seeing in post-secondary science courses. Some epistemological insights resulting from it included that it *is* possible for two worldviews to be held together at the same time, and Indigenous Sciences and Western Sciences are complementary knowledges, not contradictory. For example, in the first case study, the teacher was able to make sense of time being both linear (from a Western lens) and cyclical (from an Indigenous lens) as they explored weather patterns and seasons with students. In the third case study, the teacher developed lessons to explore complementary classification systems where students had opportunities to explore, for example, how the Anangu People in Australia have names for classifying geographical areas for food finding, as well as the Latin taxonomical system for organizing organisms. Additionally, in the second case study, the teacher experienced success by changing her chemistry teaching practices. She realized students were more engaged in learning when they had opportunities to begin with hands-on practical work. It was also realized that there were complementarities between the Western Science inquiry process and Indigenous Medicine Wheel, so she began using a circular framework for introducing each science concept. Because of this, the "students now have a context, epistemic insight, such that they are now able to create their own bridges between Indigenous and Western science and ways of knowing and learning" (p. 1213).

What Pedagogical Innovations Have Emerged?

According to existing research, enacting Two-Eyed Seeing in the science classroom is built upon the following foundational ideas: teaching Indigenous and Western ways of knowing science together; de-compartmentalizing different science disciplines; prioritizing reflexivity and developing consciousness of each person's positionality; and be wholistic—that is, the pedagogy includes physical, emotional, cognitive and spiritual aspects of learning (Bartlett et al., 2007).

People with different perspectives can come to an understanding of each other's differences, treat each other respectfully, try to find common ground as they come together to learn, and view everyone as capable in their learning (Hatcher et al., 2009). Although there are clearly differences between Indigenous and Western worldviews, it may be helpful to also think of those differences as endpoints (e.g., parts-wholeness, materialistic-spiritual, linear-cyclical) on a spectrum rather than opposing binaries (Michie et al., 2018). There are also aspects of Indigenous ways of knowing that are complementary to Western educational ideas, such as critical literacy and ethical citizenship (Munroe et al., 2013).

The research literature points to a number of pedagogical strategies for consideration in the science classroom. First, studies show that teachers are encouraged to consider their interactions with children and how the classroom environment is set up. According to Hatcher et al., 2009), some examples include providing opportunities for learners to make mistakes and trusting that they can learn from them, scaffolding learning with both visuals and verbal instructions, and fostering culturally safe spaces where learners are cared for and respected. This last point includes being mindful of nonverbal actions, being trustworthy, and understanding that students all learn and make sense of the world in different ways. Instead of mechanistic or architectural language, use organic language when speaking with students (e.g., using the term "growing" rather than "building") (Bartlett et al., 2007). In the physical environment, include elements of nature (e.g., plants), curated artwork and authentic Indigenous resources (e.g., books) for students to access (Beckford & Nahdee, 2011; Hatcher et al., 2009).

Studies indicate that thoughtful consideration of how the science curriculum is structured and enacted is also key to Two-Eyed Seeing. One aspect involves having a wholistic approach, which includes maintaining a balance between linear and circular thinking, and learning in

multimodal ways (e.g., through movement or art) (Hatcher et al., 2009). Science teachers can also provide opportunities for students to make observations of natural patterns. This might include, for example, incorporating outdoor learning experiences, having students make observations of nature from windows, or developing lessons that reflect seasonal changes (Hatcher et al., 2009). Aitken (2016) provides suggestions for creating a seasonal wheel, which can help students grow their relationship with the land. The Kwakwaka'wakw seasonal wheel records what might be harvested on the Pacific Northwest Coast during each of the four seasons and tracks annual seasonal shifts. The seasonal wheel can be used to introduce local medicinal plants and animals or local cultural activities through observation. Nature can be incorporated into indoor environments through gardening activities that foster understandings of relationships and reciprocity. Using natural materials for building with can also facilitate conversations about sustainability and responsible resource use (Bartlett et al., 2007; Beckford & Nahdee, 2011).

Additional pedagogies identified in the literature are storytelling and connecting with the community. Students can come to know science from concepts embedded within stories (Hatcher et al., 2009). Bartlett et al., (2007) share a Mi'kmaq story of how Bear's blood came to change the colour of the trees after an encounter with stars (birds) in the night sky to demonstrate the role of storytelling in students' coming to know science. The use of sharing circles when sharing stories or for problem solving is another practice described in the literature along with the importance of making clear to students the significance of circles as a symbol in Indigenous Sciences (Hatcher et al., 2009). As previously mentioned, finding ways to connect students with Elders and Knowledge Keepers in the greater community is another aspect of Two-Eyed Seeing and may be in the form of consultation during the curriculum design process, guest speakers

hosted at the school, interactions during field trips or examples of Indigenous representation in the science field (Beckford & Nahdee, 2011; Hatcher et al., 2009).

The research also shows that inquiry and project-based learning can be incorporated into the classroom. One example involves students learning about and solving a technology problem. In Snively's (2016a) cross-cultural science inquiry, grade five and six students began by learning about the use of dentalium (mollusk) shells as currency and decorative symbols of wealth by the Ehattesaht and Quatsino peoples. Located deep underwater off the west coast of Vancouver Island, the shells are difficult to harvest. In designing a prototype to gather the shells, the students considered the necessary science knowledges and available natural materials. Another science inquiry from Munroe et al., (2013) utilized visual-rich resources in the Mi'kmaw language to engage students in learning about the life cycle of oranges and other fruits. Two-Eyed Seeing was also applied as a conceptual framework in Onwu and Mufundira's (2020) mixed-methods study on developing conceptual understanding of forces with high school students from Zimbabwe. A five-phase learning sequence was used to enhance the foundational ideas of Two-Eyed Seeing: sharing a story context rooted in Indigenous ways of knowing, interrogating the context in collaborative groups, introducing science concepts through activities, supporting learners in connecting concepts to the context, and assessing conceptual understanding through application of learning to a new context. Students demonstrated an improved conceptual understanding of forces and increased engagement with science learning.

Why Two-Eyed-Seeing for This Study?

In this study, I understand existing school science education practices to be predominantly rooted in Western Science (Cajete, 1986) despite the legitimacy and value of other science worldviews—namely, Indigenous ways of knowing science (Aikenhead & Elliot,

2010; Battiste, 2013; Murray, 2016; Snively & Corsiglia, 2016). While there presumably exists other cultural worldviews on science, I also recognize the importance of addressing Indigenous Science perspectives in a Manitoba and Canadian context due to the position of Indigenous peoples as the original inhabitants of these lands, and the unique discrimination faced by Indigenous peoples due to, for example, colonization and residential schools (Manitoba Education and Training, 2017). With the understanding that a decolonizing science curriculum helps to address Indigenous students' cultural dissonance while improving science learning for all students (Aikenhead & Elliot, 2010), this research seeks to mobilize theory and pedagogy that will support science teaching practices that value both Indigenous and Western perspectives.

The strength of Two-Eyed Seeing as a lens through which to view science education is in its ability to hold multiple ways of knowing simultaneously (Hatcher et al., 2009). Two-Eyed Seeing seeks not to abandon and discard Western Science knowledges, but to acknowledge and elevate Indigenous ways of knowing science so it, too, is valued in classrooms. Two-Eyed Seeing invites science educators to grow connections between Indigenous and Western Sciences and come to understand them as complementary, not incompatible, knowledges (Michie et al., 2018). The aforementioned complementarity between the Indigenous Medicine Wheel and Western Science inquiry process is one example of how different worldviews can work together (Michie et al., 2018). There is a recognition inherent within a Two-Eyed Seeing lens that people with different perspectives have much to learn from each other (Hatcher et al., 2009).

For science educators who are unfamiliar with Indigenous values and cultures, it can be challenging to make sense of Indigenous ways of knowing science (Hatcher et al., 2009). The Winnipeg Indigenous Executive Circle's (2021) *State of Equity in Education Report* highlights the importance of Indigenous representation in school curricula—noting also, that there exists an

underrepresentation of Indigenous teachers in schools. Given that public school teachers in Canada are predominantly White (Ryan et al., 2009) and that those who are not Indigenous tend to have limited experience with reflecting on their complicity in colonization (Manitoba Education and Training, 2017), one could surmise that educators will likely experience some tensions with ideas surrounding diverse science worldviews. As Chrona (2022) writes,

> [c]hallenging paradigms about education, equity, race, and Indigenous Peoples requires difficult conversations that make some people uneasy. It is important to acknowledge feelings of defensiveness if they surface. It is a common reaction when people's ideas and habits of thought and action are challenged… we may also experience discomfort when we are in a place of not knowing. This can be especially difficult for some educators. (pp. 15-16)

The four tenets of culturally disruptive pedagogy (i.e., tensions, disruptions, self-realizations, pedagogical innovations) provide a structure that may help normalize and guide the experiences of science educators like me, as we grapple with making sense of unfamiliar worldviews. The cyclical nature of the four tenets themselves (Litts et al., 2020b) is also consistent with the Indigenous view of knowledge and learning as a sacred and life-long responsibility to both ourselves and others (Battiste, 2013). Moreover, a key element of Two-Eyed Seeing is understanding that everyone is capable of reflecting, learning, and growing (Hatcher et al., 2009). This study leverages the tenets of culturally disruptive pedagogy through Two-Eyed Seeing to explore how science educators, such as myself, can grow in our understanding of science from both Indigenous and Western Science worldviews. This addresses not only the research question of this study, but also contributes to broader reconciliation efforts in education by addressing the Truth and Reconciliation Commission of Canada's (2015) calls to

action relating to "developing culturally appropriate curricula" (p. 2), "building student capacity for intercultural understanding, empathy, and mutual respect" (p. 7), and how teachers might "integrate Indigenous knowledge and teaching methods into classrooms" (p. 7).

In speaking about the future of Indigenous peoples and traditional knowledges, Elder Albert Marshall talks about the importance of honouring different ways of knowing:

> When you force people to abandon their ways of knowing, their ways of seeing the world, you literally destroy their spirit and once that spirit is destroyed it is very, very difficult to embrace anything—academically or through sports or through arts or through anything—because that person is never complete. (Bartlett et al., 2012, p. 336)

Though there are challenges and tensions that must be navigated in this work, Two-Eyed Seeing can be a way forward for science educators to ensure that the spirits of all their learners are whole and intact. While Two-Eyed Seeing may disrupt dominant school science norms, its purpose is not to reject Western Sciences, but to ensure that silenced and invisible voices and cultures are also heard and celebrated. As Bartlett et al. (2012) have demonstrated, there are many lessons that will be learned on the journey to enacting science through a Two-Eyed Seeing lens, and the road will not always be easy. The innovations shared here tangibly illustrate pedagogical possibilities for the science classroom, and I hope that the demonstrated successes of Two-Eyed Seeing, thus far, can be a source of motivation as science educators continue growing forward in a good way.

Queering Science: From Straight to Wiggly Wonder

What Is Being Disrupted?

One of the recommendations for improving the experiences of 2SLGBTQIA+ students in *Every Class in Every School: Final Report on the First National Climate Survey on*

Homophobia, Biphobia, and Transphobia in Canadian Schools is developing curricula that better represents the intersectional experiences of 2SLGBTQIA+ people. The report indicates that students often encountered 2SLGBTQIA+ topics in only one course, and of the 2SLGBTQIA+ students who did, close to a quarter of students reported that the portrayal of 2SLGBTQIA+ people and relationships was often in a negative light (Taylor et al., 2011). In a similar study carried out in the United States, Kosciw et al. (2020) also found that approximately two-thirds of students did not experience 2SLGBTQIA+ topics in any classroom curricula and that only 16.2% of students reported exclusively positive representations. Unsurprisingly, of the students who reported that they were taught positive representations of 2SLGBTQIA+ topics, the majority indicated that this took place in social studies or English classes (60.3% and 38% respectively). In contrast, only 10.6% did so in a science class. As Gunckel (2019a) observes,

> when thinking about issues related to gender and sexual diversities, LGBTQ people, and creating a more equitable and just world, the elementary science classroom may not be where most people would start to work on building a more inclusive curriculum… [Yet,] [s]cience is the perfect place to begin reimagining a curriculum that challenges the hold that heterogendered normativity has on elementary schools. By (re)discovering the full diversity of the natural world, inspiring and following children's curiosity, and providing opportunities for all children to have embodied experiences while investigating phenomena, elementary teachers can help repair the damage that heterogendered normativity has inflicted on science learning in elementary classrooms, create a science curriculum that reflects and values LGBTQ people, and open spaces for all children to flourish as learners of science. (p. 77)

Here, Gunckel alludes to how school science has *not* been adequately acknowledging the diversity of the natural world, following children's curiosity, or encouraging children to have embodied experiences. The statement also implicates school science as complicit in reinforcing heterogendered norms that have *not* honoured and valued 2SLGBTQIA+ learners. Note, the term *heterogender* is a reframing of heterosexuality and gender to include *both* sex and gender as social constructs (Ingraham, 2002). Indeed, school science resources and activities often make invisible the human and more-than-human beings that do not conform to heterogendered norms. In one example, an elementary school crayfish kit neglected to include species that have both female and male body parts or can change sex (Gunckel, 2019a). Many science textbooks also construct sexuality as strictly heterosexual, neglect to portray family structures that do not conform to heterosexual norms and use binary-reinforcing language (Bazzul & Sykes, 2011; Snyder & Broadway, 2004), which portrays heterosexuality "as the only normal and natural form of being human" (Gunckel, 2009, p. 63). Additionally, science has a penchant for classification and categorization. Dichotomous keys, for instance, are written with binary descriptors, which further serve to reinforce heteronormativity by masking the diversity that exists between (Gunckel, 2009).

Binaries are also extended to constructions of children and adults, where children are seen to be incomplete, immature, or incompetent in contrast to the whole, mature, and competent adult. When children desire to explore and investigate the world, they may be met with adults who try to manage, restrain and tame the "wild" child (Gilbert & Gray, 2019; Leafgren & Sander, 2019). Educators sometimes also interact with children in ways that both reinforce heterogendered norms and disregard their emotions. Letts (1999), for example, documented how same-sex groupings were used in the science classroom, as well as a boy being ridiculed for not

wanting to interact with a cockroach despite "girls" doing so. Western Science typically emphasizes positivistic ways of making sense of the world, and strives to be portrayed as objective, rational and emotionless—traits which are traditionally and stereotypically associated with masculinity in opposition to femininity (Brickhouse, 2001). As such, emotionally embodied ways of knowing are often sidelined in the science classroom in favour of transmission pedagogies that privilege cognition, reinforce teacher-student hierarchies and fail to acknowledge the ways desire and pleasure are bound up with learning (Gilbert & Gray, 2019; Gunckel, 2009).

What Is Queer Theory and Queer Pedagogy?

Because what is queer is always relational to what is considered the norm in the moment, "queer pedagogy, like queer theory, resists stable discrete definition" (Shlasko, 2005, p. 123). However, one can begin by exploring how queer pedagogy emerged from queer theory. Shlasko (2005) describes what queer and queer theory mean by using ideas from Morris (1998) and Green (1996). *Queer* can refer to a gender or sexuality subject position that does not conform to societal norms, a politic that challenges what is "normal", or an aesthetic, meaning that one can interpret a text in a politically radical way even though the text itself may not have been intentionally queer (Morris, 1998, as cited in Shlasko, 2005). *Queer theory* itself can also be interpreted as a noun (as in a theory that is about queerness), an adjective (where the theory itself considers ideas that are unusual), or a verb (meaning to interrogate a theory from a different perspective) (Green, 1996, as cited in Shlasko, 2005).

Queer pedagogy, then, could be described as the application of queer theory to pedagogy where the pedagogies used by teachers are examined through a queer theoretical lens (Luhmann, 1998). Rather than focusing on adding queer content and representation, queer pedagogy asks

teachers and students to trouble the processes, products and conditions of coming to know (Luhmann, 1998). In the context of science education, a *queer science pedagogy* means viewing science curricula through a queer lens by, for example, examining how cis-heteronormativity might be privileged, understanding the process of science inquiry itself to be queer, and exploring how students come to know science as they participate in and interpret their science experiences (Broadway, 2011). It seeks to reimagine science education and question what the world considers to be normal by disrupting structures that reinforce Western Science and heterogendered norms, as well as binaries (e.g., female-male, student-teacher, emotion-cognition) (Gunckel, 2019b)—though Fifield and Letts (2014) remind us to be mindful not to approach binaries as always good or bad, as doing so would fall into the trap of constructing yet another binary. As Gunckel (2009) writes, a queer science pedagogy:

> makes space for the new identities, new knowledge, and new ideas necessary for citizens to engage intelligently in matters of scientific concern in a postmodern world. Queering science education opens possibilities for understanding the complexities, multiplicities, and power dynamics that operate within science education and within the public scientific discourse. (p. 72)

A queer science classroom allows for ideas to be re-examined and new possibilities to be imagined. Queering science invites conversations on what science is and who gets to decide (Gunckel, 2009).

What Are the Tensions?

A tension of queer science pedagogy involves reconciling its relationship with 2SLGBTQIA+ inclusion and representation. Although inclusion strategies are an important part of social justice initiatives, they also presume that the dominant way of thinking is the only

perspective of value and aims to enculturate those on the margins into that way of thinking (Britzman, 1995). This additive "add lgbt and stir" (Letts, 2002, p. 119) approach originates from gay and lesbian identity politics and emphasizes equal representation in the science classroom (Fifield & Letts, 2014). This approach might involve, for example, incorporating positive representations of queer scientists and highlighting their contributions in the classroom (Cooper et al., 2020). However, rather than being "a project of assimilating LGBTQ people into schools" (Gunckel, 2019b, p. 149), queering science is about interrogating the power structures that discriminate against those who do not conform to what society considers "normal", as well as removing the boundaries that constrain how we make sense of the world (Gunckel, 2019b). Like other critical pedagogies, queering strives to move *beyond* inclusive practices to interrogate and transform systemic structures. However, inclusion of sexual and gender diverse students is a continued challenge within schools (Kosciw et al., 2020; Taylor et al., 2011) and:

> science education is nowhere close to the assimilationist vision of including queers (n.) among the normal. We should be so fortunate to have radically queer classrooms replete with normalized gay and lesbian identities and science content about diverse sexes, sexualities, and genders. (Fifield & Letts, 2014, p. 398)

Confronting how we understand sexuality and how it relates to teaching and learning is another tension that needs to be grappled with when queering science. Adults often try to hide sexuality from children, as it is often considered to be a taboo topic relegated to lessons designated exclusively for "sensitive" issues (Gunckel, 2009). To be clear, bringing the construct of sexuality into science education is *not* about sex or sexualizing pedagogy. It is about interrogating the ways in which science is already heterosexualized (Fifield & Letts, 2014) and bringing wonder, feeling, and pleasure into learning. Sexuality in this context is about

encouraging learners to be curious and to value embodied knowledges. Drawing ideas from Britzman (2000) on sexuality and learning, Shlasko (2005) asserts, that "engaging with pleasure and desire in the work of learning means confronting some of our most basic assumptions about sexuality, childhood, and teaching" (p. 127). To think about sexuality "as a positive element of intellectual exploration and inquiry, necessitates a thorough re-evaluation of dominant understandings of young sexuality, as well as [the construction] of 'normal' and 'deviant' sexualities. That process, and that pedagogy, would be queer indeed" (p. 127).

Relating to this point, educators also need to reexamine assumptions about how child-adult relations are constructed. As alluded to earlier, adults consider sexuality to be something children require protection from, and teachers are often portrayed as "virtuous, non-sexual, mothering role models" (Shlasko, 2005, p. 127). Charged with keeping their wards safe, what else might teachers feel children need protection from? Perhaps an uncertain and ambiguous world? Wild, untamed curiosity that challenges authority and power structures? Emotions that might go against the objectivity and rationality of (Western) science? Leafgren and Sander (2019) suggest that adults might have much to learn from children if we could only reconceptualize the child not as a lesser, deficient being in need of guidance from the rational, in control adult, but as one whose ways of explorimenting—a "joyful fusion of *experiments* and *explorations*" (p. 225)—are legitimate forms of coming to know the world. No one is, of course, advocating for child endangerment or the complete absence of structure here; only that educators might be encouraged to join with young learners in becoming more comfortable with ambiguity and uncertainty (Gunckel, 2019b), resist "domesticating the thoughts of the child scientist... whose thinking challenges others (particularly adults/teachers)" (Gilbert & Gray, 2019, p. 114),

and lean into the tension of a science inquiry that is “profoundly entwined with how reality works in its strangeness, pleasure and beauty” (Bazzul & Sorensen, 2021, p. 99).

What Self-Realizations Have Been Made in the Field?

In the theorizing and application of queer theory, science education scholars have come to a few realizations about the field. First, queer science theorizing involves inquiry of science itself, and not just inquiry of nature via science (Snyder & Broadway, 2004). For instance, one could consider how the very nature of science inquiry could be understood to already be queer because science is changed by being interacted with. Because no two people are identical, and no two people have the exact same lens with which to see the world, there is no limit to the ways in which science can be interacted with, interpreted, and transformed. In that same instance, science also transforms the one with which it is interacting. Science practices and meanings “can be (and often are) questioned and transformed through the diverse stand points and identities of students and teachers. Viewed in this way... science education is already quite queer, even when it outwardly might seem anti-queer" (Fifield & Letts, 2014, p. 399).

To reconcile the tension between 2SLGBTQIA+ inclusion and a queer pedagogy, some scholars may suggest a pragmatic approach. Gunckel (2019b) concedes that raising up queer identities in schools and society is, indeed, “a worthy project and one in which [Gunckel] participates... [and] in terms of what makes a difference in improving LGBTQ people’s immediate everyday lives and happiness, the assimilationist project produces tangible results” (p. 149). However, “although queering may feel somehow less productive in terms of addressing the immediate inequities that exist for the not-straight" (Gunckel, 2019b, p. 150), it is necessary to also view science through a queer theoretical lens so that the very structures which have led to inclusion practices being necessary in the first place can be challenged and dismantled.

Following a review of both additive and queer approaches found in the literature, Wright III (2022) has also come to a similar realization that both are necessary to achieve short-term *and* long-term advances towards social justice. Likewise, I also take a pragmatic approach in consideration of my science teaching practices and this project.

Hearing the voices of all those involved in science education is also important. In exploring classroom dissections through a queer lens, Tolbert (2019) realized that engaging students, teachers, and scholars in conversation could disrupt binary thinking about dissections (i.e., for or against) and allow more complex thinking to emerge. Although some students clearly expressed sadness about participating in a dissection, they were still able to consider some potential benefits, like career preparation. The conversations invite questions about how the diverse backgrounds of participants orient themselves to various aspects of dissection, as well as how these orientations help others reconsider their orientation to science teaching itself. Finally, in taking time to listen to student perspectives, educators can be challenged to think differently about their own role in classrooms. Rather than acting as "*representatives of* scientific communities... [science educators can] develop a role as interlocutors of/within more critical, multilogical socio-scientific practices... [where] students' multiple gendered, cultural, and ethical subjectivities can be nurtured as well as critically transformed" (Tolbert, 2019, p. 49).

What Pedagogical Innovations Have Emerged?

I now review approaches to queering science provided by scholars in the literature. A queer science pedagogy begins with

> excavat[ing] your assumptions about teachers and their sense-making abilities. There isn't a threshold one must cross to 'really' be using this information in powerful and evocative ways. There are as many ways to take up these ideas as there are teachers and

> classrooms. (Fifield & Letts, 2014, p. 404)

According to Fifield and Letts (2014), examples of approaches to queering science include becoming more aware of existing dichotomies, learning more about sexism and the language that reinforces it, and critically examining how science is enacted in the classroom (e.g., how activities are structured in ways that favour heteronormativity). Other examples provided by the authors include interrogating the science content itself, disrupting the idea of a universal science with answers to everything, and providing opportunities for students to read texts critically through a queer lens. Fifield and Letts (2014) also remind educators that queering science is not just about navigating 2SLGBTQIA+ issues and suggest moving towards a framework involving desire (Fifield & Letts, 2014).

To that end, Leafgren and Sander (2019) illustrate how being nomadic, tapping into how children feel and honouring the ways they think is part of a queer science pedagogy. The authors build upon the Deleuze and Guattarian concept of smooth nomadic spaces that are heterogeneous and open to flow in many different directions in contrast to striated sedentary lives that are homogenous, but restricted. This may look like teachers bringing their science classes outside, being open to detours and following students' leads. Leafgren and Sander (2019) offer vignettes of children exploring various events like a strange sound on the roof or a flower peeking through a wall and liken the child to a nomad in school. Through explorimenting, children resist the power structures and prescriptive curriculum that permeates striated classroom spaces. Rather than trying to conform the child to the straight, oft-trodden path, the teacher becomes attuned to how children are human beings who "live and desire in relation with the world, with bodies and objects, happenings and events, signs and utterances—all moving fluidly, joyfully, smoothly in, out, with, and through the concepts and surprises inherent in engineering, science, mathematics

and technology" (Leafgren & Sander, 2019, p. 240) found in this wiggly world. As demonstrated by the fuzzy spider with four eyes vignette, the teacher was able to queer science by letting go of her own desires for the lesson's direction, and in doing so, created a nomadic space for the student to share his own science learning desires.

Gilbert and Gray (2019) also agree that queering science involves engaging students with their emotions and argue for the concept of wonder in honouring embodied ways of knowing. Drawing from Hadzigeorgiou's (2012) conceptualization of wonder, Gilbert and Gray (2019) describe *wonder* as being about the aesthetic and emotional—having an appreciation of that which is beautiful and unknown. It is also the desire to question what we think we understand and don't understand yet. Wonder pushes boundaries and challenges us to (re)imagine possibilities. A wondering pedagogy provides opportunities for students to better understand nature and how different scientific phenomena are connected. Although the pursuit of science is sometimes portrayed as rational and acultural, the authors provide examples of scientists (both real and fictional) who embody and experience a variety of emotions in their science journeys. It is important to clarify, that wonder and curiosity are different constructs. *Curiosity* is more related to the cognitive dimension of learning and could be defined as "the drive to investigate or study something while wonder is a state of mind or feeling" (Hadzigeorgiou, 2012, p. 987). According to Gilbert and Gray (2019), queering science involves embracing both emotion and cognition rather than denying the presence of one or the other.

Gunckel's (2009) research indicates that queering science may involve providing opportunities for students to question how science knowledge is produced and who decides and including more diverse science resources in classrooms that are representative of different families and sexual orientations. Other examples provided by the author include addressing

student misconceptions about sexuality (e.g., that sex is only for reproduction, that same-sex sexual behaviour is absent in nature), exploring controversies surrounding topics like genetics, and keeping organisms like fruit flies in the classroom to provide opportunities for students to engage in inquiry on mating and life cycles. According to Gunckel (2019a), other ways of queering science involve interacting with students in ways that *actually* honour student voices rather than moving a lesson in the teachers' direction regardless of what students wanted to explore, as well as critically re-examining already science resources and considering potential modifications. For example, in the crayfish kit previously mentioned, the author suggests having students make observations about other similarities and differences (e.g., colours, adaptations, habitats) between crayfish species rather than focusing on sexual differences.

Why Queer Theory and Queer Science Pedagogy for This Study?

In this research study, I understand current school science norms to be those that value binaries, heterosexuality, and masculine ways of knowing (Gunckel 2019a). Typically, this would include an overemphasis on objectivity, rationality, and transmission pedagogies (Brickhouse, 2001; Gilbert & Gray, 2019; Gunckel, 2009). As not all learners may be served by these norms regardless of sexual or gender identification, science ought to consider other ways of making sense of the world, such as valuing embodied experiences (Gunckel, 2019a). According to research synthesized by Baker (2016) on gender and science education, science teaching often emphasizes teacher-centered pedagogical strategies, memorization and the use of textbooks (Tobin, 1988, as cited in Baker, 2016) and these strategies tend to privilege male students (Oakes, 1990, as cited in Baker, 2016) by creating classroom conditions where, for example, male students are more vocal during class or called on more frequently by the teacher (Baker, 1987, as cited in Baker, 2016).

Although there have been efforts to make women more visible in science, this has also contributed to reinforcing gender binaries (Knezz, 2019). For example, Baker's (2016) review of equity issues in science focuses on "*women* and minorities in science" (p. 134, emphasis added), uses women and female interchangeably, and makes no mention of gender diverse students or scientists. When gender equity discourse focuses on gender binaries, "students with gender identities that do not align with the binary feel especially left out. A student in this position neither feels comfortable with the majority cis-male image of a scientist nor with the cis-female image used to encourage and empower the minority" (Knezz, 2019, p. 828). It is for this reason, that queer theory was selected as a lens for this research study, which seeks to explore how I, as a science teacher, might be able to disrupt existing science norms to better support gender equity. Queering science in this study means exploring how science classrooms might create spaces for marginalized learners by disrupting gender binaries, heteronormativity, and social constructions of identity (Snyder & Broadway, 2004). It also means trying to look at science and inquiry in different and more expansive ways by questioning what science knowledge is, how it is created, and who gets to decide (Gunckel, 2009). As Gunckel (2009) writes,

> queer theory in education opens new identities, new knowledge, new ways of constructing understanding, and new ways of teaching and learning to everyone… [it] is more than claiming equal rights for all; it is also about claiming the previously unseen and previously unknowable for everybody. (p. 67)

The tenets of culturally disruptive pedagogy are, once again, leveraged when queering science. In my own exploration of queer science pedagogy in the classroom, there may be tensions that arise, disruptions and realizations that take place, and implementation of new pedagogies. The concepts of wonder (Gilbert & Gray, 2019) and desire (Leafgren & Sander,

2019) are particularly useful in this study because queering science in school contexts where discourse on gender and sexuality is controversial (Gunckel, 2009) is a tension likely to arise. However, encouraging students to appreciate beauty and mystery in science while questioning what we know or have yet to know by wondering still allows us to challenge boundaries (Gilbert & Gray, 2019). We can (re)imagine science through a queer lens by following children's desires as they explore the world around them while (re)connecting with our own desires as science educators and learners (Leafgren & Sander, 2019). These are practical and tangible ways in which I, as a science teacher, can queer science in a middle years classroom context. There is also complementarity between queering science and Two-Eyed Seeing as theoretical frames. Two-Eyed Seeing also encourages embodied learning through, for example, movement and dance, art making, and being open to nature with our body, senses, and spirit (Hatcher et al., 2009). In a sense, desiring to teach science differently by valuing multiple science perspectives rather than privileging Western Science, which is the norm, is already somewhat queer.

Although much of this work with queer pedagogy has focused on (re)connecting students with their desires to learn, Gunckel (2019b) reminds us that this work is also about (re)connecting teachers with their own desire for learning and passion for teaching children. As educators embark on or continue their own journeys to queer science, it is okay to feel vulnerable and anxious, and it is okay to be confused and uncomfortable (Gilbert & Gray, 2019). Sometimes, educators might need to add new science content that is more representative of students' diverse identities, and at other times, educators might need to look at what is already there through different lenses to "make the familiar strange" (Fifield & Letts, 2014, p. 405). Like Gilbert and Gray (2019), Fifield and Letts (2014) remind teachers that it is okay that ideas are

sometimes incoherent and that it is okay for teachers to not know or understand everything all the time. At the end of the day, science educators can take away:

> anything they want to, anything of use, anything that affords them a broadened view of their students and the important work that they do. 'To queer' is to denaturalize coherent selves, to resist the narrow logic of binaries, and to dislodge the sense of safety that comes with 'really knowing'. (Fifield & Letts, 2014, p. 405)

Critical Race Theory and Anti-Racist Pedagogy in Science

What Is Being Disrupted?

Scholars in STEM (science, technology, engineering, and mathematics) education are calling for more attention to equity and diversity (Rodriguez et al., 2022). Although gains made in this area often materialize when the interests of racially marginalized groups align with those of the dominant culture (e.g., economics, global competition in science and technology) (Delgado & Stefancic, 2023; Rodriguez et al., 2022), the reality is, that communities—and by extension schools—are also becoming more racially and ethnically diverse (Manitoba Education and Training, 2017). In Manitoba's capital city, it is projected that nearly fifty percent of students will be those who identify as Indigenous, Black, or a member of another racially marginalized group within a decade (Manitoba Education and Training, 2017). Diversity is an important aspect of *all* Manitoba Schools, not just urban or inner-city neighbourhoods (Manitoba Education and Training, 2017), and notwithstanding economic and (the somewhat cliché) demographic rationales for attending to equity and diversity, science education has an important role to play in making the world a more socially just and equitable place for everyone. Students should, of course, have opportunities to engage with science knowledges and practices; but science teachers also need to empower students to think ethically about, and take social

responsibility for, the environment, their communities, and each other (Galamba & Matthews, 2021; Hodson, 2003).

Science classrooms and curricula are not free from oppressive systems and racial injustices (Lodge, 2021). When only the contributions of (usually) White, European scientists are recognized and those of others are made invisible by omission, or inaccurate and racist pseudoscience claims a biological basis for the superiority of certain human beings, (Western) science is complicit in hegemonic practices (Ash & Wiggans, 2018). Sadly, this can contribute to racially marginalized learners believing that there is not a place for them in science. This sentiment is captured by the words of a Black pre-service teacher in Mensah's (2019) longitudinal case study who feels "'science is not for people of color'" (p. 1446) like herself. Science teachers need to better understand how marginalized students are negatively impacted by systemic inequalities by developing what Madkins and Morton (2021) refer to as *political clarity*, which is "the understanding of the sociopolitical and classed realities that shape our learners' lived experiences, and how structural and school inequalities work to (re)produce differential learning experiences for minoritized learners" (p. 241). They, along with authors of other studies, call for eliminating deficit views of racially marginalized learners (Sparks, 2018) and the disruption of racial discrimination in science education (Sheth, 2019; Walls, 2022).

What Is Critical Race Theory and Anti-Racist Pedagogy?

Science education "has the potential to unravel misconceptions about race and ethnicity by addressing fundamental aspects of our shared humanity, as well as evoke critical questions about the social and historical discourse of diversity in education" (Ash & Wiggans, 2018, p. 111). As such, this study hopes to contribute to unravelling and disrupting racial injustice in science by exploring how critical race theory can be used as a lens to inform anti-racist science

pedagogies in my science teaching. *Critical race theory (CRT)* originated from the legal field in the United States during the 1970s and examines how race, racism and power are related. Importantly, critical race theory aims not only to understand these relationships, but also to take actions that transform racialized landscapes (Delgado & Stefancic, 2023). Education scholars have since applied CRT to school contexts on a variety of education-related issues including, but not limited to, assessment, curricula, and discipline. Racism in schools and educational theory, as well as deficit views of students have also been explored through a CRT lens (Delgado & Stefancic, 2023). For example, in contribution to the Truth and Reconciliation calls to action in education, Manitoba educators are encouraged to better understand racism through critical/courageous conversations. These conversations about inequity and impacts on diverse peoples are built on the ideas of critical race theory (Manitoba Education and Training, 2017).

CRT has a number of foundational tenets, one of which, is what race is and is not. Not to be confused with *ethnicity*, which is a categorical identification based on "shared linguistic, historical, geographical, religious, and/or racial homogeneity" (Manitoba Education and Training, 2017, p. 59), *race* is a social construct that classifies human beings based on physical features or cultural characteristics (Manitoba Education and Training, 2017). Although some physical traits are common among those with a shared geographic origin, race is not biologically intrinsic to human beings, but an idea created by the dominant (White) group to justify the categorization of certain groups as inferior so that the dominant group can exert power over them (Canada Race Relations Foundation, 2023; Delgado & Stefancic, 2023). Larkin et al. (2016) contend that race can still be a useful model for race-conscious science teaching and research even though it is somewhat contradictory to work with race as real even when it is not. Though it

has no genetic basis, race remains entangled within various power dimensions and its effects and impacts on racially marginalized groups are very much real. As Kendi (2019) explains,

> for all that life-shaping power, race is a mirage, which doesn't lessen its force. We are what we see ourselves as, whether what we see exists or not. We are what people see us as, whether what they see exists or not. What people see in themselves and others has meaning and manifests in ideas and actions and policies, even if what they are seeing is an illusion. Race is a mirage but one that we do well to see, while never forgetting it is a mirage, never forgetting that it's the powerful light of racist power that makes the mirage. (p. 37)

In addition to race being a social construct, other key tenets of CRT are also discussed by Delgado and Stefancic (2023). Another foundational idea is that racism permeates every aspect of society, including schools. Because racism is so ordinary, it is often not acknowledged, which also makes it difficult to address. This is related to ideas of White privilege and colourblindness. Many people who benefit from Whiteness also do not recognize their own privileged position in society, and when people treat everyone the same without "seeing" the differences that affect how racially marginalized groups are treated, little is done to advance equity issues. As discussed previously, interest convergence, which is when the interests of marginalized groups progress because they align with those of the dominant group, is another key tenet of CRT. Many members of society have little reason to actively counter something they benefit from. This is also related to the idea of differential racialization, which means that different communities are racialized at different times when it is convenient and beneficial for the dominant group. Another key idea is that to understand racism, it is necessary to understand and listen to the voices of those who experience racism. It has been suggested that work involving CRT be carried out by

scholars of colour (or at least be involved in co-authorship) (Rodriguez et al., 2022). In his critique of the draw-a-scientist studies, Walls (2022) also emphasizes the importance of centralizing and privileging the voices of racially marginalized students and teachers who, often, "are not asked their views of a scientist, or what they think about science" (p. 166).

Critical race theory informs an anti-racist pedagogy that aims to help learners develop critical skills needed to challenge systemic racism and can be enacted in any discipline, including science (Kishimoto, 2022). According to Kishimoto (2018), anti-racist pedagogy has three main components. The first is challenging Eurocentric worldviews—in this case, Western Science—by incorporating racial content in all aspects of a course (e.g., activities, resources used) in ways that are neither tokenized nor additive. During this process, it is also important to remember that diversity exists within racial groups and to avoid reinforcing Black-White binaries, as well as considering intersectionality. Anti-racist teaching is not only about what one is teaching, but also how. It involves leveraging collaborative learning to help build classroom community and framing learning as something done together between teacher and students. It also means helping students become critical thinkers who are aware of their positionality and able to put their learning into practice. The third component is extending anti-racist work beyond the classroom into other areas of influence involving research, work with colleagues, or the community.

What Are the Tensions?

A tension of work with critical race theory and anti-racist pedagogy arises when teachers' and students' worldviews make it difficult for them to engage with discourse on race and racism. The way a person's experiences and understandings of ideas like race, equity, power, and education are interrelated with one another can be referred to as their *conceptual ecology*, and this can be difficult to change (Larkin et al., 2016). Many educators themselves are unaware of

racism, uncomfortable with discourse on race, racism, and other social issues, or are unable to acknowledge their own privilege (Manitoba Education and Training, 2017). They may not see the relevance of race in the science classroom or recognize how race and pedagogy are connected (Larkin et al., 2016). A challenge for educators who do engage with this work is finding ways to challenge worldviews without alienating others, and to validate everyone's realities and experiences without centering dominant norms (Kishimoto, 2018).

This connects to the tension that educators who want to engage in CRT and anti-racism teaching may be deterred by the potential dangers and risks, especially for those who themselves may identify as a member of a marginalized group (Kishimoto, 2022). Those who initiate conversations around race, privilege and injustice may experience "social and political backlash" (Kishimoto, 2022, p. 121). For example, Delgado and Stefancic (2023) describe how the political climate in the United States led to legislation banning schools from teaching about White privilege, how racism is embedded in society, or that people today should have responsibility towards historical wrong doings like slavery. In their case study of two science teachers, Riley and Mensah (2023) also found that the participants, both of whom were Black women, experienced emotional burdens as they tried to subvert colourblind ideologies and assessment practices in the science curriculum and school context. It is important for all educators to understand how race is entangled within teaching and learning. However, it is especially important for educators from the dominant racial group to better understand how racial inequalities operate in school spaces and engage in anti-racist work not only to be in solidarity with their racially marginalized colleagues, but also because of the power they are privileged with (Bratman & DeLince, 2022; Kishimoto, 2022).

Like other critical approaches to equity, there is a tension between different approaches to addressing racial injustices. Although multicultural and inclusionary approaches do contribute to increasing diversity and representation, they also continue allowing the norms of the dominant group to be norms others must aspire to (Kishimoto, 2022). Simply celebrating different cultures and diversity on its own without critiquing power dynamics maintains the illusion that all racial and ethnic groups are treated equally in society when they are not (Kishimoto, 2018). On the other hand, anti-racist pedagogy, which utilizes CRT as a theoretical lens, strives to dismantle the structures that made approaches like inclusion necessary at all (Kishimoto, 2022). Sheth's (2019) ethnographic study illustrates how science teachers can inadvertently reinforce racism in their classrooms despite good intentions. Although the teachers attempted to include more student interests, diversify the scientists represented, have students explore socioscientific issues and engage in inquiry, when analyzed through a CRT lens, their teaching practices instead perpetuated racism by normalizing White experiences, individualizing student differences, maintaining the myth of meritocracy, and dismissing student thinking and experiences involving race. Turning towards an allied struggle for systemic justice in science education requires teachers to grapple with the tension of recognizing that there is much to learn *from* students and that the teacher need not always be the expert (Calabrese Barton & Tan, 2020). It may be helpful for science educators to approach race-conscious science teaching as a continuum rather than a hierarchical binary between approaches. The diversity and equity pedagogies continuum described by Kishimoto (2022), where approaches move along axes of social position awareness and change from individual to systems is a useful way to reconcile this tension.

What Self-Realizations Have Been Made in the Field?

In Larkin et al. (2016), a realization of their study is that it can be very difficult for people to change their conceptual ecology as it relates to race, racism, and pedagogy. Although some small shifts in thinking were observed, the understandings of the two pre-service teachers remained largely unchanged. One could say the participants were unable to come to any significant self-realizations about how race, science and teaching are related during the study, though they did come to some realizations on more general classroom management strategies and lesson planning techniques. As the authors pointed out, a limitation of this case study is that it was descriptive and not an intervention study. However, it was indicated that the teachers participated in some course work during their teaching program that included relevant readings and reflections. Additionally, the interview questions designed to elicit participants' thinking on various science classroom situations involving race could have served as potential provocations for the teachers to reflect on.

Teachers also need to *want* to support equity goals in science education. The result of Sheth's (2019) study was the creation of the grappling with racism framework, which involves desiring, knowing, and doing. A key idea here is that science educators need to have a *desire* to learn about dynamics between race, students, and their science pedagogy. A part of this desiring involves being reflexive and engaging in ongoing reflective practices. This reflective piece aligns well with the circular anti-racist praxis framework, which involves critical self-reflection and learning, analyzing changes that need to be made in our educational work, implementing those changes in our practice, and connecting with community (Clifford et al., 2022, as cited in Kishimoto, 2022, p. 119, Figure 6.3). Although it can feel easier to continue doing things the same way, or remaining in only one quadrant of the framework, educators need to challenge

themselves to get uncomfortable so that this process of learning and acting remains fluid rather than static (Kishimoto, 2022).

Another realization is that a critical part of this work and journey involves being in community with others, which can be an important source of support and accountability (Kishimoto, 2022). Forming and maintaining relationships with supportive peers and mentors was also a strategy used by the Black female pre-service science and math teachers in Sheth's (2019) study for adapting to fields where they were underrepresented. The teachers also hoped to become role-models for future students. Relationships can have a profound impact on educators' motivation, retention, and pedagogical approaches to science teaching (Mensah, 2019). Mensah's (2019) study demonstrates the importance of having racially diverse role models to guide teachers in developing their relationship with science and teaching. Michele, who was the Black female pre-service teacher in this study, came to several transformative realizations because of Mensah's science methods course and mentorship. Initially, she did not like science, felt that science was not for her, and considered leaving the program. However, Michele came to realize that "'the face of a science teacher is changing'" (p. 1432). Having opportunities to engage with race and ethnicity in her science methods class empowered Michele to try planning science units in different ways and find her voice as a science teacher. Michele's reflection captures the profound growth that had occurred: "'I was awakened to something totally different. Who would have thought I'd ever want to be into science? Like never in a million years, never. Never would have seen it'" (p. 1433).

What Pedagogical Innovations Have Emerged?

Regarding the "how" component of anti-racist pedagogy (Kishimoto, 2018), I now provide a review of pedagogical strategies found in the research literature. Studies indicate that

there are different ways for science educators to engage students in the racialized dimension of science concepts and help students become aware of the role science has played in reinforcing biological racism. One example includes creating space for dialogue on the cultural and political meanings hair can hold along with racialized experiences with hair rather than only learning about the science behind the structure of different hair types (Larkin et al., 2016; Sheth, 2019). In Indigenous cultures, for instance, hair holds cultural significance and is only cut when a close family member passes away. However, at residential schools, children had their hair forcibly cut "to strip away their personal and cultural identities" (Canadian Museum of Human Rights, 2022, para. 2) and "to force the children to conform to racist cultural ideals and Christian settler-colonial gender stereotypes" (para. 14). Another example from the literature is learning about the genetic similarities between humans to illustrate how differences are ideological and not biological, as well as the role of geography in genetic variability and how differences are for survival (Ash & Wiggans, 2018).

Research also shows that counterstories support the fostering of students' critical consciousness in the science classroom (Sheth, 2019). *Counterstories* are stories that provide a different perspective challenging the validity of stories from dominant perspectives (Delgado & Stefancic, 2023). As Delgado and Stefancic (2023) explain, counterstories can "begin a process of correction in our system of beliefs and categories by calling attention to neglected evidence and reminding readers of our common humanity" (p. 52) and support diverse peoples in developing empathy and bridging gaps between their different lived experiences. Examples provided in the literature include learning about the story of how Henrietta Lacks' immortal cell line was used in countless scientific advances without consent or recognition, or how racially marginalized communities continue to experience disparities in healthcare access (Riley &

Mensah, 2023). According to Mensah (2019), sharing counterstories of how racially marginalized teachers approached their own science learning and navigated education systems may also help people better understand the lived realities of others or find solidarity in their similar experiences.

Studies also show that inquiry learning experiences create opportunities for students to critically think about community science issues. For example, open-ended experiential learning where students get to ask and investigate their own questions helps students see themselves in science (Riley & Mensah, 2023). These explorations can also be leveraged to provide opportunities for discussions surrounding ethics and accountability in science (Sheth, 2019). In Davis and Schaeffer (2019), the Flint, Michigan water crisis is used in a water unit to explore how grade four and five students make meaning of justice in science. Although classrooms often include science concepts like the properties of water or bodily uses of water, an exploration of "how these phenomena are imbued with cultural, sociopolitical, and experiential meanings" (p. 369) is usually absent. However, the study demonstrated that students began to see community science issues as systemic and connect science issues to "larger (raced) struggles for dignity and rights" (p. 385). In their work with rightful presence as a framework, Calabrese Barton and Tan (2019, 2020) also demonstrate how a design inquiry project might provide opportunities for students to disrupt systemic injustices in their own classroom. Using concepts of electricity and circuits, a group of grade six students created a lighting system to stop classmates from intentionally barging in on marginalized students in the washroom. Throughout the inquiry process, privileging students' voices and thinking is key, while solely focusing on the inquiry methods themselves presents a missed opportunity to value the racialized experiences students might bring to their science sense-making (Sheth, 2019).

Why Critical Race Theory and Anti-Racist Pedagogy for This Study?

This study uses critical race theory as a lens to expose the ways in which racism operates in science education. An assumption of critical race theory is that racism is embedded in the fabric of daily life (Delgado & Stefancic, 2023), and it is my understanding that racism is embedded in school life and existing science education practices that privilege and perpetuate Whiteness (Ridgeway, 2019). We see this in science textbooks that primarily use images of people who are White (Powell & Garcia, 1985, as cited in Baker, 2016), the small numbers of racially marginalized science role-models (Mensah, 2019), and limited availability of science curriculum materials that represent or reflect the lives of Indigenous and Black students (Baker, 2016). The presence of racial inequity is a contributor to disparities in students' achievement in the science classroom (Wallace & Brand, 2012). Awareness of these discriminatory practices and their potential impacts on science learners is an important part of disrupting complicity in my own science teaching practices.

In addition to recognizing how racial inequity impacts learners' science experiences, it is also important to interrogate how race and racism intersect with gender and Indigenous perspectives in science. Drawing from Lugones' (2011) scholarship, Johnson and LeMaster (2020) describe "the gender binary [as] a White supremacist project used to distinguish White notions of gender being and becoming from racialized notions of non-human embodiment" (p. 3). The standard for human has become synonymous with the White, Western man, while "reproducing and upholding the human (read: White, patriarchal) race" (p. 3) was the role of White women. Colonization was, and still is, a way for White, Western men to advance their own interests through the dehumanization of those they considered less than (or entirely not) human. Similarly, Hamad (2020) argues that,

> over the course of centuries, as the proponents and beneficiaries of colonialism, whites have set the standards both for humanity as a whole, embodied in the white man, and for femininity that is designed to complement the white male and so is embodied in the white woman. (p. 16)

An exploration of gender and reconciliation in science education, then, necessitates a consideration of race. As Chrona (2022) writes, "We cannot move forward in Reconciliation without addressing Indigenous-specific racism" (p. 58). Because of colonialism and the residential school system, Indigenous peoples in Canada experience racism in distinct ways. Rooted in European notions of superiority, First Nations, Métis, and Inuit peoples were not considered persons under the *Indian Act*, and because Indigenous children were not permitted to practice their cultures, languages or traditions at residential schools, intergeneration trauma continues to impact Indigenous communities (Manitoba Education and Training, 2017). Although other racialized persons also experience racism in Canada, they and their ancestors generally resettled on these lands for the purposes of "seeking freedom, security of life, and opportunities to flourish" (Manitoba Education and Training, 2017, p. 7).

Being and becoming anti-racist "is about understanding the various ways racism manifests itself and doing the personal and professional work to uncover and eliminate it" (Chrona, 2022, p. 58). Standing up against discriminatory curricula and practices is a responsibility we have as science educators occupying positions of privilege in society. In this research study, I grapple with the tension of being a racially marginalized science educator who has been, and is, complicit in science teaching practices that have not always honoured Indigenous ways of knowing. It means acknowledging my own privilege, working to disrupt

hegemonic science practices rooted in racism, growing through self-realizations, and having the courage to explore pedagogical innovations that address racial inequities in my classroom.

Science education scholars and classroom teachers can leverage critical race theory and anti-racist pedagogy to inform their practice and "illuminate how systems of oppression shape science education and to reconstruct science education as a justice-oriented field" (Sheth, 2019, p. 56). This journey begins with a critical examination of our own conceptualizations of race and pedagogy, our own biases and prejudices, and how we can better create learning spaces for students to engage in discourse on race, racism, and power (Manitoba Education and Training, 2017). Anti-racist science teaching is an ongoing process that involves connection, community and expanding the borders of our practice beyond individual classrooms. It calls on educators to have humility, to be vulnerable, and to learn from our mistakes and failures (Kishimoto, 2022). The "fear of imperfection, making mistakes, conflicts, etc. should not stop us from beginning the antiracism journey. In fact, being in fear and waiting for perfection only benefits white supremacy" (Kishimoto, 2022, p. 120). By expanding our conception of science education beyond transmission of scientific knowledge, educators can reimagine the role of science in creating an equitable world and empower science learners in their becoming as "people who will fight for what is right, good and just; people who will work to re-fashion society along more socially-just lines; people who will work vigorously in the best interests of the biosphere" (Hodson, 2003, p. 645).

Summary

Though building upon a rich foundation of scholarly work on social justice in teaching and learning, the literature on culturally disruptive pedagogy, particularly as it pertains to science education, is still emerging. Although science might not appear, on the surface, to be the most

obvious place to address equity, the literature illustrates that science education does have an important role to play in disrupting the Western, White, and masculine norms that continue to permeate science teaching. Moreover, the research highlights the need for the (re)centering of science discourse on the voices and experiences of those who have been and continue to be marginalized in intersectional ways. An intersectional approach highlights the uniqueness of each lens, while also revealing the common threads running through our shared human and more-than-human world. The literature on Two-Eyed Seeing, queer theory, and critical race theory demonstrate how science education needs to be (re)imagined in a way that embraces emotions and embodied learning; honours relationships and community; fosters horizontal interactions between student learners and teacher learners; and embeds opportunity for all learners to live and experience their way into knowing science. This journey that science educators embark on will require courage and vulnerability. It will require visiting and re-visiting our assumptions about what it means to learn and teach science. Fortunately, the scholarly work carried out so far provides many pedagogical innovations that might be helpful along the way.

Chapter 3: Methodology

This chapter provides an overview of the methodological framework and research design of this research project. A summary of the underpinning theories is provided, along with an outline of the research design for data collection, data management and analysis, report writing, methodological cautions and ethical considerations. This critical autoethnographic study aims to address how I, as a science education scholar, can engage in justice-oriented science pedagogies in contribution to more equitable science learning experiences through the following research question: How can culturally disruptive pedagogies inform my becoming as a middle years science educator working to enact more socially just conceptualizations of science in a pluralistic society? The following sub questions inform the main research question:

i. How can I, as a racialized settler/Guest, engage in teaching practices that honour coming to know science from both Indigenous and Western perspectives?
ii. How can I enact science pedagogies that support gender equity in the science classroom?
iii. How can my teaching practices honour students' ethnoracial diversity in the science classroom?

Theoretical Underpinnings

Critical autoethnography was the method of inquiry for this study. In this section, I first provide an overview of autoethnography and its origins. Then, I explain how critical autoethnography distinguishes itself from autoethnography, articulate why critical autoethnography was an appropriate methodology for my research questions and consider the implications of critical autoethnography.

Autoethnography

Autoethnography is a qualitative inquiry focused on making sense of the researcher's personal experiences in connection to a particular cultural context. The approach draws on both autobiographical (telling stories about your own life experiences) and ethnographic (studying a culture to understand it better) traditions (Ellis et al., 2011). Although different autoethnographers may lean closer toward one or the other, in my research study, I aimed to remain consistent with Chang's (2007) argument that "that "autoethnography should be ethnographic in its methodological orientation, cultural in its interpretive orientation, and autobiographical in its content orientation… self-reflective writings deficient in any one of these ingredients would fall short of 'auto-ethno-graphy'" (p. 208). Similarly, Wall (2016) proposes a moderate autoethnography that is aesthetically descriptive in its storytelling through the researcher's lens while remaining analytical in its connection to and critique of the social, cultural, and political. While autoethnography and autobiography both involve personal narratives, autoethnography differs by using stories to examine broader cultural contexts (Chang, 2008).

Ethnography itself has imperial, colonial and positivist roots in social anthropology where early ethnographers were outsiders entering the field to objectively study the "other" (Jones, 2010). Consent and confidentiality of community members were rarely attended to and, oftentimes, their cultures were portrayed negatively (e.g., as uncivilized) with intent to justify conquest and colonization (Jones, 2010). Since ethnographers spent significant time making field observations, they were often members of the privileged dominant group (i.e., high socioeconomic status, White, Christian, male, from Euro-Western cultures) (Jones, 2010). For example, French Jesuit Louis Nicolas, who studied Anishinaabe language and perspectives on

nature in the 1600s, imposed his own views in categorizing nature, had strained relationships with Indigenous peoples and disparaged their worldviews (Marks, 2022). Yet, as Marks (2022) notes, traces of Indigenous beliefs in Nicolas' writing cast doubt on his absolute objectivity.

Though both seek to understand culture, autoethnography departs from other forms of ethnography in that autoethnographers are "insiders (cultural members)" (Ellis et al., 2011, p. 275) writing personal stories, analyzing their personal experiences and connecting their individual story to the patterned experiences of others as opposed to "outsiders (cultural strangers)" (Ellis et al., 2011, p. 275). As mentioned earlier, traditional ethnographic fieldwork privileged those with the time and resources to participate (Jones, 2010). On the other hand, "autoethnography has sought to reposition and resituate unheard voices… [and] provides pathways for stories of the socially marginalized to enter the discourse of academics" (Marx et al., 2017, p. 2). In other words, autoethnography provides a larger tent for a broader segment of society to participate in doing research—including practicing classroom teachers who might be unable to leave their own classroom to enter another's for extended periods of time. Rather than operating under the guise of objectivity, autoethnography also understands research to be a value-laden endeavour by recognizing and forefronting the researcher's subjectivity (Ellis et al., 2011), though ethnographic research today pays greater attention to subjectivity and reflexivity (see Jones, 2010, for examples of such ethnographies). Both methodologies may include detailed accounts of culture with contextualized meanings of those experiences or what Clifford Geertz (1973) has termed *thick descriptions* (as cited in Ellis et al., 2011). However, autoethnography also strives to be aesthetic and accessible to wider audiences (Ellis et al., 2011).

Next, I discuss how critical autoethnography both builds on and distinguishes itself from autoethnography. I will also explain why this particular approach was selected for this study.

Critical Autoethnography

This research study used critical autoethnography to explore how culturally disruptive pedagogy informs my becoming as a middle years science educator working to enact more socially just conceptualizations of science in a pluralistic society. Boylorn and Orbe (2021b) conceptualizes critical autoethnography as an analysis of personal experiences in connection to culture, all of which are situated within systems of power and privilege. Being informed by critical scholarship is what distinguishes critical autoethnography from other forms of autoethnography (Boylorn & Orbe, 2021b).

Critical qualitative inquiry originates from "sociopolitical and emancipatory traditions" (Fossey et al., 2002, p. 720) and emphasizes the sociohistorical context in which human actions are embedded. According to Guba and Lincoln (1994), within a critical qualitative paradigm, the world is shaped by underlying contextual forces informing what society believes to be real. Knowledge and truth are not static but revised as those forces shift and insights are gained. This study recognizes Western Science is often accepted in mainstream society as universal, while knowledges and truths of other perspectives (e.g., Indigenous Sciences) are devalued due to their socially, politically and historically subjugated positions in society. This research critiques dominant science perspectives and seeks to recognize additional ways of knowing of science. In critical qualitative research, the research quality is determined by the degree to which the study situates itself within these sociopolitical and historical contexts, along with how much the study "erode[s] ignorance and misapprehensions" (Guba & Lincoln, 1994, p. 114) and serves as impetus for transformation (Guba & Lincoln, 1994). Research processes and findings are value mediated because the researcher brings personal values into their scholarly work (Guba & Lincoln, 1994). A position statement, for example, is included to reflexively situate my

interpretations of the findings within the contexts of my life experiences (Creswell & Creswell, 2018). Additionally, the researcher is understood to be a "transformative intellectual" (Giroux, 1988, as cited in Guba & Lincoln, 1994, p. 115) who leverages their sociopolitical consciousness to serve as an advocate or activist. In short, critical scholars research not only for the sake of understanding culture, but also with intent to ameliorate oppressions.

The emphasis of critical autoethnography on culture and power structures (Boylorn & Orbe, 2021b) aligns with this study's aim to interrogate the school science culture and how Western Science, stereotypically masculine norms and binaries, and Whiteness reinforce and perpetuate hegemony in science education. Critical autoethnography "value[s] subjugated identities and experiences in addition to and alongside how such identities and experiences create differently valued knowledges" (Holman Jones, 2018, p. 9) making it appropriate for research centering my counterstory as a racially marginalized female science educator working to uplift the ways of knowing and being of marginalized groups. As Boylorn and Orbe (2021a) write, "telling [our] own stories, as well as facilitating the stories of others, is an act of resistance. It is a response to attempts to silence and mute [our] experiences and maintain the normativity of majority group experiences" (p. 7). Critical autoethnography also encourages the researcher to reflexively interrogate their experiences within a particular culture and reflect on how cultural differences are navigated (Boylorn & Orbe, 2021b). This is applicable to my research questions, which explore how I can interrogate my teaching practices and approach science education in ways that honour learners' diversities as it pertains to Indigenous ways of knowing science, gender and ethnoracial backgrounds. My experiences both represent existing school science culture and challenge hegemonic science teaching practices by critiquing and making visible the oppressive structures that our practices are embedded within (Boylorn & Orbe, 2021b).

Boylorn and Orbe (2021b) further articulate, that attention to intersectionality is needed in critical autoethnography to account for the experiences of oppression and privilege that emerge from interdependent, overlapping identifications. Attending to intersectionality is routine for critical autoethnographers who "situate their stories and lives to call out positions of privilege and expose moments of vulnerability" (p. 7). For instance, in Johnson and LeMaster's (2020) collection of intersectional autoethnographies, gender is understood to be a racialized performance rooted in colonization that continues to perpetuate the "dehumanization of those who fall outside of White Western criteria for 'appropriate' gender performance, comportment, embodiment, and identity" (p. 4). Intersectionality allows the critical autoethnographer and audience to critically consider "the roles patriarchy, racism, sexism, binary gender, and colonialism play in their experiences and provide complexity, nuance, and possibility for emancipation" (pp. 8-9). The following criteria for a rigorous (critical) autoethnography are suggested by Johnson and LeMaster (2020): Maintain internal and structural consistency when telling stories and acknowledge that stories are informed by intersectional structures of power; engage in self-reflexivity during the inquiry process and unpack the ways in which power structures influence how we carry out research and tell our stories; and recognize that social identity categories targeted by sociopolitical discourse can also exclude other identities by disregarding the nuanced complexity of human experience.

Because critical autoethnography is framed by critical scholarship, its goals differ somewhat from more general conceptualizations of autoethnography, which focuses primarily on understanding individual experiences and their connection to culture (Chang, 2008). However, in addition to understanding the lived experiences of marginalized individuals, critical autoethnography seeks to interrogate power structures and "fuse theory and action to challenge

processes of domination" (Boylorn & Orbe, 2021b, p. 9). According to Holman Jones (2016, 2018), critical autoethnography should interrogate how existing social structures and discourses uphold injustice, engage in praxis through storytelling, and connect theory with real-world action. Therefore, my research aimed to address the aforementioned goals that distinguish critical autoethnography while balancing the storytelling, analysis and connection to culture (of science teaching and learning) inherent to autoethnography (Chang, 2007; Wall, 2016).

Implications of Critical Autoethnography as a Form of Inquiry. Holman Jones (2016) argues that sharing our counterstories meets the transformation commitment of critical autoethnography because it "has the power to embody and materialize the change we seek in ourselves and our lives" (p. 235). Boylorn and Orbe (2021a) similarly recognize critical autoethnography as a way of *becoming*, "an ongoing, ever-changing, and never-ending process" (p. 5), through research. How I become as a justice-oriented science educator is documented through the stories of my critical autoethnography. Snapshots "captur[ing] the in-betweeness of past and present, memory and story" (Boylorn & Orbe, 2021a, p. 9) of self-transformation are provided through narratives relating back to the tenets of culturally disruptive pedagogy (tensions, disruptions, self-realizations and pedagogical innovations). By critically examining my teaching practice, I better understood the social structures and power dynamics embedded in the culture of school science, which supported me in navigating tensions related to the research questions. This included, for example, reflecting on how I could leverage my privilege as an educator to center the voices of Black and Indigenous peoples in science, while also being a racially marginalized science educator without the privileges of the dominant culture. The learning that emerged from this study has encouraged more intentional self-reflection, influenced

my curricular and pedagogical decision-making, and served as an impetus for connection with diverse peoples, which has further influenced by own understandings of different cultures.

Through critical autoethnography, we can better understand how personal stories connect to institutional practices, disrupt binaries (Reed-Danahay, 2017), and challenge what constitutes truth by legitimizing voices on the margins (Boylorn & Orbe, 2021b). This research hopes to contribute to shifting hegemonic science education norms toward practices that embrace a plurality of cultural science perspectives, value both embodied and cognitive knowledges, and foster greater consciousness of how race operates in science. From an ecological perspective of systemic transformation, systems are constituted by all individuals and relationships, and transformation is understood as paradigm shifts resulting from ongoing introspection and conversation (Squire & Reigeluth, 2000). Through the Anishinaabe teaching "Aanji-Bimaadizing" (Vukelich Kaagegaabaw, 2023, p. 79), we can also understand that nations are changed when individuals transform themselves because of our interconnectedness with all relations. As both individuals and social group members (Sensoy & DiAngelo, 2017), educators and systems are interconnected.

Transformations at micro-levels, one person at a time, matter because educators are agentic actors with/in/of institutions and systems. For example, Chrona (2022) argues that "[e]ducation systems play a significant role in the achievement of these goals [for reconciliation]. While education systems reflect societal norms and values, educators, in turn, help shape those values" (p. 33). As teachers author or read critical autoethnography, they may gain insights that influence their practices. These changes might inform the work of other educators and indirectly contribute to broadening students' conceptualizations of science, schooling and social justice. Additionally, policies and laws are not static, meaning they can be challenged and changed

through our decisions and actions. Individual educators can leverage their sociopolitical consciousness to influence systems through advocacy work or civic engagement and serve as catalysts for transformation within and beyond their personal and professional spheres of influence.

Research Design

Boylorn and Orbe (2021b) understand the variations of autoethnography, in their "labels and characterizations… [to be] descriptions, but not prescriptions, of the method" (p. 6). Thus, critical autoethnographies can be "both critical and evocative, performative and reflexive, political and cultural, analytic and theoretical" (p. 6). Critical autoethnography embraces both/and rather than either/or thinking (Boylorn & Orbe, 2021b). I interpret this to mean that mixing and matching of characterizations can occur provided the study adheres to the goals of critical autoethnography, which in the context of this study, are to interrogate systems of inequality in school science, use storytelling to capture the relationship between theory and action as it relates to science teaching, and connect theoretical insights to enacting new pedagogical practices within and beyond the science classroom. Thus, for data collection, management and analysis, I also used practical techniques suggested by authors of non-critical autoethnography (e.g., Chang, 2008) to complement broader recommendations on criticality (Boylorn & Orbe, 2021a, 2021b) and intersectionality (Johnson & LeMaster, 2020). In what follows, I outline my researcher~participant context; field text collection, management and analysis methods; and how the critical autoethnography was created.

Researcher~Participant and Context

Boylorn and Orbe (2021b) believe critical autoethnography "should be focused on people who live their lives on the margins and who are members of nondominant groups joining, if not

starting, conversations that are grounded in lived experiences" (p. 13). As the researcher~participant in this critical autoethnographic study, my voice, experiences, and interpretations constitute the basic unit of analysis (Cooper & Lilyea, 2022). Here, I use the tilde (~) to represent the reciprocal relationship within participant and researcher in autoethnography (Sellers, 2013). This study centers my perspectives as an in-between cultural member who continues to live with/in various identifications.

Despite my urban upbringing, over the past decade, I have always commuted to teach in rural communities. My school is located in a small city in a rural school division, where many students are bused from surrounding areas. Because I do not reside in the community in which I work, I remain somewhat of a cultural stranger in this context. And yet, time has also made me an inside cultural member of my school community. I have taught at my current school for nine years. Additionally, I identify as a racially marginalized female teacher of Chinese descent continually grappling with what it means to be a settler/Guest on the lands of Indigenous peoples. Of the approximately six hundred grade five to eight students at my middle school, there are some Indigenous, Black, Asian, and Latinx students, but most are predominantly White. In my school context, there have been very few colleagues with whom I have worked who are also members of racially marginalized groups.

While teachers across K-12 may benefit from engaging with culturally disruptive pedagogy and critical autoethnography, I briefly comment on middle years to contextualize my teaching role. I am a science educator with multiple science sections but also responsible for teaching several other subjects to my homeroom students. Though this study focuses on science education, it is inevitable that ideas and practices may bleed beyond the boundaries of a scheduled science class to other courses or recess breaks. Since common grade-wide assessments

are not required for science, there is greater flexibility within individual classrooms to explore new pedagogical practices. Middle years is also a time when students undergo many social-emotional, moral, psychological, intellectual and physical changes (Association for Middle Level Education, 2010). Early adolescents are looking to the adults in their lives for guidance while forming their own values and possibly experiencing heightened awareness of their cultural and ethnic identities (Association for Middle Level Education, 2010). This, combined with what is often declining engagement with science in the middle years (Turner & Peck, 2010), makes middle years a particularly sensitive time for science teachers to role model what it means to value diverse science perspectives, act for social justice and grapple with the ambiguity of the learning process (Association for Middle Level Education, 2010).

Field Text Collection

When accumulating data for this critical autoethnography, I over-included information upfront to generate a substantial collection of data from which more intentional pieces can be later drawn (Cooper & Lilyea, 2022). I also refer to data as *field texts* since many texts are accumulated, and also for distinguishing the methodology from quantitative research where the term data originated (Chang, 2007). The forms of field texts that can be used are numerous and varied (Chang, 2007; Cooper & Lilyea, 2022; Ellis et al., 2011). To document how culturally disruptive pedagogy might inform my understanding of science and science pedagogy, I gathered multiple forms of field texts, which I will elaborate on shortly. Where appropriate, field texts were recorded digitally using Excel spreadsheets and Word documents (Chang, 2008) in order to streamline the management process by reducing the amount of digitization needed later on.

One set of primary field texts included over 250 redacted and anonymized journal reflections from my teaching. In my role as a teacher, these journal reflections included

descriptions of and reflections on activities relating to my daily teaching practice. This included, for example, lesson planning and implementation, reflections on how I thought or felt the lesson went (e.g., successes, challenges, improvements or future modifications), or the planning of science related events. I also reflected on any activities related to teacher professional learning (e.g., presentations or workshops attended). Identifying information was removed from my daily reflections as a practicing teacher in order to convert them into field texts that I could analyze as the researcher. While there was no involvement of other participants (e.g., students, other teachers, etc.) in this study, I understand science teaching and learning to be a sociocultural practice that does not occur in isolation (Leach & Scott, 2003). As a science teacher, I encounter and interact with many people each day and engage in frequent conversations relating to science learning and teaching. These encounters and interactions may spark pedagogical ideas or elicit emotions that I later reflect on in my teacher notes. However, as the researcher~participant, I did not use specific conversations or references to individuals as data sources. Only the ideas, thoughts, and feelings I have about science pedagogy were included as field texts for this study.

Although memories allow field texts that are sometimes hidden away and invisible to emerge, they are also selective and may fade over time (Chang, 2007). Memory may "trigger aversion when it attempts to dig deeper into unpleasant past experiences… [or] select and embellish pleasant moments" (Chang, 2007, p. 210). Thus, in addition to the redacted and anonymized journal reflections, as the researcher~participant, I also collected other artefacts generated from my teaching practice that were useful for informing this study, especially those relating to Indigenous Science perspectives, queering science, and anti-racist science pedagogy. These artefacts were created as part of my regular routine as a teacher, but were then documented, analyzed, and further reflected on as a researcher. The artefacts included documents

like lesson or unit plans, lesson materials like handouts or presentation slides, instructions for assignments or projects, and notes from my teacher planner. These were helpful for documenting activities that took place in my science teaching that perhaps were not reflected upon in my teacher journal, or for demonstrating disruptions to my teaching practice after grappling with tensions and coming to some self-realizations. For example, the instructions or scope of a science project were sometimes modified or reimagined after working through the process of culturally disruptive pedagogy. Another example was documentation of changes in lesson sequence and the addition or removal of certain science learning experiences between school years.

Primary field texts generated in my role as a graduate student and researcher~participant were also gathered. These included fifty reading responses to various texts (e.g., scholarly literature, books, videos), as well as graduate coursework artefacts. The reading responses documented my understanding of concepts, critiques, and ideas I found particularly interesting, connections relevant to this study, applications to science teaching, or wonderings and questions. Artefacts from my graduate coursework included positionality statements or products (e.g., essays, research papers, projects) relevant to this research study's themes and topics. I also gathered field texts in the form of field notes generated from this project. These field notes included thoughts, questions, and connections that emerged during analysis of the field texts. It was helpful, once again, to consider Two-Eyed Seeing, queering science, critical race theory, as well as the four tenets of culturally disruptive pedagogy when writing field notes.

Timeline for Collection of Field Texts. In this study, field texts in the form of teacher journal notes, reading responses and researcher field notes primarily came from documents gathered from the 2022-2023 and 2023-2024 school cycles. However, as this is an autoethnographic study, relevant artefacts created prior to 2022 were also gathered. Concurrent

collection and analysis of field texts and writing of this study took place starting in the 2023 Fall Term until the end of the 2024 Fall Term.

Management and Analysis of Field Texts

Figure 1

Sample Screenshot of Field Text Organization Tags and Codes

	A	B	C	D	E	F	G	H	I	J	K	L
1	Date	Data Category	What is this entry about?	Tag(s)	What are you thinking about?	Process Coding	Emotion Coding	Versus Coding	Tensions	Disruptions	Self-Realizations	Pedagogical Innovations
56	[redacted]	Pedagogy - Design/ Planning	Walking Together book	Indigenous; Directly related to science	After school, I also spent a bit of time preparing for tomorrow's lesson which will be introducing Two-Eyed Seeing ideas by using the book Walking Together by Elder Albert Marshall. I am reading this book in place of Stand Like a Cedar, which I read to my classes last year before going outside to do a nature scavenger hunt. The illustrations are really beautiful, and the book really captures the importance of learning from the land, only taking what we need, taking care of and being taken care of the land, learning from stories, and being able to see through different perspectives. "When we walk together in a good way, we learn to know the world through two eyes." I will have students reflect on what they observe from the illustrations, what they learn about Indigenous knowledges, and what they are wondering about. I'm looking forward to introducing this book to them for the first time. It is the perfect picture book for this and I am so glad that it was published this past spring. The plan is that this will lead into creating seasonal wheels and going outside to make observations.	- trying out new text with students in place of another	- beauty and science - looking forward to trying something new with class, anticipation		- deciding what resources to use	- Western science - Binary between science and art, logic and beauty		- reading picture book about two-eyed seeing to students

Note. This figure shows a sample primary field text entry from the Microsoft Excel Spreadsheet used to organize and code the primary field texts during the management and analysis process.

The management process involved organizing and refining field texts (Chang, 2008). Following Chang's (2008) recommendations, collected field texts were organized by labelling sets so that information about them could be accessed and utilized systematically during analysis. I labelled field texts with the date, identified what the field text was about, and provided a description and/or reflection. Organizing the field texts also involved classifying sets, so I added tags to aid with locating field text sets and the analysis process itself. As shown, for example, in Figure 1, I tagged the field text type (e.g., reading response, brainstorm/ideas, pedagogy

design/planning, pedagogy implementation, expanding community, research/writing, professional development), as well as their relation to my research questions or methodology (e.g., Indigenous Sciences, ethnoracial diversity, gender, methodology, etc.). Other files, such as teaching artefacts, were collected in digital or physical folders. Field text refinement means deciding what field text sets to highlight and what sets might need to be removed because they are redundant or irrelevant. The refinement process also involved noticing deficiencies and making plans to gather more field texts from those areas. Initial tentative coding and sorting of the field texts "to fracture each data set into smaller bits on the basis of topical commonality and to regroup the data bits into topical categories" (Chang, 2008, p. 119) was helpful here.

The ethnographic aspect of critical autoethnographic analysis "involve[s] shifting your attention back and forth between self and others, the personal and the social context" (Chang, 2008, p. 125). As the researcher~participant in this study, I analyzed field texts using Two-Eyed Seeing, queer theory, and critical race theory as lenses to interrogate how ideas foundational to those theories are enacted in my own science pedagogies. With culturally disruptive pedagogy as a guiding framework, I worked to disrupt my existing teaching practices and apply self-realizations to implement pedagogical innovations in my role as a science teacher. As these actions unfolded and new tensions arose, I once again documented and analyzed my science pedagogies as the researcher~participant. I continually shifted between roles as I methodically analyzed my science teaching, explored new pedagogies in the classroom context, reflected on those pedagogical experiences, and connected insights back to the research literature and wider social context.

In following the balanced approach to autoethnographic inquiry as advocated by Chang (2007) and Wall (2016), the researcher should ensure that the analysis and discussion is

sufficiently detailed while avoiding overly lengthy narratives. Also, as discussed earlier in this section, "because critical autoethnography centers critical analysis through storytelling… it also requires intersectional analyses that account for multiple identities and positionalities" (Boylorn & Orbe, 2021b, p. 7). The autoethnographer should pay close attention to the criteria provided by Johnson and LeMaster (2020) for addressing intersectionality rigorously. This is particularly important in this study because several intersecting lenses (Two-Eyed Seeing, queer theory, and critical race theory) are being used simultaneously. As discussed by Ellis et al. (2011), attending to reliability, validity and generalizability are important aspects of data analysis. Reliability speaks to the credibility of the narrator, as well as acknowledging that "we know memory is fallible, that it is impossible to recall or report on events in language that exactly represents how those events were lived and felt" (p. 282). Validity means that the story is believable, coherent, and truthful. In the context of critical autoethnography, generalizability asks not whether the study findings can be applied to large populations, but whether readers can connect stories to their own or others' lives and better understand cultural processes.

Analysis and interpretation of field texts involve identifying important features of these texts, describing how the field text sets are related to one another, making sense of the field texts, and also looking for cultural meanings that extend beyond the collected field texts (Chang, 2008). Borrowing ideas from Wolcott (1994), Chang (2008) suggests the following strategies:

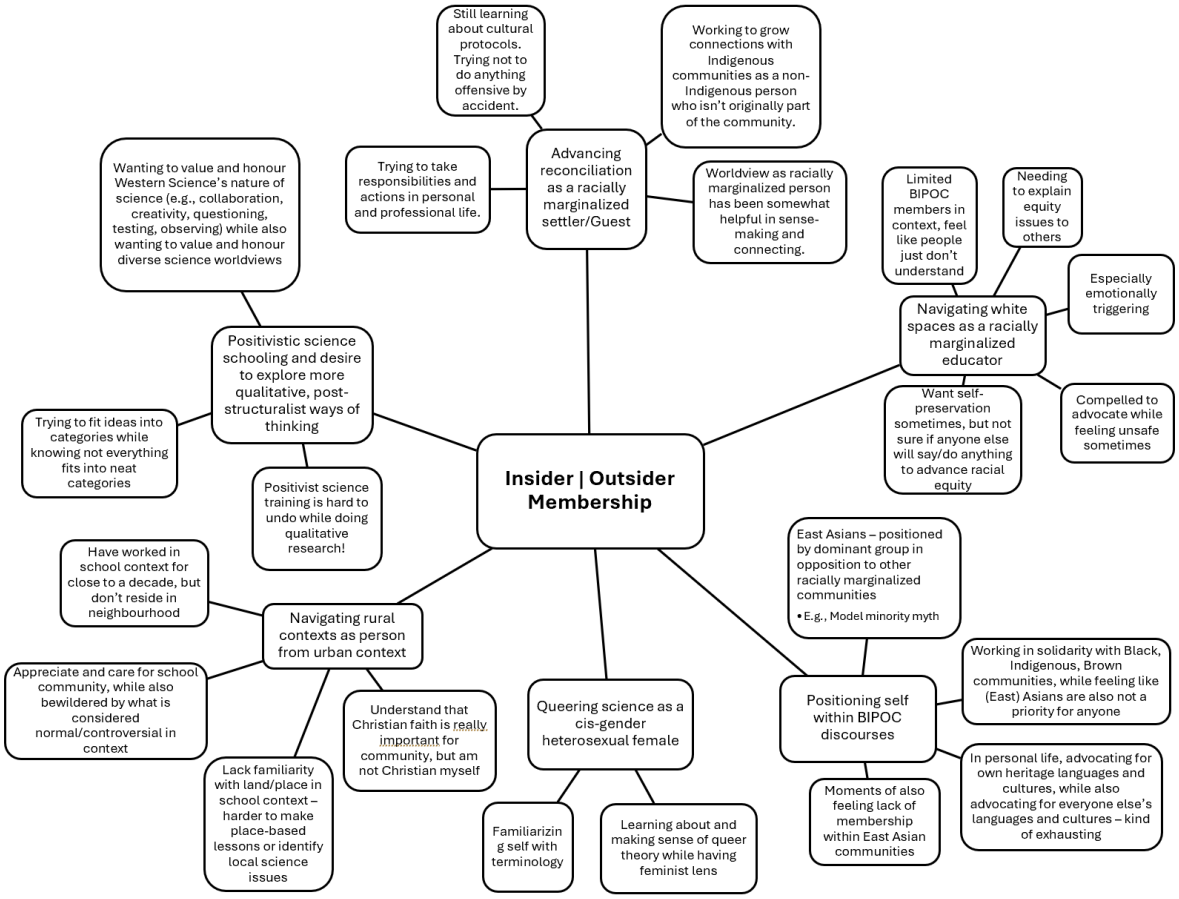
> (1) Search for recurring topics, themes, patterns; (2) look for cultural themes; (3) identify exceptional occurrences; (4) analyze inclusion and omission; (5) connect the present with the past; (6) analyze relationships between self and others; (7) compare yourself with other people's cases; (8) contextualize broadly; (9) compare with social science constructs and ideas; and (10) frame with theories. (p. 131)

In qualitative research, the analysis method can be adjusted as the study unfolds (Saldaña, 2011). As a way of "patterning, classifying, and later reorganizing" (Saldaña, 2011, p. 95), coding involves assigning *codes* (word/short phrase) to capture the content of a field text (Saldaña, 2011). In this study, I used a combination of mixed and matched coding methods as outlined by Saldaña (2011) and Saldaña (2016, as cited in Cooper & Lilyea, 2022) to fracture the field texts (Chang, 2008). The coding process, which I will describe next, was applied to the primary field texts (e.g., redacted and anonymized journal reflections, reading responses, field notes) that were gathered.

Because my research question asks *how* culturally disruptive pedagogy might inform my science teaching practice, process coding, which uses verbs as codes to make sense of how something is happening, was applicable to this study (Saldaña, 2011). Emotion coding, which identifies any emotions experienced and described in the field texts, was also used to support the writing of the "auto" component of the autoethnography (Saldaña, 2016 as cited in Cooper & Lilyea, 2022). Though the term itself seems counter to the disruption of binaries that critical autoethnography (and this study more generally) calls for, versus coding, which "identifies the conflicts, struggles, and power issues observed in social action, reaction, and interaction" (Saldaña, 2011, p. 107), was also useful due to its relevancy to the critical and intersectional aspects of this critical autoethnographic study and for the identification of tensions that arose. In addition to inductive coding, I also deductively coded for the four tenets of culturally disruptive pedagogy (tensions, disruptions, self-realizations, pedagogical innovations) (San Pedro, 2018; Litts et al., 2020b) as this is the guiding framework of the study.

Figure 2

Sample Visual Web of a Tensions Tenet Theme



Note. Codes generated from the primary field texts were grouped (and re-grouped) into categories, which eventually formed the theme for insider | outsider membership. This graphic was created using Microsoft SmartArt tools.

The codes were then organized into categories and larger themes (Saldaña, 2011). To make sense of the codes, visual webs organized around each culturally disruptive pedagogical tenet were created (see Figure 2). However, the Microsoft SmartArt graphic tool used had some constraints. For example, the maximum number of nodes was limited at certain levels and there

was no intuitive method to make horizontal connections between codes or categories. This made it challenging, at times, to adequately represent the complexity of ideas. In such cases, creating webs by hand or using digital whiteboard tools was helpful for sense-making (see Figure 3 and Figure 4). Also helpful throughout the process, was keeping in mind the interconnectedness of the (not necessarily linear) stages of collecting, analyzing and writing (Chang, 2007). It was sometimes necessary to deepen my understanding of a concept by searching the literature in order to see connections between codes more clearly. At other times, it was the writing process itself that allowed me to recognize relationships between categories that I had not previously noticed. Although the themes presented in this thesis may appear obvious now, in the beginning, they were anything but.

Figure 3

Making Sense of Disruptions Using Pen and Paper

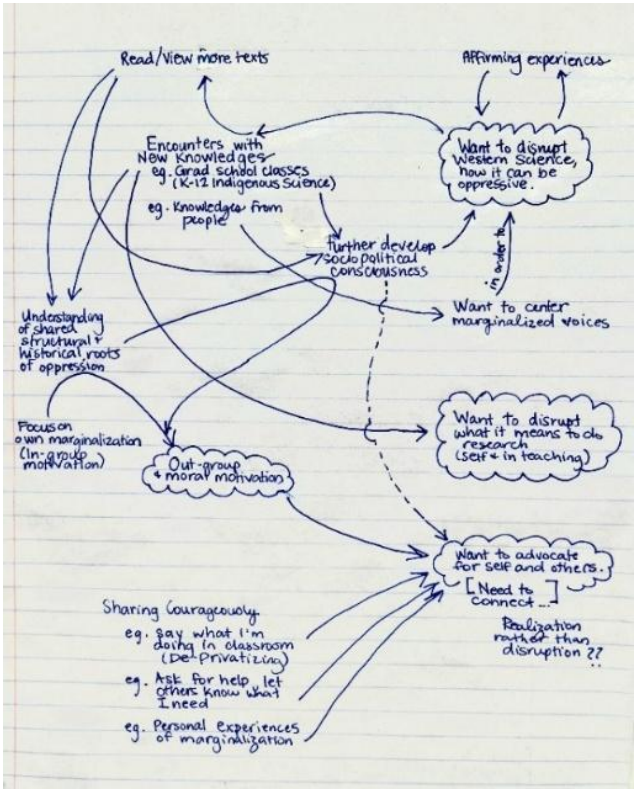
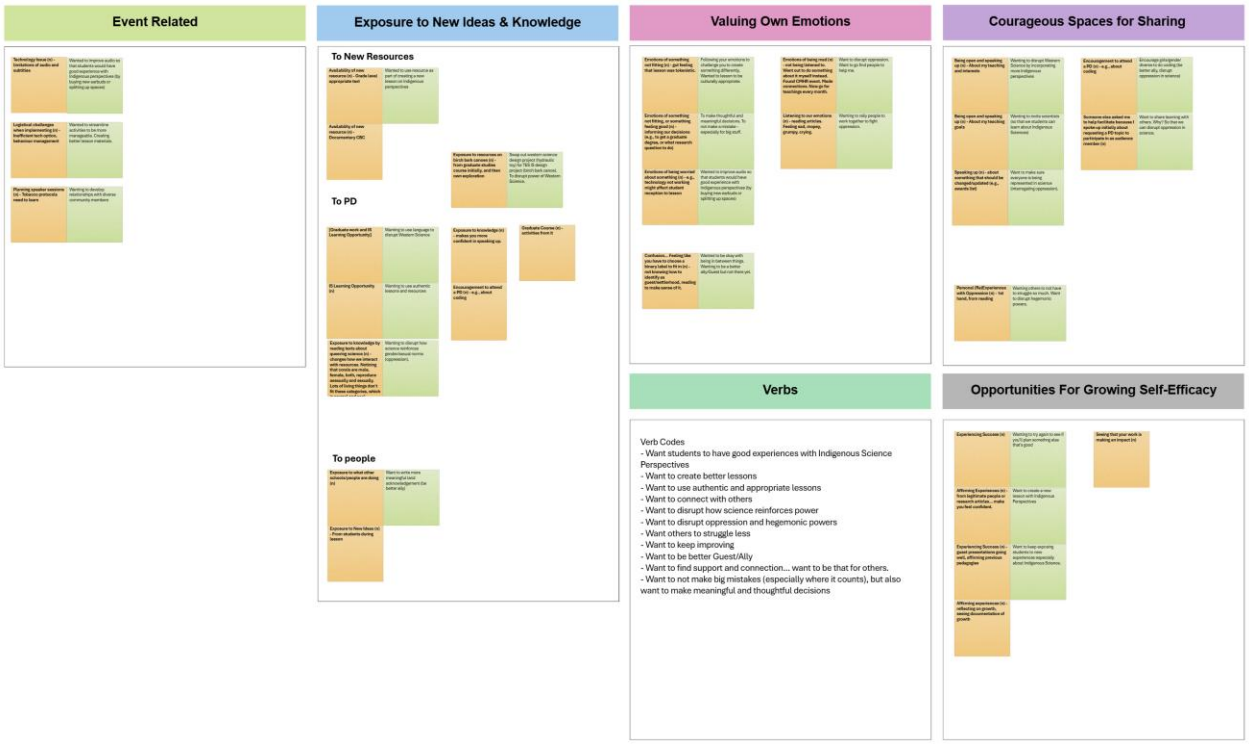


Figure 4

Making Sense of Disruptions Using Microsoft Whiteboard



Note. This digital bulletin board organized codes using digital sticky notes. Yellow sticky notes identified encounters that served as moments of disruption (nouns), while green sticky notes identified what those encounters disrupted (verbs). Codes were grouped into tentative categories during the sense-making process.

Creating the Critical Autoethnography

Following analysis of the primary field texts and identification of themes and sub-themes, secondary field texts were crafted in the form of anonymized composite reflective vignettes. Each reflective vignette was framed around a sub-theme and wove what were initially fragmented pieces of information from the primary field texts into a coherent narrative (Chang, 2008). To create these secondary field texts, I continually revisited the primary field texts and

mined the "memories of my lived experiences" (Wall, 2008, p. 45)—gazing inward while making connections to and critiquing the broader cultures of schools and science education. The process of creating the critical autoethnography involved making sense of personal teaching experiences as I decided what moments to include or elaborate on, as well as engaging in self-transformation by becoming differently through the writing process (Boylorn & Orbe, 2021a; Chang, 2008). Through writing, I reckoned and reconciled with moments of marginalization, critiqued how my science teaching and research approaches had been shaped by hegemonic forces, and found strength in my voice and commitment to advancing science education for a more just world. To capture emotional and sometimes chaotic aspects of my lived experiences (e.g., trying to learn something new or encounters with resistance and oppression), I wrote in a confessional-emotive style (Chang, 2008). My writing style was also analytical-interpretive (Chang, 2008) so that personal teaching experiences could be woven with the social, political and historical contexts of my teaching. Developing a more in-depth understanding of my lived experiences in connection to their cultural contexts allowed me to interrogate those experiences and contexts more deeply through the theoretical lenses of my study.

Methodological Cautions and Ethical Considerations

Autoethnographers have been accused of being self-indulgent navel-gazers and the methodology itself has been criticized for overemphasizing emotional and aesthetic storytelling while lacking in analytical rigour, involving too few cultural members, and relying on biased data (Ellis et al., 2011; Wall, 2016). Simply put, autoethnography is criticized for being too much and not enough. However, critical autoethnography, which connects the researcher~participant's individual perspective to wider patterns of cultural experience embedded in intersectional power structures and seeks to bridge theory and action to enact embodied societal changes, addresses

the critique that autoethnography is too self-focused without tangible action (Boylorn & Orbe, 2021b). Ellis et al. (2011) argue that "these criticisms erroneously position art and science at odds with each other... Autoethnography, as a method, attempts to disrupt the binary of science and art" (p. 283). This study addressed these concerns by applying a balanced approach equally valuing the aesthetic, cultural and analytical (Chang, 2007; Wall, 2016).

These issues stem from the goals and paradigms of differing research traditions (Ellis et al., 2011). As discussed earlier, autoethnography (in its variations) approaches social science—and concepts of reliability, generalizability, and validity—through a different lens than the positivist origins of those terms. The quality of an autoethnographic study is based on the storyteller's credibility (i.e., the writing is sincere, honest and plausible) (Ellis et al., 2011) and how the story connects with readers rather than its generalizability to large populations (Boylorn & Orbe, 2021a; Ellis et al., 2011). Coherence and believability of stories, their ability to connect readers with cultures, and their impact on both authors and readers also matter (Ellis et al., 2011). Using external field texts (e.g., artefacts) in addition to personal memory field texts to inform the research can be helpful for "enhanc[ing] content accuracy and validity of the autoethnographic writing" (Chang, 2007, p. 217). A final consideration is ensuring the study is actually autoethnographic in methodology and not just in name (Chang, 2007).

The primary ethical issues that arise in critical autoethnography relate to relational ethics, self-disclosure, and personal care. Researchers~participants live in relationship with other individuals and organizations, and must be cognizant that

> [w]hat I write as an autoethnographer is my story, and it is not my story, in the same way that waves are particles and particles are waves, and that the earth is flat (to the eye) *and* spherical (to the mind) *and* 'round' (as we language its shape). (Andrew, 2017, p. 29)

Protecting the privacy and safety of those who might be implicated by the study must be kept at the forefront of the critical autoethnographer's mind (Ellis et al., 2011). I do so by focusing reflections on my own feelings and experiences (Cooper & Lilyea, 2022) and rely on my own personal artefacts, notes and journal entries. This research focuses on my personal journey and growth as a science educator. No student information, student pictures/videos/audio or student-generated artefacts were used, and I avoided (over)sharing information about other people (Wall, 2016). However, I recognize it may be challenging for location identifiers to be completely blinded given the nature of this study, since photographs and names of all staff members are identified on our school website.

In addition to protecting others, the researcher also needs to consider their personal privacy and safety. When critical autoethnographers share their own stories, they put themselves in potentially vulnerable situations, so it is important to not over-disclose personal information (Wall, 2016). It is acceptable to remove irrelevant information and stories that are too personal or vulnerable to share (Cooper & Lilyea, 2022). It is necessary to acknowledge that while "the autoethnographic process is an exciting journey of exploration and disclosure… it can also lead into highly emotional, vulnerable, and even unresolved parts of ourselves" (Cooper & Lilyea, 2022, p. 204). An ethic of personal care was important throughout this emotional, but meaningful exploration of my becoming as a science educator through and with critical autoethnography.

Care was also taken to ensure research materials were stored properly throughout and after the study. Unedited research field texts containing confidential information about myself or others implicated in the study were stored digitally on a password-protected computer. During the research process, only I had access to unedited research material; my advisor and advisory committee members had access to the anonymized field texts only. Note, that regarding research

materials, any teaching artefacts that I have used or may use in my classroom teaching practice were not stored confidentially as those were already expected to be shared with students and sometimes colleagues. This included, for example, PowerPoint slide decks, handouts, or lesson plans. Finally, I would like to emphasize, that I had been exploring justice-oriented science teaching in my classroom for some time already prior to this research study. Although the inquiry process no doubt informed my teaching practice, I did not engage with this work solely for the purposes of carrying out research. Exploring different ways of becoming as a science educator, expanding the boundaries of my teaching practice, and engaging in ongoing reflection are things that would be occurring irrespective of this research study. However, I acknowledge that I am simultaneously both a practicing teacher and graduate student, so there is always the possibility that knowing I am also a researcher could influence my notes and reflections.

Summary

As a classroom science teacher, I have continually engaged in learning new ways of conceptualizing science education as I explored different pedagogical strategies. Now, in my role of researcher~participant, I approached teaching science more methodically by grounding my practice in the theories of this research. When planning and enacting lessons, I drew ideas from existing scholarship on Indigenous Sciences, queer science pedagogies and anti-racist pedagogies. I critiqued my classroom practices and resources through Two-Eyed Seeing, queer and critical lenses to identify areas for improvement and renewal. The tenets of culturally disruptive pedagogy were kept at the forefront of this critical autoethnographic study to guide the process of growing with/in my science teaching.

As Boylorn and Orbe (2021b) write, “theorizing one’s own lived experiences is liberatory and emancipatory” (p. 10). Telling this story allowed me to explore my personal experiences as a

racially marginalized female science teacher while making visible the systems of oppression that school science is embedded within. This critical autoethnography is my counterstory, and it acknowledges, validates and legitimizes my lived experiences by centering my voice within discourses of colonialism, gender and racial power. The stories in the next chapter unpack tensions I faced as a marginalized science educator trying to disrupt my own teaching in pursuit of a more just and equitable world. They honour the self-transformation that occurred—is still continuing to occur—as I came to realizations through the process of enacting culturally disruptive pedagogies in the science classroom. This process of becoming through research also allowed me to discern my own responsibilities toward our diverse communities and act beyond my classroom to challenge educational norms.

Chapter 4: Findings and Discussion

This chapter is framed by the four tenets of culturally disruptive pedagogy (tensions, disruptions, self-realizations and pedagogical innovations). Although there may be hints of each tenet woven throughout due to the non-linear nature of this process, I begin by documenting tensions arising from this research, followed by an analysis of disruptions. I then describe critical self-realizations that emerged from learning to become as a justice-oriented science educator, as well as enacted pedagogical innovations. To disrupt Western Science's overemphasis on learning *about* nature, each tenet section opens with an introductory narrative and discussion on my understandings of the tenet itself in connection to something we might learn *from* or *through* nature. How can we make sense of tensions within institutional, sociocultural, political and historical contexts through the webs spiders spin? What wisdom might rocks impart as we work to disrupt our thinking and teaching? What can fungi teach us about becoming and teaching differently as we come to self-realizations and enact new pedagogies?

Following the introductions, each tenet section contains themes with nested sub-themes emerging from the primary field texts during analysis. Each sub-theme has an accompanying reflective vignette (i.e., secondary field text)—a story woven from pieces of primary field texts to illustrate the sub-theme. Where appropriate and in ways that minimize disrupting the flow of storytelling, more direct connections to primary field texts are provided within the reflective vignette in the form of italicized text (e.g., from teacher journal or reading responses) or figures (e.g., teaching artefacts). Following the collection of reflective vignettes for each sub-theme is a discussion of that particular theme. The discussions connect my personal experiences to and interrogate the broader cultures of schooling and science education. Here, text that is directly taken from a reflective vignette is italicized to distinguish it from discussions about that text.

Tensions Tenet: Webs of Entanglement

This section explores tensions I faced while enacting socially just approaches to science teaching. In culturally disruptive pedagogy, tensions arise from unfamiliar situations or ideas and may manifest as resistance, defensiveness, or feelings of inadequacy (San Pedro, 2018). In the tensions stage, I am in the midst of wrestling with the dissonance created as I move within and between different worldviews and structures. Making sense of dominant ideological positions are in focus, and critical self-transformations have not yet taken place. I introduce this section with a nature framed narrative and discussion reflecting on my understandings of the tensions tenet:

Each fall, an enormous spider with the most bulbous abdomen spins its perch in the upper recesses of our classroom window. Undoubtedly, a crowd of curious onlookers will find themselves gazing upward through the transparent glass pane. Strands of thread cling to the brick corner, swaying rhythmically with the outdoor breeze. As we draw the blinds, its immense shadow casts itself upon the pale grey fabric. What is its name? I wonder. Where did it come from? I ask. Why is it here? And where will it go?(Manitoba Education and Early Childhood Learning, 2023). This eight-legged relation has a captive audience, and my half-hearted attempts to redirect their attention are futile. Should we stop to gaze and wonder a while longer or follow the pre-determined course?

Spider silk can withstand greater tensile strength than even synthetic fibres like Kevlar (Ko & Jovicic, 2004; Sensenig et al., 2012). Some spiders, like orb-web-weavers, use silk for spinning webs to trap prey (Lewis, 2006). Radial threads running from the center outward are particularly resilient for absorbing energy when prey collides with the web. The capture spiral silk forming the inner web patterns have primarily evolved for sticking to and wrapping the

spider's food (Sensenig et al., 2012). Thin and difficult to see, spider silks allow orb weavers to entrap insects with the misfortune of getting caught in their webs.

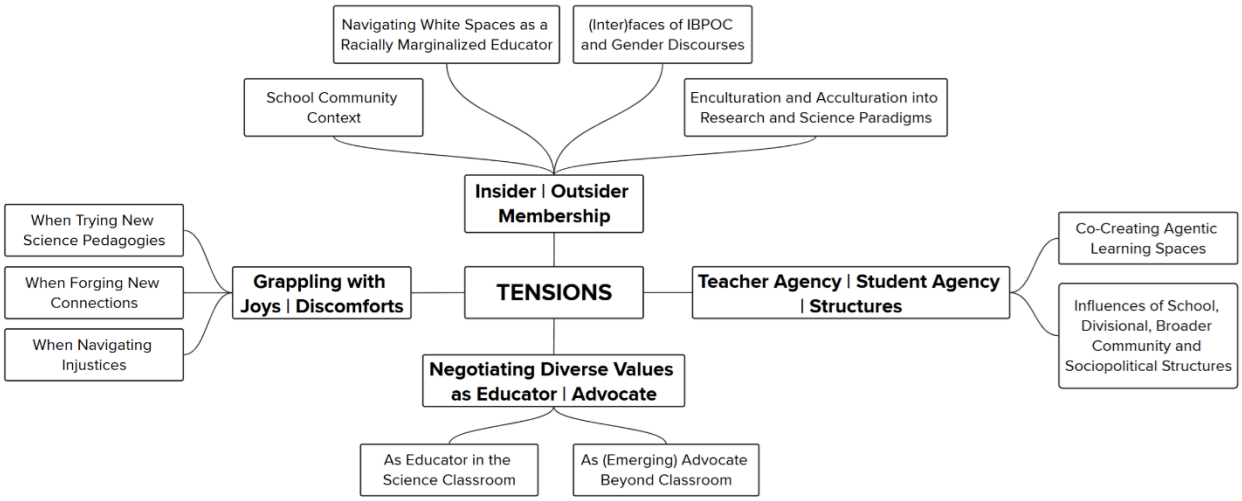
How are educators and researchers entrapped within our own webs of hegemony and cognitive imperialism? Like barely perceptible threads deployed by orb weavers, these forces, too, can be difficult to recognize and see. Do insects know they have been ensnared? Will they struggle to escape, or have they already accepted their fate? Sometimes it feels like the energies invested into disrupting this web are constantly absorbed and dissipated by the tough radial threads of the status quo. At other times, I am unsure of how to escape from the glue-coated capture spirals that have evolved as a mechanism to keep prey in their place. What has become increasingly clear throughout this research process is that, in education, there exists myriad interconnected threads all entangled within one another—each with its own push and pull.

The tensions in this study stem from complex, entangled relationships—with structures and systems, with others (both human and more-than-human), and with ourselves. Although my experiences and memories as the researcher~participant are centered, adapted models of Bronfenbrenner's socio-ecological systems (Christensen, 2016; O'Connor et al., 2012) help situate me within interconnected environmental systems. Individuals are deeply embedded in their social contexts (e.g., family, school, workplaces, broader community), which mutually shape one another (Christensen, 2016; O'Connor et al., 2012). Broader sociocultural, political and historical forces, along with policies and values, also influence individuals (Christensen, 2016). My experiences as a racially marginalized female teacher are mutually shaped by my school, division, and community, which are embedded within White, colonial, and heteropatriarchal systems that impose science teaching norms—whether followed consciously or subconsciously.

Next, I present themes for the tensions tenet. The Sheffer stroke is used to illustrate how ideas appearing dichotomous mutually inform each other, sometimes creating a third space in between. Arising from this research are tensions between insider | outsider membership, teacher agency | learner agency | structures, negotiating diverse values in the roles of educator | advocate, and grappling with joys | discomforts. Nested within each tension are reflective vignettes that illustrate sub-themes of that tension. Following the reflective vignettes is a discussion of ideas emerging from the field texts. Figure 5 shows an overview of the themes and sub-themes.

Figure 5

Themes and Sub-themes Emerging from Tensions Tenet



Note. This graphic was created using digital tools from Mural.co. The tensions tenet is shown in the center in bolded capitalized letters. The tensions themes are shown in boxes with bolded text. Sub-themes are shown in boxes with plain text.

Tensions Theme 1: Insider | Outsider Membership

School Community Context. Early in my career, I changed schools several times to take on teaching positions in several rural communities. Learning new grades and subjects was stressful but helped me become a more agile and flexible teacher. At the time, I yearned for

consistency and predictability. Diving deeper into topics (science or otherwise) or investing in creating new programs was hard because of the uncertainty. What joy it was to finally be able to put down roots and grow new offshoots in my teaching! Time has made me an insider to the institution and community I teach in, and the privilege of tenure allows me to explore justice-oriented science pedagogies some might consider controversial. Yet, learning about what American educators in White, conservative communities faced when teaching about racism was unsettling. As I reflected in my teacher journal, *[i]t was kind of scary… the teachers had their contracts terminated… their colleagues didn't back them up or support them when this was happening*.

Because I grew up and reside in another city outside my school context, I remain somewhat of an outsider. My school is technically a small city but belongs to a rural division. Faith runs deep roots here. As someone who is not religious and continues to commute, there are culturally and historically situated knowledges I am still coming to know and spaces and connections I cannot access. Admittedly, I am somewhat embarrassed by my limited knowledge of local places beyond my school, the nearby woods I bring students to and a few restaurants. This makes developing place-based lessons or identifying socio-scientific issues for science class challenging, though I sometimes refer to my undergraduate project with alfalfa and nitrogen-fixing bacteria to illustrate science's relevancy to land and agriculture. More learning and (physical) exploration are needed as I work to incorporate place-based pedagogies.

Navigating White Spaces as a Racially Marginalized Educator. I sometimes find comfort in my teaching context because in many ways, it parallels my K-12 schooling. I am intimately familiar with spaces filled with White students, White teachers and White ways of knowing and being—so much that in junior high, I was told that with eyes closed, they would

think I was White. In university, someone also remarked that I was the most "normal" Chinese person they knew. With the former, I am ashamed that I felt a little proud at the time. With the latter, I tentatively recognized it as a microaggression but stayed silent to avoid potential ostracization.

After much inward reflection and learning in order to dismantle my internalized racism, I have tried to make good on second chances to disrupt dominant narratives in schools by reclaiming those very same stories. The first time I shared my counterstories of microaggressions with students, I was shaking and sweating… hoping desperately no one would notice. Racism discourse is still considered taboo and given the precarious nature of this topic in my school community context, fears ran untamed through my mind. But practice with vulnerability makes being vulnerable easier, and now, most of the time, I am able to deliberately leverage those stories in my classroom without breaking stride and with much less sweat.

Still, it is emotionally triggering and exhausting to constantly explain the subtleties of equity issues—some of which I am still working to understand. Documented in my teacher reflections are microaggressions like "ching chong" noises, being questioned about where I am *really* from, and backhanded compliments about how good my English is. A war is waged in my mind between speaking up (again) and self-preservation. Silence is not the answer, and on more generous days, I recognize we are each on our own journeys. However, more learning is needed. The emotional labour must be shouldered amongst many rather than the marginalized few.

(Inter)Faces of IBPOC and Gender Discourses. Graduate studies and this research project helped me understand how various oppressions are interconnected and rooted in white supremacy. My reading response field texts documented many books, articles, podcasts and videos that supported my understanding of historical and contemporary allyship and solidarity

between various (possibly intersecting) marginalized groups. Still, I sometimes struggle to make sense of how to appropriately position myself with/in these various communities.

For this study, I deliberated on the appropriateness of a straight cis-gender heterosexual female using queer theory and queer science pedagogy in my theoretical framework. I was unfamiliar with the theory and terminology despite having a feminist lens. Understanding what it meant to queer science was challenging. In the classroom, I make clear that a person's gender identity is not up for debate, but there have also been times when I used incorrect pronouns or could have pursued more severe consequences for homophobic/transphobic remarks. I want to do right by 2SLGBTQIA+ students, but as an outsider, I must continue learning.

From reading literature on the Model Minority Myth, which perpetuates stereotypes of Asians "as the perfect minority group—quiet and industrious, with intact families and high academic aspirations and achievement" (Delgado & Stefancic, 2023, p. 94), following anti-Asian racism news (e.g., during the COVID pandemic), and hearing stereotyped comments about the cleanliness of Asian establishments, I know the dominant group often positions East Asians for different purposes. Sometimes we are dirty and diseased; other times we are the model minority against which other racially marginalized groups are judged. My own marginalization makes me an IBPOC[3] insider, but I do not know the experiences of Brown, Black, or Indigenous bodies. Thus, I am also an outsider—one who has likely benefitted from the oppression of other racially marginalized groups. This is, indeed, a strange and difficult tension to contend with.

As a racially marginalized settler/Guest, I am working on learning the truth and advancing reconciliation with Indigenous communities. Through interactions, I have noticed

[3] To center the "unique history and context of colonization, displacement, and cultural genocide enacted upon Indigenous peoples in Canada, and the ongoing national conversation about reconciliation" (UBC Equity and Inclusion Office, 2023, May, n.p.), I use the term IBPOC (Indigenous, Black, People of Colour) instead of BIPOC.

common threads of experience, especially around racial discrimination, sense of belonging, and needing to walk in different worlds. As I grow my understanding of cultural protocols, I fear unintentionally doing something inappropriate or offensive. I worry about appropriation, tokenization, and misrepresentation of cultural knowledges. Even within invited circles, I am unsure if I will ever truly belong. Showing up and doing the work may be the antidote, but it does little to ease my mind that I might be perceived as little more than an imposter.

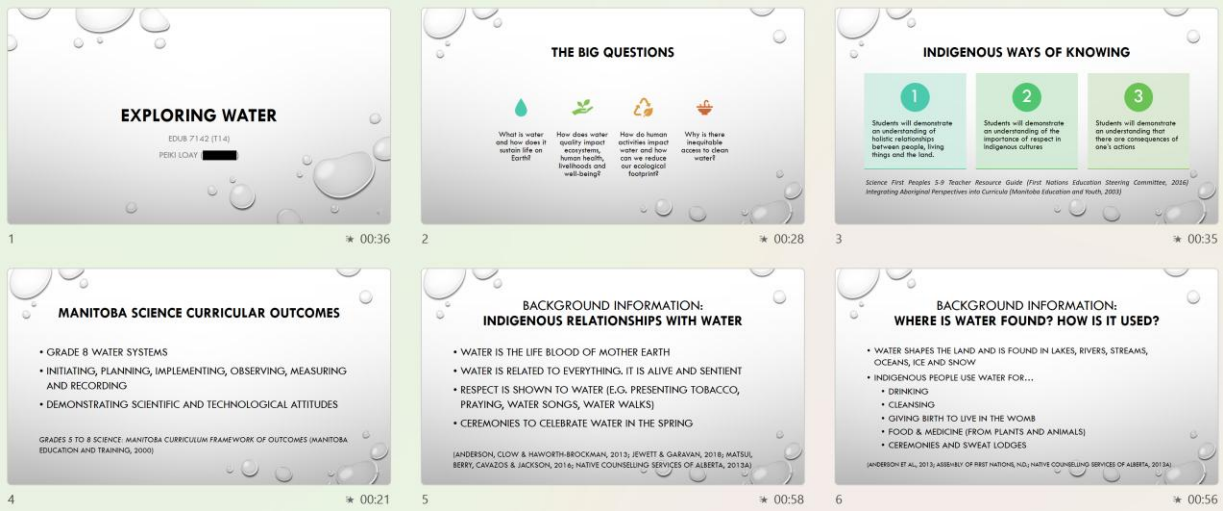
Enculturation and Acculturation into Research and Science Paradigms. Graduate studies opened my eyes to different research and science paradigms. For my first M.Ed. course, I read *The Sociocultural Turn in Science Education and Its Transformative Potential* by Tobin (2015) and Short's (1991) *Forms of Curriculum Inquiry*. I had no idea what they were talking about. Words like "epistemology" and "ontology" kept reappearing, and there were so many inquiry types (hermeneutic, phenomenological, ethnographic…). My prior research experiences involved hypothesis testing, so qualitative research was beyond the scope of my understanding with rare exceptions. For example, I accidentally conducted qualitative research for a conference during my B.Ed. program. To compare my informal outreach and formal practicum science teaching, I coded and analyzed feedback forms. I did not know looking for key phrases and ideas was coding or that the forms were field texts—I just tried finding a way to answer my question.

Through courses like K-12 Indigenous Perspectives on Science, I learned that "science" was actually Western Science, which stems from (post) positivism. This marked the beginning of my re-oriented teaching, though I had previously paused when encountering student questions about rocks being living or non-living. Developing a water unit for the course was my first attempt at what I now consider Two-Eyed Seeing (see Figure 6). This process was challenging because I lacked Indigenous Science knowledges and had to consciously resist adding on

Indigenous Sciences to existing lessons. I encountered similar challenges later when planning a northern lights lesson for my classroom. As I stretched towards Indigenous Sciences, my Western Science worldview—ingrained through years of schooling—beckoned me to return like a recoiling slinky.

Figure 6

Exploring Water Teaching Artefact



Note. This image shows several PowerPoint slides from the Exploring Water unit created for the K-12 Indigenous Perspectives on Science course final project.

Even now, I grapple with perceived constraints of what constitutes "research". I admire but remain unsure of how to apply art forms of evocative research exemplars to my study. Mining pages and files of field texts and memories, the Western Science part of me aches for the tidy and orderly. Instead, I find myself immersed within blurred boundaries and messy entanglements that resist my attempts to organize them. My enculturated Western Science background marks me as an insider to (post) positivistic and quantitative thought, while my teacher education acculturation makes me an insider to alternative interpretive frameworks and qualitative ways of thinking and being. This dual insider membership has, simultaneously, made

me an outsider to both. No longer can I view science and research the way I once did, but neither am I able to carry out my science education research in the absence of those vestigial structures.

Discussion. The Insider | Outsider Membership theme troubles cultural membership binaries by capturing the tension of embodying both insider and outsider status in different social group contexts. These inbetweeners, as Wilson-Raybould (2022) discusses, must move between worldviews, connect those with "histories of injustice, silos, and conflict" (p. 306), and "navigate the space of the new, the evolving, and the changing. Who embrace, at once, recognizing and respecting distinction and diversity, and interdependence, cohesion, and unity" (p. 315). Here, existing in this sometimes-nebulous space is understood as a strength. Four reflective vignettes frame this tension: *School Community Context*; *Navigating White Spaces as a Racially Marginalized Educator*; *(Inter)Faces of IPBOC and Gender Discourses*; and *Enculturation and Acculturation into Research and Science Paradigms*.

The *School Community Context* vignette illustrates how tensions can be embedded within places. Although the story recognizes how sustained time spent in communities can confer a degree of insider status, dissonance is created when there is misalignment in values, cultural understanding and life experiences: *As someone who is not religious and continues to commute, there are culturally and historically situated knowledges I am still coming to know and spaces and connections I cannot access*. When navigating different geographical communities, it is important for educators to understand and value the landscapes in which they interact with students and families (Murphy et al., 2020). There is recognition of the outsider's onus to learn and understand unfamiliar communities, but also the sense that outsiders are responsible for assimilating into dominant cultural norms. This *limited knowledge of local places… makes developing place-based lessons or identifying socio-scientific issues for science class*

challenging since recognizing place-based curricular connections is less intuitive when unfamiliar with the area. An important consideration is that non-Indigenous teachers also need to consider the limitations of place-based pedagogies in the absence of colonial critiques (O'Connor, 2020). This vignette also highlights how teacher hiring practices may disincentivize social justice teaching. That the *privilege of tenure allows me to explore justice-oriented science pedagogies some might consider controversial* implies that teachers on probationary contracts may be hesitant to rock the boat if they perceive a lack of support for social justice education.

Navigating White Spaces as a Racially Marginalized Educator highlights tensions of racially marginalized individuals negotiating identity within predominantly White educational contexts. Whiteness is positioned as the standard identity and the "other" is constructed as deviant (e.g., being referred to as a *"normal" Chinese person*) while reinforcing stereotypes of Asians as perpetual foreigners (e.g., *Where are you* really *from?*). These incidents can contribute to internalized racism (e.g., *with eyes closed, they would think I was White… I am ashamed that I felt a little proud at the time*) (Sensoy & DiAngelo, 2017). Tensions exist between living in our authentic worlds and those we have been assimilated into (that we now attempt to disrupt). My experiences draw parallel to Black teachers learning to teach White students and DuBois' concept of double-consciousness (Bates Oates, 2019). That students and educators may choose to stay silent (e.g., *I tentatively recognized it as a microaggression but stayed silent to avoid potential ostracization*) or experience negative emotions about speaking up (e.g., *given the precarious nature of this topic in my school community context, fears ran untamed through my mind; the first time I shared my counterstories of microaggressions with students, I was shaking and sweating*) speaks to the power of Whiteness in institutions. Hesitancy to engage in systemic oppression discourse serves only to reinforce the status quo.

The *(Inter)Faces of IBPOC and Gender Discourses* vignette problematizes tensions between privilege and marginalization—reflecting on the differential racialization of Asians (Delgado & Stefancic, 2023) where *we are dirty and diseased… and the model minority*. I exist "in a strangely liminal space in the Black-white binary" (Kim, 2022, p. 59) because my *marginalization makes me an IBPOC insider, but I do not know the experiences of Brown, Black, or Indigenous bodies. Thus, I am also an outsider—one who has likely benefitted from the oppression of other racially marginalized groups*. Educators working on goals for reconciliation with Indigenous communities may worry about *unintentionally doing something inappropriate or offensive*. This stems from a cycle whereby education systems privileging White, Western epistemologies produce students unfamiliar with a plurality of cultural knowledges who then become teachers uncomfortable with incorporating diverse ways of knowing into their (science) teaching. Jewett and Garavan (2018) advise that "the rest of the world cannot be Indian of course. We cannot adopt another people's rituals or sensibilities in any genuine manner. But we can listen and pay attention and discern the echoes of our own place and [that of Indigenous] peoples" (pp. 56-57). We can understand cultural interfaces as the "contested knowledge space… [where] things are not clearly black or white, Indigenous or Western" (Nakata, 2007, p. 9) by noticing *common threads of experience, especially around racial discrimination, sense of belonging, and needing to walk in different worlds*.

This vignette also highlights the challenge of changing our actions despite recognizing and desiring to behave more equitably. Among tensions experienced by authors in Doyle et al. (2022) while advocating for queer communities as inbetweeners was "the tension she [the straight cisgender author] felt about being an outsider to that community and yet wanting to show support" (p. 169). Because of our socialization into heterogendered linguistic patterns, it

takes conscious effort to change ingrained habits: *I make clear that a person's gender identity is not up for debate, but there have also been times when I used incorrect pronouns or could have pursued more severe consequences for homophobic/transphobic remarks. I want to do right by 2SLGBTQIA+ students, but as an outsider, I must continue learning*.

Finally, the *Enculturation and Acculturation into Research and Science Paradigms* vignette unpacks tensions surrounding research and science paradigms: *My prior research experiences involved hypothesis testing, so qualitative research was beyond the scope of my understanding*. When learners are only exposed to dominant ways thinking about science and research (i.e., the positivist, Western epistemologies privileged by White, colonial, patriarchal systems), unlearning our training creates tensions: *No longer can I view science and research the way I once did, but neither am I able to carry out my science education research in the absence of those vestigial structures*. But as Corbin Dwyer and Buckle (2009) write,

> as qualitative researchers we have an appreciation for the fluidity and multilayered complexity of human experience. Holding membership in a group does not denote complete sameness within that group. Likewise, not being a member of a group does not denote complete difference. It seems paradoxical, then, that we would endorse binary alternatives that unduly narrow the range of understanding and experience. (p. 60)

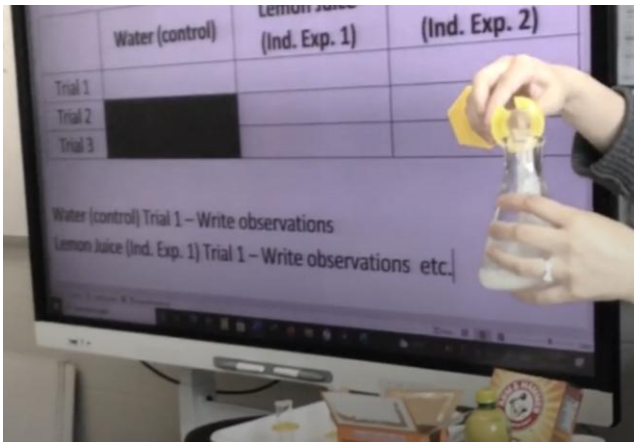
I find solace in the authors' affirmation that being an inbetweener is a normal and less restrictive way to exist in this world, and that it is not necessarily "insider or outsider status but an ability to be open, authentic, honest, deeply interested" (Corbin Dwyer & Buckle, 2009, p. 59) in the experiences of others—whether in research, the classroom or community—that truly matters.

Tensions Theme 2: Teacher Agency | Learner Agency | Structures

Co-Creating Agentic Learning Spaces. I usually approach the classic vinegar and baking soda demonstration[4] as a guided group experiment to support learning how to design fair experiments from a Western Science lens. We use water as the control, two acids for experimental variables, and run tests multiple times. There are usually wonderings about how results would change if, for example, we used different ratios of the acid and base, and I try to honour their wonderings by trying it out during class (see Figure 7).

Figure 7

Screenshot from Video of How Acids React with Baking Soda Experiment



Note. The display shows students how to organize observations in their science journals. At this point in the image, we have finished collecting data and are exploring students' wonderings.

While reading about queering science, I wondered how existing experiments could be a little more… wiggly, but I was not prepared for just how wiggly things got. I thought I could get them to develop and test their own big questions relating to acids and bases in groups. The

[4] Combining baking soda and vinegar creates a chemical reaction that releases carbon dioxide gas. Adapted from "Chemical Reaction: Baking Soda and Vinegar" by Encyclopaedia Britannica, 2024 (https://kids.britannica.com/students/assembly/view/233555#:~:text=In%20this%20demonstration%2C%20baking%20soda,flask%20and%20inflates%20the%20balloon)

experimental design could incorporate various materials and supplies from a provided list. One group followed my instructions fairly conservatively, and from my perspective as the teacher, everything unfolded as envisioned. Another group found my materials list insufficient and requested all sorts of other things that seemed reasonable, so I headed to the store after work.

Once plans were made and testing could begin, things began unravelling (at least from my perspective). Managing the experience was harder because there were more materials available. Apparatus prototypes were being created on the spot to test emerging hypotheses—an unintended design process side quest. Wiggly world… wiggly world… I muttered. As I reflected in my teacher journal, *there were materials everywhere... so nuts. It took me forever after school to finish tidying up our room… I'm glad that I tried to follow their lead a bit… but I'm also glad that we are moving on tomorrow*. With another group, we returned to whole class guided experimenting, which was much calmer and required less class time overall. I am still a little conflicted about how much wiggly-ness I can handle. Whether or not this teaching experiment will see a few more trials is yet to be determined.

Influence of School, Divisional, Broader Community, and Sociopolitical Structures. Mining and analyzing field texts made visible the school, division, broader community and sociopolitical structures that inform each other while constraining my practice as I attempt to assert my agency to teach in equity-minded ways. Procedures and norms decided by and enacted by personnel (e.g., administration, teachers) in the immediate school context I refer to as school structures and those at the district level (e.g., school boards, senior administration) as divisional structures. Broader community refers to values and norms of families (and by extension, students) and community members at large, while sociopolitical structures include policies and decisions made by education ministries, the political climate, and continued impacts of

colonization and oppression. I reflect on these structures in the context of collaborating with Indigenous Knowledge Keepers and Elders.

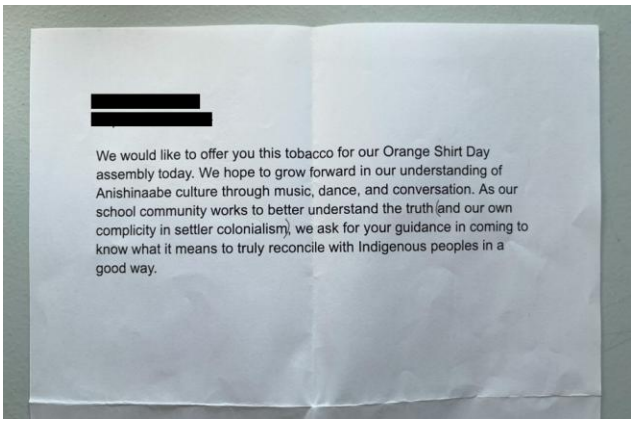
The importance of collaborating with Knowledge Keepers and Elders is frequently espoused in the literature and advocated for by department of education policies. I support these recommendations while also recognizing their procedural challenges. Good intentions matter, but so do structural supports. Legacies of colonization and Residential Schools may leave community members hesitant to engage with schools. Funding is needed to compensate guests for sharing knowledges and to alleviate constraints (e.g., hosting frequency, release time for the organizing teacher). I try to be a good host by having refreshments and honoraria ready. Providing honoraria is an act of reciprocity, one of the Four Rs of developing "rightful relations… [that] support and strengthen our understanding of how to engage with community in… a Good Way" (Manitoba Education and Early Childhood Learning, 2023, p. 3). I also try to care for guests by organizing student helpers. As noted in a teacher journal entry, I was *so proud of my helpers… for greeting, setting up and carrying out different protocols*.

I am continuing to grow in my understanding of the Four Rs, which also include relevance, responsibility and respect (Kirkness & Barnhardt, 1991; Manitoba Education and Early Childhood Learning, 2023). After being a nervous wreck and awkwardly forgetting what to say the first time I offered tobacco, I started writing out notes in advance to bring with me for more formal events (see Figure 8). Sometimes I feel embarrassed when I forget to make an offering or bring the honorarium despite having prepared them in advance. Many cultural protocols are new to me, so I need to research or ask for help. Cultural understandings of time differ; flexible scheduling, class coverage, and time for organizing are needed. In my experience, schools have rigid schedules, guest teacher shortages, and already inadequate preparation time. I

am thankful for support with hosting guests and attending professional learning, but it is also tiring to make guest teacher plans and follow up on incidents occurring in my absence.

Figure 8

Tobacco Offering Notes



Note. This image shows my assembly tobacco offering notes with sensitive information redacted.

Additionally, anti-Indigenous racism, misunderstandings about cultural protocols (e.g. offering tobacco, smudging), and divisive political climates create challenges for teachers like me to encourage student participation in learning opportunities. Fear of repercussions also makes rallying broader support within schools and divisions difficult. While I have met with some success in my classroom, this has not been in the complete absence of needing to reprimand and manage offensive remarks and behaviours from students. Finally, while this reflection focused on an aspect of incorporating Indigenous perspectives, it has been my experience that similar tensions are involved when addressing racism and gender diversity.

Discussion. Teacher Agency | Student Agency | Structures is another tensions theme. This theme is about relational power dynamics between various stakeholders involved in education. Relationships exist between teacher and student agency, as well as between teachers and other educators, families, school administration and education departments (Scanlon and

Connolly, 2021). Scanlon and Connolly (2021) argue that the degree to which agency can be achieved is influenced by these relationships and their situated contextual and sociopolitical factors. Within this web of connections, power is "something fluid which places people in powerful positions, rather than something one holds" (Scanlon & Connolly, 2021, p. 5). This theme is framed by two reflective vignettes frame: *Co-Creating Agentic Learning Spaces* and *Influence of School, Divisional, Broader Community and Sociopolitical Structures*.

The *Co-Creating Agentic Learning Spaces* vignette interrogates power dynamics between teachers and students[5]. Both are living, thinking and feeling beings with desires and motivations, but school science norms typically privilege the authority of teachers (i.e., adults) over students (i.e., children) (Gilbert & Grey, 2019; Leafgren & Sander, 2019). Queering science attempts to disrupt this adult-child binary through horizontal teacher-student interactions. The vignette documents how I followed students' leads by testing their *wonderings about how results would change if, for example, we used different ratios of the acid and base*. Acknowledging students when they communicate learning preferences respects their agency as science learners (Tas, 2016). However, the findings also illustrate how student desires may conflict with school or teacher expectations for classroom management: *Another group found my materials list insufficient and requested all sorts of other things… Managing the experience was harder because there were more materials available… I am still a little conflicted about how much wiggly-ness I can handle*. Valuing students' science ideas supports engagement (Dewitt & Osborne, 2008; Olitsky, 2007) but also exists in tension with teaching preferences for orderly, structured environments.

[5] While student learners are not the focus of this research, and I can only provide reflections on my personal perceptions and experiences as the researcher~participant, it remains necessary to acknowledge that a significant aspect of teaching involves interacting with students.

The vignette *Influence of School, Divisional, Broader Community and Sociopolitical Structures* situates tensions of Indigenous education within these systems. Sociopolitical and divisional structures such as policies and funding can support and constrain teachers' work: *The importance of collaborating with Knowledge Keepers and Elders is… advocated for by department of education policies… Funding is needed to compensate guests for sharing knowledges and to alleviate constraints (e.g., hosting frequency, release time for the organizing teacher)*. Documents like the Mamàhtawisiwin policy framework (Manitoba Education and Early Childhood Learning, 2022) are key for institutional accountability. Governmental and divisional allocation of funds is important for advancing the policy in schools (Manitoba Education and Early Childhood Learning, 2022). Additionally, because *[l]egacies of colonization and Residential Schools may leave community members hesitant to engage with schools*, it is paramount that educators learn to engage respectfully community members (Manitoba Education and Early Childhood Learning, 2022; Manitoba Education and Early Childhood Learning, 2023; Manitoba Education and Training, 2017).

There are also school structures that create constraints when implementing Indigenous education. Mirroring the values of most educators, schools are predominantly designed by and for dominant cultural members (i.e., urban, White, middle-class) (Indian Tribes of Manitoba, 1971, as cited in Manitoba Education and Early Childhood Learning, 2023). This means many educators and schools are lack experience with Indigenous cultures. For example, offering tobacco can be anxiety inducing when you are unfamiliar with cultural protocols: *After being a nervous wreck and awkwardly forgetting what to say the first time I offered tobacco, I started writing out notes in advance to bring with me for more formal events... Sometimes I feel embarrassed when I forget to make an offering or bring the honorarium despite having prepared*

them in advance. Many cultural protocols are new to me, so I need to research or ask for help. The vignette also describes other school constraints relating to scheduling and timetabling, sufficient guest teachers for class coverage, and inadequate preparation time for organizing.

Finally, community worldviews may also impede relationship building with Indigenous communities. The *Influence of School, Divisional, Broader Community and Sociopolitical Structures* vignette reflects on other challenges: *[A]nti-Indigenous racism, misunderstandings about cultural protocols (e.g. offering tobacco, smudging), and divisive political climates… Fear of repercussions… While I have met with some success in my classroom, this has not been in the complete absence of needing to reprimand and manage offensive remarks and behaviours from students*. These findings draw attention to the normalization of dominant group knowledges, protocols and practices in schools, which remain unquestioned and are treated as acultural. Indigenous ways of knowing and being, however, are subjected to criticism, met with suspicion and misunderstood. Educational institutions need to interrogate and disrupt structures privileging White, Western cultural norms by working towards authentic engagement with Indigenous Elders and Knowledge Keepers, valuing diverse worldviews, and redistributing power in order to work with rather than for Indigenous communities (Kirkness & Barnhardt, 1991; Manitoba Education and Early Childhood Learning, 2023).

Tensions Theme 3: Negotiating Diverse Values as Educator | Advocate

Negotiating Diverse Values as Educator in the Science Classroom. Conversations on racial and cultural oppression were staples growing up but always remained unspoken in public. Even as a child, there was awareness that not everyone in society is treated the same, levels of social and financial capital vary, and treading lightly around the dominant group was necessary for survival. I reflected in my position statement that *my parents taught me to be as undisruptive*

as possible (at least publicly) in a world where some people have more power and privilege than others. I look back now and understand why I was told those things, but at the time, I mostly just felt deeply that this was incredibly unfair. Even as an adult, in the presence of dominant group members, I have a habit of weighing my words carefully and automatically self-censoring thoughts and feelings that might be perceived as too controversial or taboo to speak about.

Over time, I have become more comfortable expressing my ideas. In the classroom, this looks like sharing personal counterstories with gender or racial discrimination, introducing Two-Eyed Seeing or facilitating discussions on how racism and sexism impact health. Classroom communities contain diverse worldviews, especially about reconciliation, equity or other "controversial" topics, like vaccinations. There are tensions in navigating how much to share. Enough to validate marginalized voices; keep dissenting voices from disengaging; provide knowledge while leaving space for valuing personal decisions; and maintain forward momentum without taking too many steps back. Perhaps my practice with weighing words is helpful here. I do experience emotions when encountering hurtful words or actions I disagree with, but in the classroom, I am focused on finding ways to meet my students where they are while providing opportunities for them to each grapple with what it means to live in a pluralistic society.

Negotiating Diverse Values as (Emerging) Advocate Beyond Classroom. Despite holding space for negotiation and co-creation of norms and knowledges within the classroom, there remains a teacher-student power dynamic. Enacting equity-minded practices may carry risk, but there exists some degree of safety and comfort within science classroom boundaries. A teaching shared with me once, was that cleanliness means living with integrity, without secrecy, and openness about our choices and actions. Within a Euro-Western hegemonic school context, it has at times, been difficult to teach cleanly. I was uncomfortable sharing we were having class

discussions about privilege and systemic discrimination or learning about Indigenous Sciences. I frequently shared my own positionality with students through stories and objects (e.g., I reflected in my teacher journal that I included chopsticks in my mystery bag as an invitation to tell stories about culture and lived experiences as a second generation Canadian) but rarely did so with colleagues. When asked about my research, I give vague descriptions and avoid referring directly to "controversial" concepts. Apparently, anti-racism, queering, and white supremacy are trigger words. Is this being strategic by knowing your audience or an act of conformity?

I want to become a better advocate for a socially just science education, for marginalized students and families, and also for myself as a colleague and human being. Staying within the bounds of my classroom walls may be safe and undisruptive, but the role of advocacy in teaching needs expanding. When I first became involved in planning a series of professional development sessions about diverse science perspectives, I found it so enjoyable to connect with others. Initially, it felt awkward because I was figuring out how to be a facilitator rather than a participant. Early on, much self-censoring took place and I tip-toed around the issues. However, I could also sense that over time, the process became more natural. In subsequent sessions, I was able to find my courage and voice to speak more directly about various topics.

Teacher and facilitator roles have a pre-established role dichotomy; I enter expecting to encounter and manage diverse worldviews. Being a marginalized person educating (mostly) dominant group members on equity issues did not bother me since the purpose of my role was to help others grapple with complex ideas. Having become comfortable discussing equity concepts within my classroom, at professional development sessions, and in my graduate work, I was taken aback by how emotionally triggering it was to say and hear the same things in an immediate school context. I was suddenly hyper-aware of my position as (usually) the only

visibly marginalized person. In horizontal role contexts, I want to advocate for collective learning and responsibility-taking for (re)centering marginalized voices. However, I should not be the only one recognizing and addressing inequities. In this context, as equals, it is not the job of marginalized group members to educate dominant group members. The frustration, weariness and loneliness stem from knowing that if you do not speak up, few others will.

Discussion. The Negotiating Diverse Values as Educator | Advocate theme unpacks tensions arising from interacting with diverse peoples at differing stages of social justice understandings and our shifting roles. This theme interrogates how educational institutions continue privileging silence when it comes to discourse on systemic oppression while placing the responsibility of equity work on the shoulders of marginalized communities. The reflective vignettes framing this theme are: *Negotiating Diverse Values as Educator in the Science Classroom* and *Negotiating Diverse Values as (Emerging) Advocate Beyond Classroom*.

The *Negotiating Diverse Values as Educator in the Science Classroom* vignette illustrates how minoritized educators shoulder the responsibility of understanding and navigating diverse perspectives, while dominant group members have the privilege of focusing on personal worldviews. In my teaching, I needed to *validate marginalized voices*; *keep dissenting voices from disengaging; provide knowledge while leaving space for valuing personal decisions; and maintain forward momentum without taking too many steps back.* Dominant group members do not need to understand other worldviews to survive because institutions legitimize their norms and values (Sensoy & DiAngelo, 2017). However, students cannot be challenged to grow their sociopolitical consciousness by educators who have not developed their own (Goodman, 2011). This privilege of ignorance is not extended to minoritized families who must address systemic oppression: *Even as a child, there was awareness that not everyone in society is treated the*

same, levels of social and financial capital vary, and treading lightly around the dominant group was necessary for survival. Additionally, self-policing behaviours like *automatically self-censoring thoughts and feelings that might be perceived as too controversial or taboo to speak about* is consistent with internalized oppression (Sensoy & DiAngelo, 2017).

The *Negotiating Diverse Values as (Emerging) Advocate Beyond Classroom* vignette notes the *degree of safety and comfort within science classroom boundaries* when teaching for social justice because of teachers' authority and autonomy within classrooms. Though I trouble teacher-student binaries through a queer science lens, this power-dynamic could also be re-framed for advancing justice-oriented teaching. However, silence is privileged over addressing systemic oppression in schools as evidenced in the perceived lack of safety: *I was uncomfortable sharing we were having class discussions about privilege and systemic discrimination or learning about Indigenous Sciences… When asked about my research, I give vague descriptions and avoid referring directly to "controversial" concepts. Apparently, anti-racism, queering, and white supremacy are trigger words.* This calls into question *whose* safety and comfort are prioritized when institutions avoid certain conversations.

This vignette also speaks to the tension between our existing and evolving roles as we work to break free from societal expectations of silence and accommodation. Stemming from extended mental and emotional loads, in horizontal role contexts, I often felt that *I should not be the only one recognizing and addressing inequities… it is not the job of marginalized group members to educate dominant group members*. However, I also wanted to *become a better advocate for a socially just science education, for marginalized students and families, and also for myself as a colleague and human being*, eventually becoming involved in facilitating *professional development sessions about diverse science perspectives*. Initially, *it felt awkward*

because I was figuring out how to be a facilitator rather than a participant. Early on, much self-censoring took place and I tip-toed around the issues. However, I could also sense that over time, the process became more natural… I was able to find my courage and voice to speak more directly about various topics. This reflection alludes to the self-transformation that can start to occur as we redefine our roles and reclaim our power.

I use Goodman's (2011) definition of educator (someone who guides others' learning) and Cochran-Smith's (2010) definition of advocate as more akin to activist (someone who exposes inequities, collaborates to promote justice, and interrogates school norms and values) to clarify my shifting roles and associated tensions. In my role as educator (e.g., in my classroom, when facilitating teacher learning), I work within what Hardiman and Jackson's (1997) social identity development theory for social justice refer to as the stages of redefinition (making sense of own social justice identification and making connections between different oppressions) and internalization (applying new identity across contexts, seeking affirmation from like-minded individuals) (as cited in Goodman, 2011). This is consistent with how educators in these stages "find it easier to be an educator or coalition builder" (Goodman, 2011, p. 49). However, in the role of advocate in horizontal contexts, I am sometimes working with the redefinition stage, but mostly in the active resistance stage (taking actions in overt ways). Within these stages, minoritized educators are more interested in being around other marginalized group members and find it draining to interact with dominant group members not at the same level of sociopolitical consciousness (Goodman, 2011).

Tensions Theme 4: Grappling with Joys | Discomforts

Emotions When Trying New Science Pedagogies. I was excited to develop another design challenge[6] incorporating Indigenous Sciences but struggled to find authentic, locally situated resources. No tangible lesson would result from the invested time, which was frustrating and disappointing. Eventually, I recalled a research article on dentalium harvesters used by the Ehattesaht and Quatsino peoples from the West Coast (Snively, 2016a). Though not local to Manitoba, the resource was authentic and aligned with our unit. I worried about my adaptations (e.g., creating physical prototypes instead of only drawings) because I wanted to ensure the spirit of the original lesson was honoured properly. This was reflected on in my teaching journal:

> *I wasn't able to find a sufficient number of authentic resources… I decided to go back and do the dentalium shell design... I feel more comfortable with this because it was a well researched and authentic activity... I do wish it could be a more direct connection to the place of our school context… the author had students draw their designs using paper/pencil, whereas I will be getting students to build a prototype with recyclable or natural materials and use it to "harvest" shells… at the bottom of a bucket or tank.*

Despite having an idea, it was draining to think about logistics, parameters and what materials to gather. It took so much energy just to decide on an oversized container for simulating "the ocean". Introducing the lesson early in the year also added anxiety because Two-Eyed Seeing concepts and understanding science as sociocultural would be new. I was also nervous throughout because sometimes I encountered unanticipated questions or situations.

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[6] Design challenges focus on the engineering design process, which involves identifying problems, developing a plan (e.g., materials, sketches), creating and testing a prototype, and reflecting on possible improvements. Adapted from "Grades 5 to 8 Science: Manitoba Curriculum Framework of Outcomes," by Manitoba Education and Training, 2000, pp. 3.58-3.62 (https://www.edu.gov.mb.ca/k12/cur/science/outcomes/5-8/full_doc.pdf)

Although how others respond is beyond my control, my students' receptiveness still matters to me. Perceived resistance is hard, especially when trying something new for the first time, because it makes me feel I could have planned or executed the activity better. On the other hand, when things go well and there is enthusiasm all around, I feel reassured, encouraged, and proud that I took a risk to try something new. Holding onto those positive feelings is important to avoid defaulting to what is comfortable. In moments when a lesson feels really exciting and fun, or calm and easy, I must remember that those feelings exist not because they were inherently Western Science activities, but because I had taught them many times. This tells me that with patience and time, what is new and strange now, can also become old and familiar, and that there will come a day in the future, when they too might be implemented with similar ease.

Emotions When Forging New Connections. I love inviting guests to support students' science learning, but growing new relationships does not come naturally to me. Even on a good day, I am always a bit awkward. As an introvert, it takes time for me to be comfortable with others, so I really appreciate the support I have received when connecting beyond my personal network. I also put a lot of pressure on myself to ensure guests feel valued, appreciated, and taken care of. I try to foster collaborations that are actually collaborative. As the host, I want to make sure I do my homework properly because depending on the guest, sometimes there are cultural protocols to learn and navigate—adding another layer to the process. I also want to represent our school and community well, so I prepare my students to be good hosts too.

I can say now, after the fact, that everything went quite well in the end. However, the process—at least in the beginning parts of getting to know people—was very anxiety-inducing for me: *Am feeling a bit anxious and nervous about everything right now. Overall, things are going well... looking forward to confirming a format and some dates!* Whenever there was a

hiccup, the first thing popping into my mind was usually related to thoughts about what I might have done wrong: Did I communicate too much or not enough? Was I too specific or too vague about the session aims? Maybe I said the wrong thing at the wrong time in the wrong place. Maybe the technology could have been tested a few times more.

Emotions When Navigating Injustices. There are few documentaries I have seen, that capture the emotional burdens of scientists as well as *Chasing Coral* (Orlowski, 2017). In my first viewing, the contrast between living and dead corals brought me to tears—as it did for scientists sitting in the conference auditorium. I have since shown this film to students many times, and still actively hold back tears when the corals begin to fluoresce. We are told this is happening because the corals are protecting themselves from rising temperatures, that it is a final cry for help before death in the hopes someone will notice. As humans dance and party on a boat, project team members says that it is typical of humanity to be completely oblivious to what is happening around them. The same could be said for injustices taking place within our schools and institutions. At a conference, I learned about racial stress and how it affects the health of racially marginalized peoples. Racism is literally killing us, and it probably would not be too much of a stretch to say the same for other forms of oppression. Will people ever notice? Will they ever care enough to take responsibility and action?

While it may be hard for humanity to notice, the act of noticing itself, too, is hard. One of the most difficult parts of this process has been the heightened awareness of injustice. The bulletin boards, the events, the resources, the things people do, and the things people say all remind me of what and who is valued in these spaces, and what and who is made invisible. It was easier to notice and forget when I was only “teacher,” but as researcher~participant, the constant revisiting and reliving of these moments as I continually mine my memory and writings

tightens the persistent knot in the pit of my stomach. The systemic and covert injustices might seem small, but as we can learn from corals, even a two degree increase in ocean temperatures can have devastating effects. A low-grade fever haunts and clouds my mind, making me doubt myself and wonder if I am seeing things that are not really there. Continuing to engage in the work of resisting injustice acts as a cool compress to bring me to my senses… a reminder that it is the ingrained hegemony of white supremacy trying to gaslight me.

Then, like trash thrown into the reefs, there are obvious and overt acts of injustice that I must address in the classroom. Teasing through intersecting oppressions is most challenging of all. I often wonder whether we will ever be able to just name oppressions for what they are. What world is this, where naming and calling out injustice might, instead, turn the tables and fasten a target onto my own back? No one should need to hide who they are or live in fear because society has decided to dehumanize certain groups of human beings. Some of what I have encountered makes me angry and disgusted, and in moments of solitude and safety, it also makes me feel a deep sadness. But if a small rise in temperature can cause so much destruction and death, maybe small decreases can contribute to not only restoring what was but also allow for a new kind of thriving—one where all of our sorrows and struggles are noticed and all of humanity takes on the responsibility of caring for one another.

Discussion. The final tensions theme, Grappling with Joys | Discomfort*,* is about the emotional labour of justice-oriented science teaching, especially for educators from minoritized groups interacting with dominant members at varying stages of sociopolitical consciousness (Goodman, 2011; Rivera Maulucci, 2013). Since Western Science emphasizes objectivity while devaluing emotions (Brickhouse, 2001), it is unsurprising that research on science teachers' emotions and identifications as social justice educators is limited (Rivera Maulucci, 2012).

However, emotions help us recognize tensions between the current realities of science education and how they ought to be in a more-just world (Rivera Maulucci, 2012). The reflective vignettes framing this theme are *Emotions When Trying New Science Pedagogies*; *Emotions When Forging New Connections*; and *Emotions When Navigating Injustices*.

The *Emotions When Trying New Science Pedagogies* vignette unpacks the emotions of creating a new design activity. There are both positive (e.g., excitement, feeling proud, encouraged) and negative emotions (e.g., frustration, disappointment) during the planning process. During implementation, I was *nervous throughout because sometimes I encountered unanticipated questions or situations… perceived resistance is hard, especially trying something new for the first time, because it makes me feel I could have planned or executed the activity better*. In traditional classrooms where science instruction is predominantly teacher-centered (Tobin et al., 1994), the teacher is considered the knowledge expert. Not knowing everything can feel really vulnerable, as evidenced by feelings of nervousness. Racially marginalized educators face additional pressures to perform well due to racist assumptions that they are less competent than White teachers (Vargas, 1999). The comment about having *added anxiety because of Two-Eyed Seeing concepts and understanding science as sociocultural would be new* for students implies that learning from a Western Science lens would be the familiar, dominant worldview.

Emotions When Forging New Connections focuses on emotions experienced when developing relationships. When inviting and hosting guests, *I try to foster collaborations that are actually collaborative*. This is consistent with recommendations for respectful co-planning, especially when hosting Indigenous community members (Manitoba Education and Early Childhood Learning, 2023). The process of growing new connections *was very anxiety-inducing for me* and when *there was a hiccup, the first thing popping into my mind was usually related to*

thoughts about what I might have done wrong, which demonstrate concerns about being accepted by others and valuing dialogic relationships. There is tension in wanting to connect but not being in control of whether or not others want to connect with us. Because schools are rooted in White, Western norms, educators may be unaware that *sometimes there are cultural protocols to learn and navigate—adding another layer to the process*. Part of disrupting these norms is being aware of and taking steps to learn about diverse cultural backgrounds of community members.

The vignette *Emotions When Navigating Injustices* reflects on emotions relating to systemic injustice. Negative emotions like anger and disgust were documented in the vignette. There was also sadness: *I have since shown this film to students many times, and still actively hold back tears when the corals begin to fluoresce… a final cry for help before death in the hopes someone will notice... At a conference, I learned about racial stress and how it affects the health of racially marginalized peoples. Racism is literally killing us.* These emotions reveal our beliefs about how people should be treated compared to how they are—a reminder of the work that remains. For marginalized educators, it is difficult to remain empathetic in the face of repeated encounters with biased, discriminatory, offensive or resistant behaviour from dominant group members (Goodman, 2011) while still being "expected to educate, to not be angry, and to be accommodating" (Goodman, 2011, p. 190). The vignette also alludes to hidden curricula in schools (e.g., bulletin boards, events, resources) that silently reinforce White, Western ideologies and *who is valued in these spaces… who is made invisible*. Additionally, attention is drawn to the racial gaslighting by White people to minimize and delegitimize the lived experiences of racially marginalized communities (Sensoy & DiAngelo, 2017): *[M]aking me doubt myself and wonder if I am seeing things that are not really there. Continuing to engage in the work of resisting*

injustice acts as… a reminder that it is the ingrained hegemony of white supremacy trying to gaslight me.

And in the space between the joys and discomfort, hope emerges. As Rivera Maulucci (2013) writes, "hope combines the primary emotion of happiness with tinges of disappointment or fear" (p. 471) and that it is "an emotion central to coping with social justice issues" (p. 475). As I write in the *Emotions When Trying New Science Pedagogies* vignette, *with patience and time, what is new and strange now, can also become old and familiar*—a sense that with practice and persistence, I can continue exploring and implementing culturally diverse science lessons. The *Emotions When Forging New Connections* vignette recounts putting *pressure on myself to ensure guests feel valued, appreciated, and taken care of*, which indicates a desire to continue centering diverse voices through relationship building. And in spite of overt and covert injustices I have had to address as a teacher, in *Emotions When Navigating Injustices*, I express hope that *if a small rise in temperature can cause so much destruction and death, maybe small decreases can contribute to not only restoring what was but also allow for a new kind of thriving*.

Disruptions Tenet: Fractures and Cracks

This section examines disruptions that began occurring on my journey to teach science more equitably. In culturally disruptive pedagogy, disruptions are moments that change both our understandings and desires to teach and be differently in the world (Litts et al., 2020b; San Pedro, 2018). Here, theory and action interact to challenge the dominant White, Western, heteropatriarchal systems my teaching is situated within. Once again, I introduce this section with a nature framed narrative and discussion of how I understand the disruptions tenet:

How many molecules of water are needed before becoming visible to the naked eye? Is fire a solid, liquid or a gas? Is a pear apple a pear or an apple? If a pencil is made of wood and

wood comes from a tree and a tree is alive, is a pencil also alive? What about rocks, are they living or non-living? Of these wonderings, the last has given me the most pause. I used to be confident in its answer—non-living, of course. Yet, as the question reappeared, like sea cliffs whittled by wind and water, my certainty eroded away. How did this question come to be? Could rocks be alive? Fractures—hairline, barely perceptible. Digging, searching… cracks emerging. The beginning of a cycle deepening its crevices with each passing encounter.

In this place, the impact of climate on rocks is unavoidable. In fluctuating temperatures that traverse the freezing point, rocks are subjected to deterioration through freeze-thaw weathering. There are multiple theories for explaining how rocks are damaged this way but crystallization pressures, which are created when liquid inside pores of the rock turns into ice crystals, is accepted as the primary freeze-thaw weathering mechanism (Deprez et al., 2020). However, "the initially formed microscopic cracks are invisible for the human eye" (Deprez et al., 2020, p. 4). Larger cracks or fragments of rock are visible not after a single freeze-thaw cycle, but over many (Deprez et al., 2020). This process occurs in relationship with other organisms. Lichens, which are symbiotic organisms between fungi and algae or cyanobacteria, can contribute to physical and chemical rock weathering (Chen et al., 2000).

Rocks are also in relationship with humans. For Indigenous peoples, consistent with the view that all things are interconnected, each rock is a sacred, spiritual, living entity. Where water, earth, air and fire meet, humans have transformed the rock face through petroglyph carvings honouring the rock's natural fissures and structures (Zawadzka, 2011). Rocks are filled with stories from and through which we can learn. They

> tell the stories of the places from which they came, stories of the land, surrounding environments, bodies of water, dried riverbeds, and the movement of continents… Rocks

> are the oldest living beings… Think for a moment of the lives they have witnessed, the changes they have seen, and the transformations they have experienced. Broken. Shattered. Dispersed. (Campbell-Ghazinour, 2020, p. 98)

Like rocks, there are different ways we might break apart and separate from the parent rock of enculturated cultural norms. Perhaps exposure to elements, beings or climates found in the environment could serve as disrupting forces. Maybe the process of telling our own stories can create cracks in what, on the surface, appears to be so solid and immovable. Like invisible microscopic cracks, the disruption may begin in small, imperceptible ways. It will likely take many cycles of disruption to truly disrupt my teaching practice, and there exists the possibility that it might never fully happen. But maybe, like rocks, we can tell the stories of where we came from, where we might be trying to go, and record, as witness, the mechanisms of change that have occurred and are still continuing to bore its way through to the very core of our humanity.

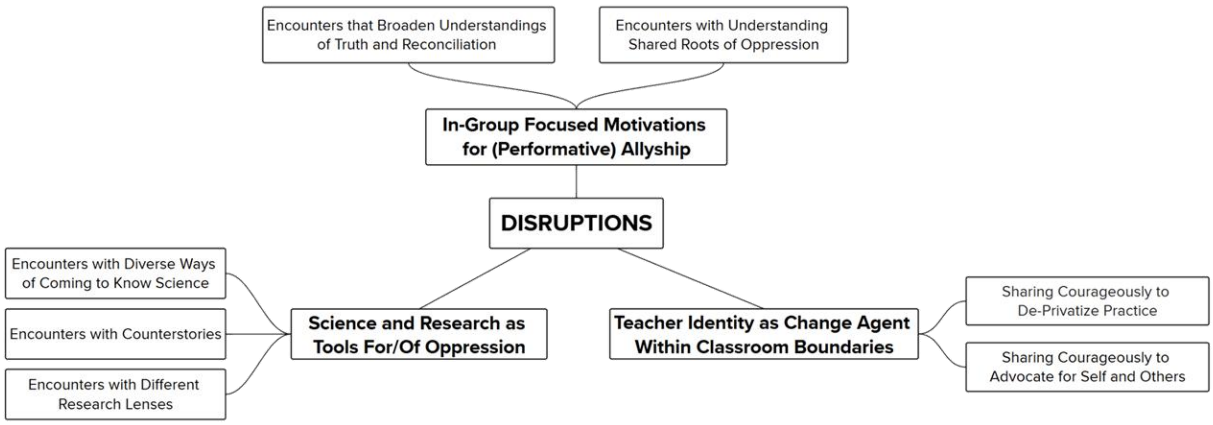
Disrupt/ion is theorized by Fontanella-Nothom (2024) as both a verb and noun—"an act of resistance" (p. 2951) and "a site of possibility" (p. 2949), respectively. As a verb, to disrupt is to engage in action that "challenge[s] dominant ideas, norms, and practices… causing a rupture to help us think and know differently" (p. 2951). As a noun, disruption is an event or object that opens up a moment of possibility for teachers to learn from and do something differently. Scholars have examined how student behaviours can disrupt hegemonic school norms while also serving as disruptions that influenced teachers' behaviours (Calabrese Barton et al., 2021; Fontanella-Notham, 2021).

Rather than focusing on student behaviours, in what follows, I highlight moments or objects of disruption (noun) that reveal disrupting (verb) thoughts and desires while considering the progress of that disruption in the context of White, colonial, and heteropatriarchal school

systems. The three major disruptions (verb) serve as themes for this section: Desiring to disrupt science and research as tools of oppression, in-group focused motivations for (performative) allyship, and teacher identity as change agent within classroom boundaries. Within these themes, disruptions (noun) in the form of encounters with new knowledges/worldviews, and moments of courageous sharing are illustrated using reflective vignettes (i.e., sub-themes). As before, a discussion of the findings will follow the reflective vignettes presented for each theme. An overview of the disruptions (both verb and noun) is provided in Figure 9.

Figure 9

Themes and Sub-themes Emerging from Disruptions Tenet



Note. This graphic was created using digital tools from Mural.co. The disruptions tenet is shown in the center in bolded capitalized letters. The themes (disruptions as verbs) are shown in boxes with bolded text. Sub-themes (disruptions as nouns) are shown in boxes with plain text.

Disruptions Theme 1: Disrupting Science and Research as Tools For/Of Oppression

Encounters With Diverse Ways of Coming to Know Science. I was very nervous about taking a graduate course on Indigenous Science perspectives. I had read a few articles on ethnoscience and Traditional Ecological Knowledge, but my exposure to Indigenous Sciences

was limited. To prepare, I recorded my worries and wonderings in order to acknowledge my fears (see Figure 10). I wondered how I could incorporate Indigenous perspectives without tokenizing, caricaturizing, or appropriating knowledges. How could I incorporate practices meaningful for both Indigenous and non-Indigenous students? I wanted to know similarities and differences between cultural protocols and practices across Manitoba, Canada, and the world. I was curious about connections to science topics I teach. How do I connect with Elders or Knowledge Keepers to learn from or invite to my classroom? And as a non-Indigenous educator, how do I do all this in a way that is in harmony with my own identities and experiences?

Figure 10

Wonderings Brainstorm for K-12 Indigenous Perspectives on Science Course

Note. These digital sticky notes document my wonderings about Indigenous Sciences and was created prior to starting the K-12 Indigenous Perspectives on Science graduate course.

Designing a lesson or unit incorporating both Indigenous and Western ways of knowing science was our final project. I remember working through the process and starting from scratch

part way through because I could feel in my gut that the original idea was too contrived. Fears crept in, but as I researched more and more about water, I was able to create a series of lessons bringing the two worldviews together. Although this experience was very intimidating, it also grew my confidence and self-efficacy.

I did not come to understand all my wonderings during those two short summer months, but it did open my eyes to conceptualizing science in more wholistic ways. I explored outdoors more and was humbled by how little I knew about the land, animals, and plants of this place. I read and listened to stories that taught me lessons about nature (see Figure 11) and reconnected with my own science stories that had long been forgotten. I came to understand the privilege and hold Western Science has as the universal "science". Western Science has made alternate ways of thinking invisible and marked diverse ways of being as deviant and less worthy of being known, but I began to see the legitimacy of Indigenous Sciences.

Figure 11

Constellation Story Painting (Ullaktut)

Note. Based on *Ullaktut* (the runners) as told by Noah Piugaattuk (in MacDonald, 1998), this painting was created for an assignment in the K-12 Indigenous Perspectives on Science course.

The encounters during the course made me wonder about the role of science and education in reconciliation and I wanted so much to bring this into my classroom teaching. Maybe my students, too, could develop a more expansive understanding of what science is and could be. The feelings of nervousness and anticipation have not entirely vanished, but it is not so scary anymore. The process of challenging my thinking and pedagogies continues to elicit a whole complement of human emotions, but with practice, I also know that I will be able to continue embarking on the exciting journey of weaving diverse perspectives into my teaching.

Encounters With Counterstories. Having spent years advocating for girls/women in science during university, it was important to me that science classrooms be inclusive spaces that celebrated their contributions. While writing a paper for a graduate course, I came across *Drawing a new scientist: Why I come out to my chemistry class* (Knezz, 2019). The author writes about anxiety filled experiences with coming out to lecture halls of chemistry students and the importance of inviting students to bring their identities to learning and shaping science, which has historically been primarily shaped by White men. The part that struck me was how the focus on uplifting women in science can function to keep 2SLGBTQIA+ students invisible. This was the first time I had encountered a narrative exposing how gender binaries can be reinforced despite good intentions and efforts to narrow the men/women gap in science.

Knezz's story—at once vulnerable and personal—prompted me to think about gender and science in more nuanced ways. I needed to interrogate my science teaching to identify and improve on shortcomings relating to disrupting heterogendered norms. As this desire was incorporated into my research, I began diving deeper into queer theory and queering science. I like predictability, structure and knowing, so it was challenging to sit with/in the ambiguity and not knowing that comes with queering science. My learning helped me begin disrupting binaries

and norms in my teaching. Sometimes this involved entering into conversations on gender and reproductive diversity in nature (e.g., corals, clown fish), or noticing opportunities to follow my students' leads. Without these tentative understandings, I would have missed the spontaneous moments for making visible the strangeness of nature and science.

Encounters With Different Research Lenses. During my undergraduate science program, I realized I was a good science student, but terrible science researcher. My prior experiences were content focused, so I found understanding journal articles and designing projects challenging. Calculating dilution concentrations made my head want to explode. Making sense of concepts I could not see and had not yet experienced was difficult, but I was fortunate to have encouraging mentors. I switched to working with plants—something I could see, hold, and feel (see Figure 12). No one gave up on me and with time, I learned to ask questions, run experiments, collect data and analyze findings among other nature of science aspects. I came to value science research and see it as a creative and collaborative discipline. Because of this experience, providing opportunities for my own students to engage in science research has long been something I have valued in my teaching.

Figure 12

Alfalfa Plants in Plant Chamber

Note. This is a photograph of alfalfa plants that I grew for my undergraduate research project.

I learned of many other ways to conduct research in graduate school. (Post) positivistic scientific inquiry, qualitative and mixed methodologies were all included. Once I began learning, I was struck by how mainstream "research" is assumed to be quantitative (post) positivistic research without acknowledging other paradigms. Qualitative researchers always had the onus of justifying their own legitimacy. Through the process of learning about different research designs and epistemologies, I came to see how quantitative research, which claimed to be objective and unbiased, was actually not. As I highlighted in a reading response as a key takeaway, a critical approach *does not view science as linear and absolute in truth. Instead, it should be constantly… transformed and unpacked… to counter the ways in which science has been used to reinforce hegemonic practices*. Learning how science research was used as justification for categorizing groups of humans as inferior or superior also impacted me. All this made me reflect on how certain ways of being, thinking and doing are entrenched in society.

I want to keep learning to think differently about research. It is hard to change your thinking. Theoretically, qualitative methodologies make sense to me, but as I carry out a major qualitative project for the first time, there are many aspects in actual practice to untangle. In my science teaching, I want to value different lenses and have begun providing students with opportunities to research differently. In some projects, students choose a big question and match it to different forms of inquiry. They can do arts-based inquiries, focus on design process, carry out experiments, or collect their own field texts to analyze. Even if a bit rudimentary, it was cool to collect, for example, community member narratives for making sense of science ideas. In the future, I hope to keep expanding on this. I can try introducing additional forms of qualitative inquiry or methods to the class so that one day, thinking about "research" will conjure up so much more than only variables, statistics, and hypotheses.

Discussion. The Disrupting Science and Research as Tools For/Of Oppression theme illustrates how encounters with new knowledges and worldviews provide openings for desires to disrupt existing understandings of science and research. The reflective vignettes (i.e., sub-themes) highlight encounters with *Diverse Ways of Coming to Know Science*, *Counterstories*, and *Different Research Lenses*. I intentionally use the term *encounter* (as opposed to, for instance, exposure) to capture the idea of an unexpected meeting with potential to "set [something] in motion… [and] which carries a sense of intimacy: of an event that brings into closer relation things, or people, that otherwise may not have found themselves in proximity" (Strong-Wilson, 2021, p. 93). Encounters with ideas and experiences are key for re-orienting our ideological positions, which manifest themselves in our actions (Arellano, 2022; Gay, 2013).

The *Encounters with Diverse Ways of Coming to Know Science* vignette highlights my unfamiliarity with diverse science lenses and initial acceptance of Western Science as universal: *I was very nervous about taking a graduate course on Indigenous Science perspectives… my exposure to Indigenous Sciences was limited… I came to understand the privilege and hold Western Science has as the universal "science"*. As was shown in Figure 10, I had many questions about Indigenous Sciences in the classroom. This is unsurprising since mainstream Canadian education normalizes Eurocentric knowledges (Battiste, 2023) and privileges Western Science as institutionally accepted knowledge (Snively & Corsiglia, 2000), which acts to "oppress others while it accumulates power, wealth, and economic benefit for a few" (Battiste, 2013, p. 124). Encountering Indigenous Science perspectives in the course began disrupting my Western Science worldview—creating a desire to teach differently: *[T]he course made me wonder about the role of science and education in reconciliation and I wanted so much to bring this into my classroom teaching. Maybe my students, too, could develop a more expansive*

understanding of what science is and could be. Although creating a lesson from both perspectives for an assignment *was very intimidating, it also grew my confidence and self-efficacy*. There is desire to do something differently and the knowledge that it is possible.

The *Encounters with Counterstories* vignette shows how the personal narratives of marginalized individuals can serve as disruptions. Reading Knezz's (2019) counterstory disrupted my existing conceptualizations of gender binaries in science: *the focus on uplifting women in science can function to keep 2SLGBTQIA+ students invisible. This was the first time I had encountered a narrative exposing how gender binaries can be reinforced despite good intentions and efforts to narrow the men/women gap in science*. Now, I desired to learn more about queer theory to better unpack how my science teaching might be oppressing 2SLGBTQIA+ learners. Interrogating restrictive and oppressive binaries of Western Science through queering is important for disrupting the status quo (Garvey & Huynh, 2024; Rende Mendoza & Johnson, 2024). My early attempts included *conversations on gender and reproductive diversity in nature (e.g., corals, clown fish), or noticing opportunities to follow my students' leads* in order to disrupt teacher-student binaries. I also reflected on how *it was challenging to sit with/in the ambiguity and not knowing that comes with queering science*, suggesting that the process of queering science may, itself, be queer. Grappling with unfamiliar ideas places us in liminal spaces of learning and identification (Garvey & Huynh, 2024).

The *Encounters with Different Research Lenses* vignette illustrates how encounters with new paradigms disrupted my understanding of quantitative research as universal: *I was struck by how mainstream "research" is assumed to be quantitative (post) positivistic research without acknowledging other paradigms… learning about different research designs and epistemologies, I came to see how quantitative research, which claimed to be objective and unbiased, was*

actually not. My ingrained research views were unsurprising since quantitative research paradigms are deeply entrenched as status quo across the world and their methodologies rarely critiqued (Arellano, 2022). White definitions of logic and reason set the standard by which all other groups must aspire to (Zuberi and Bonilla-Silva, 2008, as cited in Arellano, 2022), and "these practices further underscore misconceptions of deficits, further marginalizing the already marginalized communities" (Arellano, 2022, p. 2). For example, statistics—typically used in quantitative research—was developed to justify White superiority (Zuberi & Bonilla-Silva, 2008, as cited in Garvey & Huynh, 2024). The vignette documented my desire to disrupt the privilege (post) positivism and quantitative research hold by *providing students with opportunities to research differently* (e.g., via arts-based inquiries or analyzing field texts) in science class.

Disruptions Theme 2: Disrupting In-Group Focused Motivations for (Performative) Allyship

Encounters that Broaden Understandings of Truth and Reconciliation. My early contributions to "reconciliation" were limited to sharing books or videos with my class and doing short discussions or activities for Orange Shirt Week. After learning more about Indigenous Sciences in a course, I focused on incorporating Two-Eyed Seeing into my teaching but did not spend much time engaging with historical or contemporary events related to Residential Schools and reconciliation more deeply. Though changing my science teaching actually does contribute to education for reconciliation, I also feel gross and uncomfortable about how performative it was wearing that Every Child Matters shirt once a year. Despite having engaged classes in systemic injustice discussions routinely, truth, reconciliation and colonization remained on the periphery of those conversations. I was thoroughly complicit in perpetuating colonial structures.

I mine my memory and field texts for that specific encounter when knowing in my head became feeling in my heart. The burial sites at Kamloops Indian Residential School? Reading

Chrona or Battiste? Conversations in sacred truth spaces? A keynote presentation? Lesson planning? Two particular moments resonate. The first, was a podcast where Alok Vaid-Menon (ALOK), who is queer non-conforming and transfeminine, responded to a host who asked, "why do I not fight for them?" (Baldoni et al., 2021, n.p.), when he considered himself a champion for the Black community. ALOK challenged with "you said, 'Why don't I help them,' as if this struggle is not your struggle too" (Baldoni et al., 2021, n.p.). The second, was understanding the distinction between anti-Indigenous racism and racism experienced by other racially marginalized groups. *Creating Racism-Free Schools Through Critical/Courageous Conversations on Race* (Manitoba Education and Training, 2017) explains that non-Indigenous racially marginalized peoples also experience racism, but many came to Canada for "freedom, security of life, and opportunities to flourish" (p. 7) while Indigenous peoples had what was theirs taken by "colonialism, the *Indian Act*, and the residential school system" (p. 1).

These encounters provided nuanced clarity to thoughts and feelings I was unable to articulate. The document helped me understand why one form of racism takes precedence over another without diminishing my own lived experiences. Like the host, I focused on oppressions closest to me without recognizing shared struggles. No longer could I ignore how our humanities are tied together. I desire to take ownership for my complicity in colonization. Teachers have privilege and a responsibility to lead in classrooms by modelling how reconciliation matters all the time, not just once a year, and not just during the school day. This might mean letting go of established pedagogies, taking risks to engage students in unfamiliar or controversial ideas, or recognizing reconciliation matters in both our personal and professional lives. I want to learn the truth and more intentionally reflect on what reconciliation means not just as a teacher in the classroom, but as a human being in this world.

Encounters With Understanding Shared Roots of Oppression. The summer of 2021, I was taking a course on historical and contemporary approaches to curriculum while attempting to incubate an ever-enlarging fetus during a global pandemic. My constant state of displeasure was fueled by physical discomfort, nights of interrupted sleep and hands raw from over-committing to sanitization. In a twisted way, online classes were a blessing because I required frequent bathroom breaks. After class, I cycled between reading a few paragraphs from assigned readings and passing out. Despite this, tracing the curriculum journey was interesting and helped me feel out resonating perspectives. I found texts on feminist perspectives, ecological justice, and posthumanism to be particularly interesting. There were also texts on queer and critical trans pedagogies though a deeper understanding would not come till later.

A particularly interesting reading was *Toward a Posthuman Education* by Snaza et al. (2014), which discussed the human-animal binary that served to control more-than-human beings and legitimize dehumanizing marginalized groups by dominant group members. They write,

> for if one had rights simply by virtue of being human, then *not being recognized as human*—something that women, black slaves, and colonized natives face with horrifying regularity—was enough to relegate these inhumans to the status of things, objects to be used by humans. (p. 42)

Later, I found Hamad's (2020) *White Tears/Brown Scars* to contain related ideas. After reading the book, I reflected in my reading response that it *really helped me build a better understanding of how gender is racialized… The contemporary stories of how women of colour were treated in their workplaces was a little bit scary to me. It made me feel kind of worried that this might happen to me if I say something "too much" or overstep perceived boundaries*. The book explained how White women have dehumanized women of colour and those who do not fit the

gender binary to secure their own status (even if it might be less than a man's). These ideas were similarly expressed in the aforementioned podcast with ALOK.

The historical context provided by the texts was disrupting because it connected the oppressions of different marginalized groups. I used to think racism was separate from sexism involving women, which was separate from homophobia and transphobia. Recognizing their shared histories of white supremacy and dehumanization helped me understand the importance of different marginalized (and intersecting) groups joining forces. I understood people could have intersecting identifications but did not know how they related. So, in between running to the washroom and doing coursework, I reflected on what matters for my growing family. Maintaining my heritage language and culture will always be important. Addressing race and identity was something I always knew we would need to do. But now, I also desired to make space for our family to be one that cares about many diverse communities and not just our own.

Discussion. The Disrupting In-Group Focused Motivations for (Performative) Allyship theme is about how encounters with new knowledges can influence intraminority relations and support motivational shifts for allyship actions. *Intraminority relations* are relationships between people who experience marginalization because of their social, political or economic identifications (Burson & Godfrey, 2020). Because of differential racialization (or perhaps, differential marginalization when not talking about race) that seeks to divide marginalized groups (Delgado & Stefancic, 2023), considerations of these relationships is particularly salient. This theme is framed by two reflective vignettes: *Encounters that Broaden Understandings of Truth and Reconciliation* and *Encounters with Understanding Shared Roots of Oppression*.

In the *Encounters that Broaden Understandings of Truth and Reconciliation* vignette, actions like *wearing that Every Child Matters shirt once a year* would be, at best, an example of

performative allyship (expressing support for marginalized groups but without genuine actions or deeper sacrifices) (Kalina, 2020). True *allyship* involves giving up personal power and privilege when working to dismantle oppression and supporting disadvantaged group members in ways that are actually helpful (Radke et al., 2020). Taking "*action for the disadvantaged group*" (Radke et al., 2020, p. 292) does not necessarily mean you are being an ally.

Emerging actions like *sharing books or videos with my class and doing short discussions or activities for Orange Shirt Week* or *incorporating Two-Eyed Seeing*, could be considered *ingroup-focused motivation* (acting in support of a disadvantaged group provided that the ingroup maintains existing advantages) (Radke et al., 2020). Radke et al.'s (2020) motivation model for allyship focuses on actions taken by advantaged dominant group members (e.g., White, male) though it could serve "as a starting point to theorize about disadvantaged groups' motivation to engage in action for another disadvantaged group" (Kutlaca et al., 2020, p. 1250). Membership in a disadvantaged group does not mean you do not have privileges over another disadvantaged group, so when I use the term ingroup-motivation, I am referring to my own group membership, which might be advantageous or disadvantageous depending on context.

In the *Encounters with Understanding Shared Roots of Oppression* vignette, encounters with Snaza's (2014) article and Hamad's (2014) book disrupted my thinking about different forms of oppression. As I reflected, *[t]he historical context provided by the texts was disrupting because it connected the oppressions of different marginalized groups. I used to think racism was separate from sexism involving women, which was separate from homophobia and transphobia*. Rather than viewing various oppressions as entirely disparate, an understanding of shared structural and historical roots may support and promote intraminority solidarity (Burson & Godfrey, 2020). Burson and Godfrey (2020) highlight research showing that when reminded

of ingroup discrimination, Latinx and Asian Americans increased their support for Black Americans and 2SLGBTQIA+ communities, and Asian Americans are also more likely to engage in activism when they understand structural injustice.

The consideration of intraminority relations is particularly interesting because, as the vignettes demonstrate, prior to disruption, there already existed an awareness of concepts such as privilege or systemic oppression even though it had not yet been extended fully to other disadvantaged groups. In the *Encounters that Broaden Understandings of Truth and Reconciliation* vignette, I reflected on *having engaged classes in systemic injustice discussions routinely* even though *truth, reconciliation and colonization remained on the periphery of those conversations*. In the *Encounters with Understanding Shared Roots of Oppression* vignette, I indicated that *I understood people could have intersecting identifications but did not know how they related*, which shows an awareness of intersectionality as a concept. The relationship between intraminority relations, allyship, and motivations is currently undertheorized, so further work in this area may be helpful in capturing the nuances of these behaviours.

Finally, the findings show a shift towards outgroup-focused motivation (putting disadvantaged group needs over advantaged group, expanded sociopolitical consciousness), which better aligns with allyship (Radke et al., 2020). In the vignette *Encounters that Broaden Understandings of Truth and Reconciliation*, after encountering the podcast and education support document, *[n]o longer could I ignore how our humanities are tied together. I desire to take ownership for my complicity in colonization*. Expanded privilege awareness, which is an attitudinal indicator of outgroup-focused motivation, is evident here. In the classroom, to e*ngage students in unfamiliar or controversial ideas* (which unfortunately still includes Indigenous perspectives and talking about white supremacy) means risk-taking because it goes against

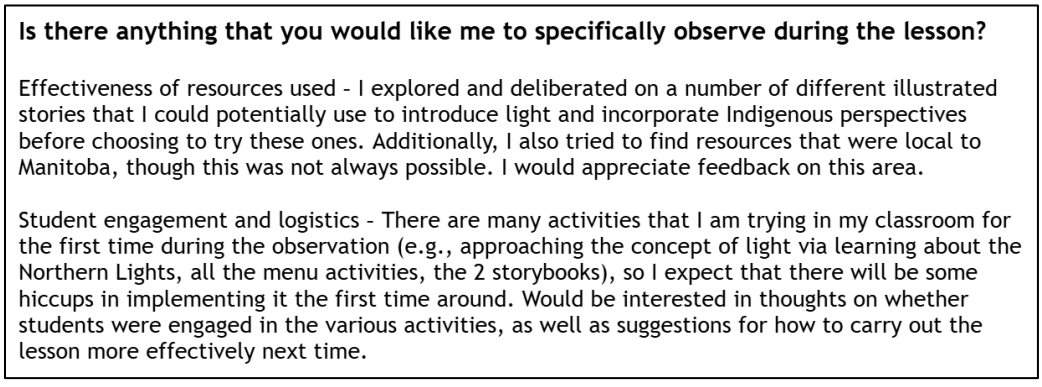
dominant ideologies. Additionally, in the *Encounters with Understanding Shared Roots of Oppression* vignette, being able to recognize *shared histories of white supremacy and dehumanization* is another example of greater privilege awareness.

Disruptions Theme 3: Disrupting Teacher Identity as Change Agent Within Classroom Boundaries

Sharing Courageously to De-Privatize Practice. School days are full. Plan the lesson, teach the lesson. Guide and grade, clean and copy. Paperwork, meetings, incidents, clubs. Little time remains for conversations on the business we are supposedly in—teaching and learning. Though they can be stressful, I always appreciate and value formal observations because we seldom receive commentary on our pedagogies. I internally debate the best approach. Plan nothing and showcase the raw beauty of our papier mâché covered classroom with noodle clogged sinks as the lesson evolves "organically" and devolves into complete chaos? Re-use a dependable, low risk lesson sure to delight learners? In the end, I planned and implemented a new lesson—seizing the opportunity for feedback (see Figure 13).

Figure 13

Observation Pre-Conference Response



Note. This screenshot shows my response to one of eight observation pre-conference questions.

The lesson used a Two-Eyed Seeing lens to make sense of a science phenomenon. Despite *Mamàhtawisiwin*'s (Manitoba Education and Early Childhood Learning, 2022) existence, this could be risky because in my context, Indigenous perspectives and frameworks have not been widely implemented in classrooms. My class already explored some similarly styled lessons earlier in the year, so I was mostly confident they would be receptive, but you never know for sure. I felt exposed. I seldom revealed the nature of my classroom pedagogies, especially those relating to diverse ways of knowing or addressing systemic injustices. It never felt safe; I never got the impression it would be well received. I did want to receive feedback, but I also chose this lesson sequence because I was tired. Tired of hiding away something that I knew in my heart was good and just. Teaching for equity and justice cannot be conflated with another education fad or strategy. It is our responsibility—even if messy. Even if imperfect.

I *was* nervous for what could transpire, but with the wisdom of hindsight, I know it was the right decision. I was encouraged by how these science lessons unfolded and because of this disrupting moment, there have since been many others made possible. Disruption interacts with disruption—their interference constructively amplifying this work. I was once content to stay within my classroom confines; I know now this is not enough. Our private practice in classrooms with students is important, meaningful and valuable. Every person counts, but this alone will not result in widespread institutional change. While I lay waiting for collective efforts to materialize, I share my learning and teaching with others. Maybe someone will read my publications. Maybe my workshops inspire others to join our coalition. I hope to remain courageous in the face of encounters with misaligned forces dampening my efforts, but there might also be like-minded encounters collectively achieving more than what we could have imagined alone.

Sharing Courageously to Advocate for Self and Others. In my first B.Ed. year, equity and diversity classroom discourse made me very uncomfortable. A few defiant words and racism had been reduced by White bodies to figments of our IBPOC imaginations. Silence. Complicity. It was all I could offer then. From social justice theories in education courses, I crafted my shields. From their language I forged my blades. How can my gaze turn to ameliorating injustices? How can continued attempts to deny our stories and lived experiences be countered?

Wielding this awareness as a new teacher, I found our student awards—each named for a notable individual in a relevant field—wanting. The list balanced men and women, but nearly all were White. As a fresh face, who was I to disturb the established order? Once again, silence. Complicity. But education—reading, researching, talking, living—has a way of worming its way into our actions through an expanded sociopolitical consciousness. I noticed all STEM related awards were men and the complete absence of Indigenous representation across all categories. Still nervous about being an inconvenience, but this time I trouble the silence.

Now there is significant Indigenous representation along with other members of the IBPOC acronym. Both men and women are well represented, but ultimately a shortcoming reinforcing gender binaries. To the best of my knowledge, there were no gender diverse individuals included due to hesitations over community reactions—the comfort of dominant members privileged over the discomfort of the "Other". My moment of conformity leaves me with regret. I should have advocated more strongly. Due to my own ignorance of his story, I also overlooked Alan Turing[7] despite having included him as an initial possibility.

[7] Alan Turing, a British mathematician and computer scientist, is known for his work on artificial intelligence. At the time, homosexuality was considered criminal in Britain. After his conviction in 1952, he was forced to undergo hormone therapy. The British government later apologized in 2009 for this injustice and in 2013, Turing was granted a pardon. Adapted from "Alan Turing," by B.J. Copeland, 2024 (https://www.britannica.com/biography/Alan-Turing/Computer-designer)

There have been other moments of conformity, but also of advocacy and agency. No longer do I desire to remain quiet as I did before, but neither do I wish to be ostracized for making trouble. Disturbing well-established performances of collegiality is risky, but I also reflect on the risks of silence. Accepting injustice begets injustice. It lulls us into believing we have no agency or power. We must speak so others know change and support are needed. Silence divides and distances us from connecting and building coalitions. Silence betrays our humanity.

Discussion. The Disrupting Teacher Identity as Change Agent Within Classroom Boundaries theme troubles the notion that teachers might only have power and agency within their own classrooms. This theme is framed by two reflective vignettes highlighting how opening and speaking up can disrupt injustice beyond our immediate classrooms: *Sharing Courageously to De-Privatize Practice* and *Sharing Courageously to Advocate for Self and Others*.

Although teachers may have institutionalized agency by virtue of being teachers, science educators may view their agency as limited to the classroom. Pre-service teachers especially, may feel they are not yet able to exert agency for social change (Moore, 2008), possibly due to school hierarchies and power dynamics. As a teacher candidate, I, too, struggled to speak out against inaccurate and false comments: *A few defiant words and racism had been reduced by White bodies to figments of our IBPOC imaginations. Silence. Complicity. It was all I could offer then* (from *Sharing Courageously to Advocate for Self and Others* vignette). This mirrors the fears other racially marginalized teacher candidates have about confronting White pre/in-service teachers (Sleeter, 2016). Denying the lived experiences of racially marginalized teachers reinforces white supremacy and systemic injustice (Sensoy & DiAngelo, 2017).

As a practicing teacher, I focused on effecting change via pedagogies and enactments of science curriculum within my private classroom space due to perceived dangers around teaching

in ways not yet normalized: *I seldom revealed the nature of my classroom pedagogies, especially those relating to diverse ways of knowing or addressing systemic injustices. It never felt safe; I never got the impression it would be well received* (from *Sharing Courageously to De-Privatize Practice* vignette). Experienced educators engaging in reform work often keep their teaching secret from colleagues (Lockton & Fargason, 2019). As new staff, I resisted advocating for changes to an awards list. I reflected in the *Sharing Courageously for Self and Others* vignette how *as a new teacher, I found our student awards—each named for a notable individual in a relevant field—wanting. The list balanced men and women, but nearly all were White. As a fresh face, who was I to disturb the established order? Once again, silence. Complicity*. Like others new to the profession or context, I thought I needed to conform to already established practices in order to maintain collegiality (Lockton & Fargason, 2019). All this points to how dominant ideologies in schools perpetuate Whiteness by keeping racially marginalized groups invisible.

However, the *Sharing Courageously to De-Privatize Practice* vignette suggests that despite perceived risks, sharing practices beyond the classrooms can expand the reach of our teacher agency. For formal observation, I shared a lesson from a Two-Eyed Seeing lens, which *could be risky because in my context, Indigenous perspectives and frameworks have not been widely implemented in classrooms… I was encouraged by how these science lessons unfolded and because of this disrupting moment, there have since been many others made possible.* Deciding to expose my teaching provided hope that change, even if slow, was possible. The desire to leverage my science teacher privilege to enact broader change is evidenced by further de-privatization efforts: *I share my learning and teaching with others. Maybe someone will read my publications. Maybe my workshops inspire others to join our coalition.* Sharing practices and experiences is important because de-privatization through conversation may encourage others to

interrogate their teaching, more so than other reform practices (e.g., mandates) (Lockton & Fargason, 2019).

In the *Sharing Courageously to Advocate for Self and Others* vignette, I reflect on advocating for a school-wide awards list to have more diverse representation—an example of change beyond the classroom: *I noticed all STEM related awards were men and the complete absence of Indigenous representation across all categories. Still nervous about being an inconvenience, but this time I trouble the silence. Now there is significant Indigenous representation along with other members of the IBPOC acronym*. However, the vignette also described conformity. Although I successfully advocated for greater racial/ethnic diversity, and for a balanced representation of men and women, the contributions of the 2SLGBTQIA+ community were rendered invisible because *there were no gender diverse individuals included due to hesitations over community reactions—the comfort of dominant members privileged over the discomfort of the "Other"*. The pressure to maintain positive relationships limited the degree to which institutionalized change was possible (Lockton & Fargason, 2019).

These findings illustrate an evolving sense of identity from one whose agency is bounded by the role of classroom teacher towards the role of advocate whose agency extends into other spaces: *We must speak so others know change and support are needed* (from *Sharing Courageously to Advocate for Self and Others* vignette). Although there exists "institutional, historical, and psychological boundaries, when a person is able to move around these boundaries and simultaneously break them down… their agency has created a formidable identity for change" (Moore, 2008, p. 607). Science teachers with a strong sense of identity and agency can make a positive difference across education spaces (Moore, 2008). Though there are structural and systemic constraints, how we see ourselves informs and is informed by what we believe we

can do, which in turn disrupts existing practices in favour of more social justice-oriented ones. However, Moore's (2008) study found that only one of the twenty-three participants viewed themselves as an agent of change outside the classroom. Thus, it will be necessary to further explore teacher preparation for addressing social justice both in and beyond science classrooms.

Self-Realizations Tenet: Becoming Mycelium

This section documents critical self-realizations that emerged from becoming as a justice-oriented science educator. In culturally disruptive pedagogy, coming to self-realizations involves accepting new knowledges and integrating new and existing ideologies (Litts et al., 2020b; San Pedro, 2018). Though theory and action continue interacting, this stage emphasizes the internal self-transformation occurring as I gain insights. Again, I introduce this section with a nature framed narrative and discussion of how I understand the process of coming to self-realizations:

As a loosely capped media bottle with pale-yellow liquid spins in our microwave, my senses reawaken. One after another, agar plates are poured. There are no autoclaves here, but we are undeterred in exploring the life that might be found in toilets, belly buttons and nostrils. Raising our index fingers into the air, we practice swab patterns by swerving back and forth on invisible quadrants. After gathering, waiting and wondering, what the naked eye could not initially see revealed themselves. Mingling amongst an orchard of red, yellow and tan bacterial colonies are their fungi fellows. Small, matte, milky yeasts bud and scatter themselves while filamentous masses branch outward from their dark, ashen centers—growing against one another like ripples formed from raindrops.

Filamentous fungi form from hyphal tubes that grow, branch and fuse into mycelium (Fricker et al., 2007). It is this mycelium buried out of sight, rather than its visible fruiting body, that comprises the fungi's main structure (Sheldrake, 2020). Mycelium has roles in human and

more-than-human worlds. Mycelium-plant root symbioses enable nutrient transfers between some plants and fungi (Martin & van der Heijden, 2024). Indigenous peoples have long known this relationship: "[O]ur elders say, the trees talked to each other… They weave a web of reciprocity, of giving and taking… the trees all act as one because the fungi have connected them" (Kimmerer, 2013, pp. 19-20). These symbioses' existence and significance are not contested, but recent studies have revisited the extent of such resource transfers (see Karst et al., 2023). Revising and renewing our understandings is the nature of research and science.

Inside decaying trees, mycelium can also form mats for textiles. Upon examining two Tlingit wall pockets, which were both decorative and likely used for holding objects, Blanchette et al. (2021) realized they were created from mycelium characteristic of Wabadou (Ojibwe), also known as *Laricifomes officinalis* or Agarikon. They stress that consultation with Indigenous Elders is needed to ascertain additional cultural uses or meanings. Other cultural artifacts made from mycelial mats likely exist but have been misidentified or mislabelled by institutions. They urge "other researchers [to] take a closer look and reexamine objects" (p. 266) in order to expand our understanding of how Indigenous peoples have utilized fungal textiles.

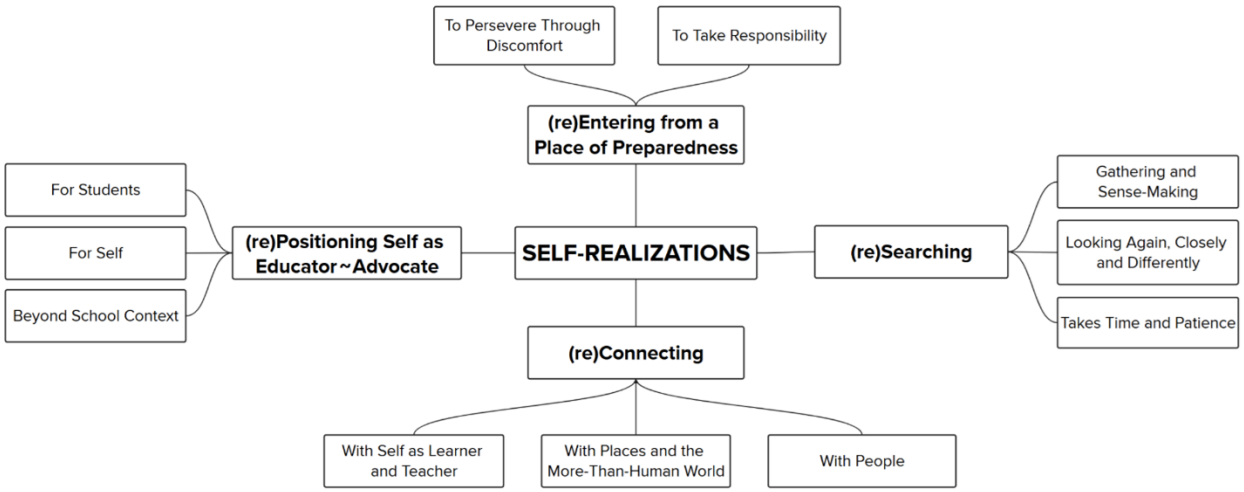
Like mycelium, teaching and research are continuously refigured processes. This undertaking is not about the activities, guest speakers, and facilitated workshops that are easily seen—the fruiting bodies. To become as a justice-oriented science educator is to become as mycelium: to engage repeatedly in the deep, difficult, discomforting reflective work occurring in moments and places which so often cannot be detected by the naked eye. Fruiting bodies develop from the branching of our knowledges and understandings both around and through obstacles into (un)familiar territories. They grow from reconnecting and fusing with the experiences we have already had, the teacher we already are, and the person we still desire to become. They

flourish within our existing and newly formed relationships as we relearn how to reciprocally receive from and share with others. They emerge from the environments with/in which we are interconnected when we notice the histories and stories of places differently. We will find our way just as fungal mycelium has continued to find theirs.

Next, I highlight realizations relating to research, teaching, and education that I have grown into understanding. I discuss how the process of coming to enact socially just conceptualizations of science within and beyond the classroom involves (re)Searching, (re)Connecting, (re)Positioning self as an educator~advocate, and the importance of (re)Entering into these processes from a place of preparedness. A discussion of each theme will follow the reflective vignettes. An overview of the self-realizations is provided in Figure 14.

Figure 14

Themes and Sub-themes Emerging from Self-Realizations Tenet



Note. This graphic was created using digital tools from Mural.co. The self-realizations tenet is shown in the center in bolded capitalized letters. The self-realizations themes are shown in boxes with bolded text. Sub-themes are shown in boxes with plain text.

Self-Realizations Theme 1: Process Involves (re)Searching

Gathering Knowledge and Sense-Making. To break free from constraints of my thinking and inactions, I realized I needed to gather knowledge. Starting from the familiar can initiate the process but also tempts us into forcing ideas onto existing ones. For example, when trying to incorporate Indigenous perspectives on light and sun into my optics unit, I initially tokenized that knowledge by hastily adding them onto existing Western Science lessons, which was contrived and at odds with my original intentions. Instead, I realized I needed to gather knowledge so that ideas could emerge from that learning. I gathered articles, books, children's literature, animated videos, and audio recordings of Elders and Knowledge Keepers sharing their stories online (see Figure 15). I read, listened and viewed—making sense of all I could. Only then, could I create something born from a renewed complement of knowledges. Each time I became immobilized, I gathered again to deepen my understanding or clarify new tensions.

Figure 15

Picture Books About Raven and the Sun

Note. This photograph shows two picture books gathered during planning and was used as part of a lesson on light and the sun. Both tell the story of how Raven brought light to the world.

Throughout this journey, I have gathered knowledge in many forms, learning from scholars (e.g., through articles, books and podcasts), the experiences of colleagues and teacher

educators, and the teachings of Knowledge Keepers and Elders—people are also embodiments of knowledge. This knowledge has taught me about similarities between collectivist cultures, the roots of Indigenous-specific racism, and how concepts of nature and wonder connect queering and Indigenous perspectives. A close reading of policy and curriculum documents also helps me justify my pedagogical decisions. Whenever I was frustrated with witnessing inequity and injustices, I sought out knowledge to better understand how dominant group members think and rationalize their own behaviours. This armed me with counterarguments while bringing clarity and confidence to my personal positions. It also helped me better turn toward others with patience, generosity, and compassion. All of this has supported not only my teaching practice and research study, but also how I think and move through this world as a human being.

Looking Again, Closely and Differently. As my knowledge gathering and sense-making took place, I began to see science and teaching differently. It was not about discarding and replacing everything that once existed, but teaching with greater awareness, flexibility, and intentionality. Learning gave me the knowledges and understandings to see what had always been there. For instance, different ways of knowing are not inherently good or bad. The issue is taking one science perspective for granted without interrogating its strengths and weaknesses while devaluing and delegitimizing another. This process has allowed me to recognize, name and make visible lessons rooted in Western Science or Indigenous Science perspectives. When I see my students pointing to different teaching materials saying this is Indigenous Sciences and that is Western Sciences, I am encouraged that maybe we are all starting to see differently together.

I have often shown to my class a very Western Science video about the history of cell theory. Initially, I used the video uncritically. Later, I noticed how all the scientists were White, European and male. However, this (re)Search has allowed me to look at it differently again. As I

reflected in my teacher journal, *the only female shown in the animation is the cartoon video host telling the story. That being said, I do think it honours students ethnoracial diversity because several German scientists were highlighted.* I recognized how, when used intentionally, the video could still honour students' identities. It highlights a Jewish scientist, as well as those from Germany, which aligns with some class demographics. We can use the video to interrogate whose voices are privileged in science to support students' critical consciousness.

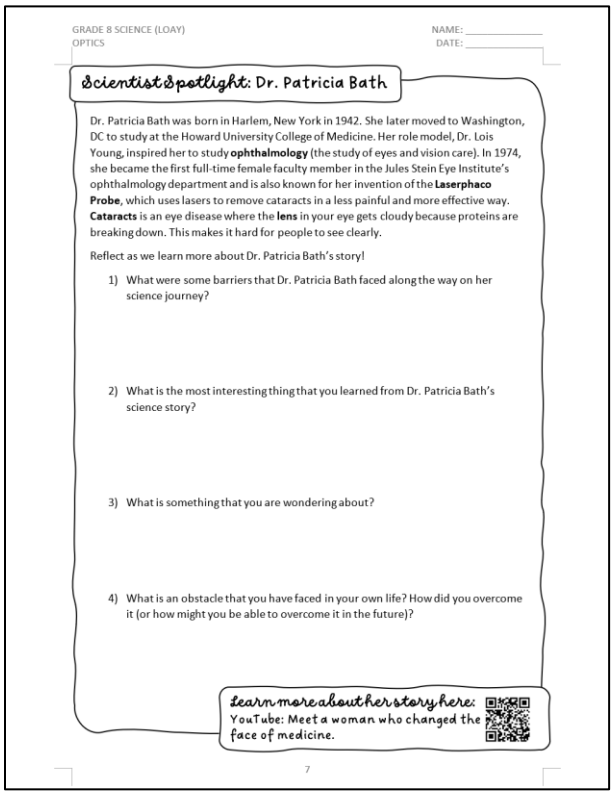
After reading about queering science, I noticed how science resources reinforced binaries and gender stereotypes. Science media personalities like Ms. Frizzle and Bill Nye, though having a clear desire to learn, are portrayed in gendered, de-sexualized ways and reinforce teacher-student hierarchies by overlooking students' needs (Gunckel, 2019b). Although Bill Nye episodes were a staple in my childhood and teaching, I now show them sparingly as I reflect on their portrayal of science and scientists and broaden my pool of alternative resources. Looking again and seeing something new brings greater depth and dimension to my understandings. However, I must also remember that it will take active efforts to engage in research that provides us with the tools and knowledges to see familiar things in strange ways.

(re)Searching Takes Time and Patience. After receiving a new picture book about ophthalmologist Dr. Patricia E. Bath (inventor of the Laserphaco Probe), I was excited to share it with my science classes. The book celebrated her science journey while highlighting systemic barriers she faced as a Black woman. It was perfect for learning about eyes and optics, but I completely forgot about the book until we were already knee deep in eyeballs and lasers. Hastily reading the book without follow up would have reduced her story to a box-ticking exercise. It took over a year from when I first laid eyes on the book to enact the lesson. To prepare, I gathered additional resources about Dr. Bath (e.g., articles or videos of her giving interviews),

created physical teaching materials and thought about reflection questions I might pose to elicit critical thinking on racism, sexism, and classism (see Figure 16).

Figure 16

Scientist Spotlight: Dr. Patricia Bath Teaching Artefact



GRADE 8 SCIENCE (LOAY)
OPTICS

NAME: _____
DATE: _____

Scientist Spotlight: Dr. Patricia Bath

Dr. Patricia Bath was born in Harlem, New York in 1942. She later moved to Washington, DC to study at the Howard University College of Medicine. Her role model, Dr. Lois Young, inspired her to study **ophthalmology** (the study of eyes and vision care). In 1974, she became the first full-time female faculty member in the Jules Stein Eye Institute's ophthalmology department and is also known for her invention of the **Laserphaco Probe**, which uses lasers to remove cataracts in a less painful and more effective way. **Cataracts** is an eye disease where the **lens** in your eye gets cloudy because proteins are breaking down. This makes it hard for people to see clearly.

Reflect as we learn more about Dr. Patricia Bath's story!

1) What were some barriers that Dr. Patricia Bath faced along the way on her science journey?

2) What is the most interesting thing that you learned from Dr. Patricia Bath's science story?

3) What is something that you are wondering about?

4) What is an obstacle that you have faced in your own life? How did you overcome it (or how might you be able to overcome it in the future)?

Learn more about her story here:
YouTube: Meet a woman who changed the face of medicine.

7

Note. This artefact was created to accompany the picture book *The Doctor with an Eye for Eyes* (Mosca, 2017). It includes a brief biography of Dr. Patricia Bath, reflection questions and a link to additional resources.

I realized it takes time to implement a new idea or resource we encounter—this is okay. Sometimes it takes even more time before it takes on a form we are satisfied with. Time is an important part of the (re)Search process because we need it for gathering, sense-making, creating, improving and re-orienting toward the person and teacher we want to become. The process also requires patience. I am working on having more patience for myself when I am

coming to know unfamiliar concepts. It is okay to feel unnerved when I am not sure what to do or how to move forward. In these moments, I can lean back into gathering and honour the time it takes to learn something new.

Discussion. A self-realization that emerged was how the *Process Involves (re)Searching*. This theme is framed by three reflective vignettes: *Gathering Knowledge and Sense-Making*; *Looking Again, Closely and Differently;* and *(re)Searching Takes Time and Patience*.

Other scholars have deliberated on what research means for their own work. Nash and Bradley (2011) distinguish between the *research* as a product (a noun) and *re-search* as "the *process* of searching for truth" (p. xiii) (a verb). The term *research*, Absolon (2022) argues, carries colonial baggage and suggests thinking about research as *kaandossiwin*—"an Anishinaabe word that describes a process of how we come to know—a process of acquiring knowledge. It is a living word that loosely translates to processes of knowledge, gathering and coming to know" (p. xvi). From an Indigenous lens, Absolon prefers *search* or *re-Search* to emphasize the idea of searching again. Because I am not Indigenous and this study does not employ an Indigenous methodological framework, I tentatively use *(re)Search* in efforts to acknowledge the aforementioned colonial baggage while attempting to honour Absolon's understanding of re-Search as a fluid process of knowledge searching.

Becoming a justice-oriented science teacher and (re)Searcher involves (re)Searching, which includes gathering knowledge. Like searching, gathering is a word that aligns with "Indigenous ways of collecting and finding" (Absolon, 2022, p. 27). In the *Gathering Knowledge and Sense-Making* vignette, many gathered texts were identified (e.g., *articles, books, children's literature, animated videos, and audio recordings*). Knowledge was also gathered from *scholars (e.g., through articles, books and podcasts), the experiences of colleagues and teacher*

educators, and the teachings of Knowledge Keepers and Elders. Of note, is the gathering of Indigenous knowledges because "living libraries exist in the form of all the lived experience and knowledge that Indigenous Elders and Peoples carry" (Absolon, 2022, p. 81). Valuing Indigenous teachings disrupts school norms privileging White, Western ways of knowing.

This vignette also reflects on making meaning (i.e., sort and interpret) from the gathered knowledges (Absolon, 2022). As I reflected in the vignette, *I read, listened and viewed—making sense of all I could. Only then, could I create something born from a renewed complement of knowledges.* Instead of treating Indigenous Sciences as an add-on, my pedagogies grew from my understandings of what was gathered. This prevented the tokenizing of cultural knowledges. This process also helped me recognize connections between pieces of knowledge (e.g., *similarities between collectivist cultures, the roots of Indigenous-specific racism, and how concepts of nature and wonder connect queering and Indigenous perspectives.* These understandings, along with *a close reading of policy and curriculum documents*, provided a strong foundation for justifying my pedagogical decisions. I also reflected that *[e]ach time I became immobilized, I gathered again to deepen my understanding or clarify new tensions*. Similarly, St. Pierre (2021) advises that "if what they [the students] do first and second doesn't work, they can try something else. If they get stuck, I advise them to read more and to trust themselves" (p. 6). In other words, when the meaning making process gets stalled, it is helpful to return to gathering.

As gathering and meaning making take place, I can no longer see my teaching the way I once did. Seeing things differently is also an important part of (re)Searching—"each time you locate is different from the last time given the accumulation of spirit, heart, mind and physical experiences that build one's knowing and place in life" (Absolon, 2022, p. 8). The vignette *Looking Again, Closely and Differently* demonstrates how changes in thinking can support

intentional selection of resources and pedagogies. For example, I can use Western Science resources *to interrogate whose voices are privileged in science to support students' critical consciousness*. Importantly, seeking to (re)center marginalized voices does not mean abandoning learners from the dominant cultural group. Rather, I must find ways to honour their ethnoracial identities while simultaneously developing their sociopolitical consciousness through science. I can also re-examine how *science media personalities like Ms. Frizzle and Bill Nye… are portrayed in gendered, de-sexualized ways and reinforce teacher-student hierarchies*. There is opportunity within my existing teaching practice to interrogate how science and scientists are portrayed while supporting students in developing their own critical eye.

The vignette *(re)Searching Takes Time and Patience* demonstrates how implementing new teaching practices demands steady effort. For example, *[i]t took over a year from when I first laid eyes on the book to enact the lesson… I realized it takes time to implement a new idea or resource we encounter—this is okay. Sometimes it takes even more time before it takes on a form we are satisfied with*. This aligns with the First Peoples Principles of Learning that emphasize time and patience (First Nations Education Steering Committee, 2016). A deliberate approach is necessary to prevent tokenizing the experiences of marginalized communities. The findings demonstrate awareness of such pitfalls as indicated by desires to avoid box-ticking (*hastily reading the book without follow up would have reduced her story to a box-ticking exercise*) and promote thinking about systemic oppressions (*thought about reflection questions I might pose to elicit critical thinking on racism, sexism, and classism*). Stories of scientists from marginalized groups should be explored with depth and thoughtfulness. Absent discussions of systemic barriers and critical consciousness, naming scientists from marginalized groups only serves to perpetuate systemic oppressions by reinforcing myths of meritocracy and equal

opportunity (Sheth, 2019). Slowing down and acknowledging limitations fosters respectful implementation. However, dominant ideologies are widespread in schools so teachers may find it challenging to adopt pedagogies diverging from mainstream curricula (Parhar & Sensoy, 2011).

Self-Realizations Theme 2: Process Involves (re)Connecting

With Self as Learner and Teacher. Over a decade has passed since crossing the stage in hat and gown. In education courses, we acted out behaviour management scenarios to the hilarity of our peers, wore our hearts and hopes for teaching boldly in fishbowls, and designed dream layouts for our future classrooms—mine was outfitted with a menagerie of living things. With time and experience, my understandings of schooling and curricula have become more nuanced and intimate. Schools are complex places. Much time is spent weighing courses of action before addressing altercations—there is nothing hilarious about racism, sexism or homophobia. My desires to enact certain pedagogies are sometimes constrained by school structures (e.g., scheduling, access to resources, and assessment practices). I stopped bringing plants to my classroom after their leaves got chopped off and they met a sad, untimely death by drowning.

Time made me cautious and wary, but throughout this (re)search, I have found some (re)Connection with that previous exuberance. I am (re)Connecting with myself as a science learner as I experience wonder through new or previously forgotten science ideas. I started reading science texts again—exploring HeLa cells, Indigenous plant teachings, night sky stories, and mushroom foraging. (re)Connecting with my university knowledge of molluscs and arthropods even sparked dreams of shrimp growing to an abnormally large size. As I reflected in my teacher journal: *I have now spent more of my lunch and prep time reading about molluscs than I have, well, ever before… I had a sea monkey dream last night… they had hatched and were gigantic!* I am also (re)Connecting with trying new things in my science teaching. After

failed shrimp hatching attempts, renewed resolve allowed us to raise them to adulthood. I had become too comfortable with climate-controlled spaces, but I have been trying to bring science classes outdoors to be with/in nature. A few potted plants—alive and (mostly) thriving—have even made a comeback. There is joy even now in this moment of reflection.

I have also been (re)Connecting with why teaching for equity and justice is important to me as an educator. For me, teaching has always been a political act. My position, even as a pre-service teacher, was that education could help make lives better by addressing the roots of injustice, though "I neither adequately nor critically paused to ask *whose* lives were to be improved, *what* roots and social issues needed alleviating, or *which* societies were in question" (Loay, 2021, p. 4). These are questions I have been grappling with throughout this teaching and (re)Searching journey. Written for a graduate course, in my curriculum philosophy paper artefact I came to the tentative understanding that,

> All our lives would be improved. Without diminishing or decentralizing the experiences of those who have been marginalized in mainstream society, I wish to express the sentiment that we might all be impassioned to become agents of change by turning towards the lived experiences of people we care about and coming to understand that their struggle is also ours. Our colonized ways of thinking need unpacking. (Loay, 2021, p. 17)

In reflective and reflexive moments, I am brought back to memories of being othered during my own schooling. In the process of telling my own stories, I (re)connect with who I am and where I come from. In the process of sharing my struggles, I (re)connect with my pain and heartache. In the process of healing, I (re)connect with my resolve and commitment to learn through others' stories and teach toward a more equitable and just future.

With People. During this (re)Search, I realized there is joy and strength in (re)Connecting with people. When I share personal stories in class about culture or injustice, I hope to create spaces where students are comfortable sharing their own cultural-historical and science experiences. This can feel vulnerable, but unpacking these stories together is also incredibly meaningful. I hope to be and do for/with them what I could not experience as a student in my own K-12 schooling. Improvements and possibilities for new pedagogies were made possible by ideas shared with me. For example, what a great idea to use marker on clear tape to create tinted lenses when designing and constructing snow goggles. I could not have conceived this myself and I was further energized for our learning activity. We also (re)Connect over shared unexpected experiences. When critters wander into our classroom, we can engage in impromptu explorimenting. How my students feel about their science learning matters a lot to me, and I was reminded of that during this process. As I encourage them to see science through new lenses, there is bound to be dissonance between all our expectations, especially for those from dominant groups. I can still acknowledge their thoughts and feelings, even if we might not always do exactly what they or I want.

(re)Connecting with like-minded social justice educators has also been a source of support and inspiration. There *are* people out there who also care deeply about dismantling oppression. I also connected with industry experts. Sometimes this was by way of invitation to speak directly with students in the classroom, but other times, it involved venturing out to ask for help or suggestions on how to implement an idea. The process also values learning from Indigenous Elders, Helpers, and Knowledge Keepers—their teachings are gifts. I learned to listen with my heart and not just my ears, to (re)listen when I have not yet learned what I need to, and (re)Connect with my own spirit and those of our human and more-than-human relations. As I

learned from a professional development session reading, we need to use "'three ears: two on the sides of our head and the one that is in our heart'" (Archibald, 2008, p. 8). Finally, I also found support from citizen scientists in online communities. There was such wealth of knowledge accumulated through lived experiences. It is amazing that in this digital age, we can connect with people hundreds of thousands of kilometres away to talk about science. That anonymous strangers took time to help me troubleshoot my science activities is nothing short of incredible.

With Places and the More-Than-Human World. I am both humbled and unsettled by how little I know about this place and their more-than-human beings. Despite driving daily on the same flat, prairie roads, I know nothing of the plants and animals, whose home we have long partitioned with concrete ink. I realized in growing my science teaching the importance of connecting with places. I try to bring my students outside more to observe, play, and wayfind with/in nature. On our treks, I have started to (re)notice the tall reedy grasses, small purple flowers dotting paths, and red barked bushes planted (see Figure 17). To my delight, I encountered a raven in the wee hours of the morning as it grunted and landed in front of me on my way to the classroom. Out on the highway, in naturalized wetland ponds near my home (though there is some irony in replacing drained, paved-over wetlands with simulated ones), and sometimes from this desk, I am trying harder to hear the calls of black-billed magpies, notice the perching red-winged blackbirds, and distinguish crow from grackle. I am also (re)Connecting with informal science learning spaces like museums and reclaimed urban green spaces. Each visit, something new and unexpected leaves its impression on me: the story of three sisters (corn, bean, squash), the northern lights in different languages, a goldfinch eating seeds and bird vetch growing alongside bird's-foot trefoil—an asters and goldenrod moment of my very own.

Figure 17

Asters from School Outdoor Learning Space

Note. This photograph of asters was taken during a seasonal wheel observation lesson.

Discussion. *Process Involves (re)Connecting* is another self-realizations theme arising from the findings. The process of becoming as justice-oriented science educator involves recognizing our interconnectedness with places, people, and more-than-human beings and learning through that relationality. Palmer (2007) has written that,

> [t]he crucial… feature of relational knowing is that it turns our human capacity for connectedness into a strength. As knowers, we no longer need to regret our yearning to connect meaningfully with the other—nor do we need to 'overcome' this 'liability' by disconnecting ourselves from the world. (p. 100)

The three reflective vignettes framing this theme are about (re)Connecting: *With Self as Learning and Teacher*; *With People*; and *With Places and the More-Than-Human World*.

Who we are and how we become as teacher can be influenced by place. Defined not by geography alone, Métis scholars have written about place as locations of "attachment, rootedness, groundedness, and materiality" (LaRocque, 2024, p. 5) that are "subject to varying expectations, policies, and guidelines, and are places of power, belonging, and non-belonging" (Tucker, 2024, p. 33). The (re)Connecting *With Self as Learning and Teacher* and *With Places and the More-Than-Human World* vignettes speak to how places both constrain and expand our

science teaching. In (re)Connecting *With Self as Learning and Teacher*, I reflect on how teacher practices may change in response to practical demands and structural constraints in schools. As I write, *[s]chools are complex places. Much time is spent weighing courses of action before addressing altercations—there is nothing hilarious about racism, sexism or homophobia. My desires to enact certain pedagogies are sometimes constrained by school structures (e.g., scheduling, access to resources, and assessment practices)… Time made me cautious and wary*. Over time, these experiences leave one feeling disconnected from who we are and why we teach.

However, (re)Connecting with my wonder for learning and enthusiasm for teaching fuels my desires to teach and (re)Search for social justice in science education. In this same vignette, I reflect on *reading science texts again—exploring HeLa cells, Indigenous plant teachings, night sky stories, and mushroom foraging* and (re)trying teaching practices like hatching shrimp with *renewed resolve… to raise them to adulthood*, taking *sciences classes outdoors to be with/in nature* and bringing back *a few potted plants* to the classroom. I was reminded that *for me, teaching has always been a political act. My position, even as a pre-service teacher, was that education could help make lives better by addressing the roots of injustice*. As Gunckel (2019b) asks, what would happen "if rather than focusing on teaching particular methods, routines, and approaches, it refocused on (re)awakening teachers' own desires for knowledge and passion for understanding... connecting their own childhood desires for learning about the world with their passion for teaching children?" (p. 157). As teachers become assimilated into school contexts, we may become insiders adopting their cultural norms and values. (re)Connecting with places and ideas provides new lenses with which to see our places of work and learning anew.

The (re)Connecting *With Places and the More-Than-Human World* vignette is about noticing stories, ideas, and the more-than-human beings found within places that I visit, live in,

work with and travel through. In the vignette, I reflect on how *I am both humbled and unsettled by how little I know about this place and their more-than-human beings* and how I am endeavouring to (re)Connect better. I attempt to *bring my students outside more*, notice the more-than-human beings both at school (e.g., *tall reedy grasses, small purple flowers)* and at home (e.g., *the calls of black-billed magpies*), and learn from *informal learning spaces like museums and reclaimed urban green spaces*. Gruenewald (2003) makes an interesting point about the widespread acceptance of "a standardized, 'placeless' curriculum" (p. 8) in schools and advocates instead for critical place-based pedagogies that foster intimate knowledges and relationships with places with the aim of reinhabitation and decolonization. This may involve "unlearning much of what dominant culture and schooling teaches, and learning more socially just and ecologically sustainable ways of being in the world" (Gruenewald, 2003, p. 9). By changing our relationships with place, science teachers can interrogate the colonial structures of schooling that disconnect us from our human and more-than-human relations.

The (re)Connecting *With People* vignette shows how learning from and finding support in others is an important part of becoming as a social-justice science educator. As Tan (2011) writes, "education is a process of experiencing and becoming and this search for personal meaning can only be realized in relation to others" (p. 564). (re)Connecting with my students through sharing my own stories and listening to their stories and ideas can help make meaning of my own experiences. For example, in *shar[ing] personal stories in class about culture or injustice, I hope to create spaces where students are comfortable sharing their own cultural-historical and science experiences. This can feel vulnerable, but unpacking these stories together is also incredibly meaningful. I hope to be and do for/with them what I could not experience as a student in my own K-12 schooling*. Kim and Hsieh (2022) also highlight a Vietnamese American

teacher who fostered student connections through counterstorytelling and dialogue on racism in order to dispel the Model Minority Myth. And through supporting students and families in navigating cultural differences, "he is forging new and renewed connections within himself" (p. 48). Though dominant school cultures can disconnect learners from who they are and where they come from, educators can play a role in restoring those connections.

This vignette also reflects on how science educators can learn from students' ideas (e.g., *use marker on clear tape to create tinted lenses*) and seize opportunities to *(re)Connect over shared unexpected experiences. When critters wander into our classroom, we can engage in impromptu explorimenting*. This demonstrates how taking learners' science ideas seriously serves to disrupt student-teacher binaries in my science classroom (Gunckel, 2019b). The vignette also demonstrates the importance of connecting locally or digitally with fellow educators and community members as they can be invaluable sources of knowledge and support: *(re)Connecting with like-minded social justice educators has also been a source of support and inspiration… I also connected with industry experts… from Indigenous Elders, Helpers, and Knowledge Keepers... I learned to listen with my heart and not just my ears, to (re)listen when I have not yet learned what I need to, and (re)Connect with my own spirit and those of our human and more-than-human relations… I also found support from citizen scientists in online communities*. In school contexts where few teachers engage in their practice from a critical lens or are members of marginalized groups, this is particularly salient. Teachers may experience a sense of non-belonging or need to spend additional time searching for resources that are not yet mainstream (Kim & Hsieh, 2022). In addition to understandings of racial identity and foundational knowledge relating to histories of marginalization in society, teachers must also have access to learning opportunities and support (Kim & Hsieh, 2022).

Self-Realizations Theme 3: Process Involves (re)Positioning Self as Educator~Advocate

For Students. As my feet connected with the giant floor map[8], socks sliding from the prairies to Great Lakes, from the Arctic Circle to West Coast, I reflected on settler colonial naming practices for places and people "discovered" as if they did not already have names and relations. In place of the descriptive and functional are entrenched legacies of notable Europeans' conquests. This exercise prompted reconsideration of how Western scientists assigned Latin names to more-than-human beings. How would trees or insects refer to themselves? What might they call us? How might those with a different science lens refer to more-than-human beings? To name is to exercise power and control. It is a political act that "establish[es] the structure of this world… There is no social agent who does not aspire, as far as his circumstances permit, to have the power to name and create the world through naming" (Bourdieu, 1991, p. 105).

I realized, throughout this (re)Search journey, that there is power in language. As I noted in a reading response, it was *interesting to read about how white teachers on the prairies were perpetuating settler colonialism in their schools. I liked the term "push out" that was used in place of "drop out" to refer to Indigenous students who are unable to complete their education because it shows how it is the school system that is not set up to help all students succeed rather than putting the blame on individual students (i.e., individualizing racism)*. There is power in referring to learners as being pushed out by a system not made with them in mind rather than assigning blame to them as dropouts (McLean, 2022). When someone is called a derogatory name, power is exerted by the one seeking to control and dehumanize the other, but we can choose to name this as an act of hate. Naming oppression exerts a different kind of power—one where we prioritize the well-being and dignity of all learners rather than kowtowing to the

[8] See "Indigenous Peoples Atlas of Canada" by Canadian Geographic Education, 2024 (https://cangeoeducation.ca/en/maps/indigenous-peoples-atlas-of-canada/)

comfort of dominant group members. Yes, teachers must advocate for students when addressing wrong doings after the fact, but they also need to explicitly state that intolerance and hurtful behaviours relating to peoples' identities have no place in the classroom. This might look like engaging learners in conversation, setting norms or putting up posters in the physical space.

Advocating for students also means equipping all learners with concepts and common language to participate in related discourses. This might include engaging perpetrators in restorative justice or enacting lessons that support learning about equity and systemic oppression. We can teach students to name and recognize microaggressions, as well as ensuring schools are actually safe for reporting (institutions often are not). As someone belonging to intersectionally marginalized groups, I can share personal experiences of oppression to show how microaggressions exist within our own communities. We can support students' understandings of diverse worldview by clarifying differences between understanding and believing or spirituality and religion (Snively, 2016b). After reading Snively's (2016b) chapter, *When uncles become killer whales: Bridging Indigenous Science, Western Science and worldviews*, I began explicitly explaining these concepts in class. The clarification was helpful for addressing learners' tensions, which is important because "[t]he continuing struggle to achieve opportunity and equal justice for all critically depends on our ability to provide rich and culturally appropriate educational opportunities for all students" (Snively, 2016b, p. 117). Whether rooted in racist ideas or unfamiliarity with new knowledges, finding ways to navigate this resistance to learning diverse worldviews in the classroom is an important part of my teaching. Explicit teaching about systemic inequalities and making Western Science visible through a Two-Eyed Seeing lens are ways in which I can continue advocating for and with learners through science education.

For Self. In circle, I stood. Shoulders back, head up, chin raised towards the sky. With eyes closed tight, I asked for courage and insight to continue advocating even during moments that are especially difficult to bear. Setting aside my own self-consciousness briefly—ahwoooo, I called out. Its sound echoing and reverberating. I cannot say with certainty Grandmother Moon heard me then, but I certainly heard that taking care of our spirit and health is important. Engaging in this area of (re)Search is filled with emotionally fraught moments; we cannot engage in a good way without taking care of ourselves. This was an important realization, though admittedly not always an area of strength for me.

An awareness of emotionally triggering events is helpful. Avoiding or preventing all instances of overt and covert forms of oppression is beyond my control (if not impossible), but I can anticipate situations or locate the source of emotional heaviness. Events in the present can elicit painful memories of past incidents, but I name and use these now to inform my advocacy. Connecting with other IBPOC community members has been a huge source of support. Engaging in this (re)Search—where at least my mind can be free—also allows me to find joy through speaking and writing my truth. Although I often enjoy listening to podcasts relating to research, education, or social justice on my long commutes, I also recognize that sometimes I need to simply drive in silence and take a rest from this work. Do members of marginalized groups really get to rest in the same way as those from dominant cultural groups? The necessity and privilege of resting are tensions that I am still working to reconcile. Planning lessons and teaching also bring me great joy; I try to remind myself to celebrate innovations or lessons that went well.

As teachers, we have a responsibility to advocate for our students. However, we must remember that teachers, too, are human beings worthy of being advocated for. As an educator belonging to intersecting marginalizations, I, too, am worthy of this advocacy. The entanglement

between advocating for students and teachers with marginalized identities is a percolating wondering. Can one exist without the other? Can institutions pay greater attention to norms and practices perpetuating and reinforcing systemic oppressions for both students and staff working within those systems and structures? How schools and districts more intentionally provide support for their marginalized staff?

Beyond School Context. Before engaging in this (re)Search, my professional life focused on actions within my classroom and school. I have realized that advocacy beyond these contexts is necessary and also that it is something within my reach. Exploring the literature, I encountered many noteworthy counterstories of educators and researchers. However, I often felt my own stories paled in comparison. Is there reason to care about my experiences? Do I even understand my own research? How is my teaching of significance beyond my own practice? The whispers of imposter syndrome are deceptively alluring.

Though far from being a public intellectual, I have realized my lived experiences as an educator do have value and see small steps I can take toward being a better advocate. I can make efforts to share my learning and walk alongside educators beyond my school by, for example, facilitating professional learning for teachers or contributing to provincial publications with wider-reaching audiences. These efforts elicited some initial trepidation because sharing thoughts and ideas publicly can leave you vulnerable to critique—legitimate or not. Still, it was cathartic and freeing to be open about my values as an educator. We can advocate within our personal and private spheres by having courageous conversations or being intentional about engaging in reconciliation and anti-oppressive learning within one's family.

Although my graduate coursework and research certainly inform the aforementioned activities, I also feel there is more to explore in the realm of advocating as an emerging scholar. I

recognize this as an important part of research but am still figuring out what that means for me. I still feel a little self-conscious about sharing my thinking publicly because there is so much I am still learning about. Do I have sufficient credibility and knowledge to speak on a topic? This is a question I frequently ask myself. Especially because my (re)search is in the context of science education, I am also cautious to not speak out on matters reaching beyond my focus area.

Discussion. The third self-realization of this study is that the Process Involves (re)Positioning Self as Educator~Advocate. In addition to teachers educating and scholars researching, teacher~scholars need to be advocates for students and staff belonging to marginalized communities. Consideration of how this advocacy takes place within and beyond schools is also important. In the context of this study, being and becoming an educator~advocate means bringing injustices to light, interrogating the purposes of schooling, revealing which knowledges are privileged or excluded, and doing so in relationship with others (Cochran-Smith, 2010). It means leveraging our own privileges as educators "to stake a position or call for the advancement of an issue" (Gonzales, 2022, p. 29). Now, I discuss ideas from the reflective vignettes in this theme, which focus on being an educator~advocate *For Students*, *For Self*, and *Beyond School Context*.

The *For Students* vignette reveals that, as a teacher, I can advocate for students in a variety of ways in the classroom. One way is to *share personal experiences of oppression to show how microaggressions exist within our own communities*. This provides an opening for students to both share their own stories and understand these acts are embedded in the fabric of their communities. Because of their relatability, other Asian educators who tell counterstories have similarly been able to encourage students to open up about their own experiences with microaggressions (Kim, 2022). Another way to advocate for students is by valuing diverse

science worldviews through *[e]xplicit teaching about systemic inequalities and making Western Science visible through a Two-Eyed Seeing lens*. This form of advocacy counters epistemic injustice, which is when dominant cultural group members delegitimize someone's epistemic authority and knowledges—refusing to learn or broaden their own worldview (Gonzales, 2022), by legitimizing Indigenous Sciences.

The *For Students* vignette also shows how language is important for advocacy. Educators need to be cognizant that words reveal our perceptions of students and the role of schooling. As I reflected, *[t]here is power in referring to learners as being pushed out by a system not made with them in mind rather than assigning blame to them as dropouts.* Rather than talking about learners through a deficit lens (e.g., referring to students as dropouts), we can, instead, use language that interrogates systems and structures privileging some and disadvantaging others (e.g., the role of schools pushing out certain learners). In Kim (2022), for example, a teacher advocated for racially marginalized students by recognizing her colleagues' deficit views of Black and Latinx students—challenging their assumption that those students should be placed in a separate support class. However, institutional structures may force schools to use deficit language. For example, educators could potentially face situations where they need to emphasize learners' challenges in order to qualify and compete for limited resources when applying for student supports.

The vignette also discusses normalizing conversations on injustice by *engaging learners in conversation, setting norms or putting up posters in the physical space* (i.e., make *not* talking about it strange). Paramount is *equipping all learners with concepts and common language to participate*, which requires teachers do the same. For minoritized learners, this counters hermeneutical injustice (a form of epistemic injustice), where they do not yet have concepts and language to describe unjust experiences (Fricker, 2007). Acknowledging oppression exists is

necessary for creating cultures that prioritize an anti-oppressive praxis. As I reflected, *[n]aming oppression exerts a different kind of power—one where we prioritize the well-being and dignity of all learners rather than kowtowing to the comfort of dominant group members*. Avoidant and evasive language obscures the roots of unjust school practices that disadvantage minoritized students (Chrona, 2022; Galloway et al., 2019). Like Galloway et al. (2019), this study points to the importance of actions that call out discrimination, engage perpetrators in restorative justice, and teach explicitly about oppression and systemic inequalities.

The vignette, *For Self*, reflects on my realization that as *an educator belonging to intersecting marginalizations, I, too, am worthy of this advocacy*. For educators who have also experienced marginalization, learning how to advocate for self (and others) requires reflection due to assimilation (Kim, 2022). Teachers may also need to navigate cultural differences where self-advocating can be viewed as disrespectful (Kim & Hsieh, 2022). Taking care of ourselves is part of this process. Throughout this journey, I found it helpful to develop an *awareness of emotionally triggering events [in order to] anticipate situations or locate the source of emotional heaviness*. Being able to recognize and navigate uncomfortable situations was one way to care for myself. C*onnecting with other IBPOC community members has been a huge source of support*, which speaks to the importance of collective efforts. Other Asian educators have similarly realized the importance of intraminority solidarity and being advocates (Kim, 2022; Kim & Hsieh, 2022). Though I reflected on the importance of resting, I also wondered if *members of marginalized groups really get to rest in the same way as those from dominant groups*. For example, an Asian teacher in Kim's (2022) study was seen by colleagues "as a leader on diversity issues" (Kim, 2022, p. 57). While this speaks positively to the teacher's

actions, it also exemplifies how, in predominantly White spaces, the responsibility of addressing equity issues continues to fall largely on the shoulders of already marginalized teachers.

The *Beyond School Context* vignette shows scholars also have a role in being advocates for equity issues. I am trying to share my learning beyond the school context by *facilitating professional learning for teachers or contributing to provincial publications with wider-reaching audiences. These efforts elicited some initial trepidation because sharing thoughts and ideas publicly can leave you vulnerable to critique*. For emerging (re)Searchers like graduate students, (re)positioning self as advocate and developing expertise and credibility take time. As I reflected, *I still feel a little self-conscious about sharing my thinking publicly because there is so much I am still learning about.* Educators need to engage as public intellectuals and combat misconceptions that social justice in education is just about being nicer to each other and helping marginalized learners feel better about themselves (Cochran-Smith, 2006). The dominant narrative of what being a public intellectual means (i.e., White men from elite universities being consulted on their factual knowledge of a topic) needs disrupting; this narrative erases and devalues what scholars from marginalized groups have long been doing as public intellectuals, which is advocating for their community through scholarship (Gonzales, 2022). As Gonzales (2022) asks, "what, if not advocate, does a public intellectual do?" (p. 25).

Self-Realizations Theme 4: Process Involves (re)Entering from a Place of Preparedness

To Persevere Through Discomfort. Despite short-term compulsions for fishing or hiking, I am not particularly outdoorsy—finding little pleasure in being chased by wasps or swarmed by bloodthirsty mosquitoes. Temperatures in the extreme positives or negatives thirty leave much to be desired and I never can scrape all the mud off my shoes after a particularly rainy spell. Despite inner hesitations, when I learned about seasonal wheels (Aitken, 2016), I

thought it would be great for science class and wanted to invite students into this learning. To mitigate physical discomfort, I picked up some gear (e.g., rubber boots, a fanny pack for carrying comfort items, anti-itch mosquito cream) and committed.

Teaching for social justice will bring discomforts, especially of the cognitive and emotional types. When trying new pedagogies, I have felt confused when gathering knowledge or disappointed with how a lesson was first enacted. When something unexpected arises during a lesson, it can be stressful. I realized it is normal to not perform to the same standard when teaching something new. Next time, I will be able to anticipate and prepare better. When working with people you have not yet developed a relationship with, you might feel anxious and nervous, or even embarrassed when engaging with unfamiliar protocols. As trust develops and I grow my knowledge, there will be more confidence. When encountering hurtful resistance or harmful aggressions, there is frustration, anger and sadness. This work can be deeply personal, especially for those who are members of marginalized communities. It takes time to figure out what we need to take care of ourselves. This work can feel disconnecting and isolating. It takes time to build coalitions with allies. The work of unpacking our own privileges and biases is also important but challenging. There are things that society has tried desperately to keep us from seeing and there are things about ourselves that we, perhaps, do not want to see even though we must look ever more closely.

All of this is to say, that I have found discomfort to be normal when learning and unlearning. I do not mean here, that mistreatments (especially from dominant group members) as we enact justice-oriented pedagogies are warranted or that marginalized group members are responsible for their own experiences of discomfort. What I am suggesting is that discomfort is part of the process of changing our thinking and actions; those who have not yet had to challenge

or change their way of knowing and being in this world might pay heed to the realities and necessities of this work. We all need to work through our tensions; this is part of the journey to knowing and being differently in our teaching. Persevere through setbacks (and yes, there will be many) and grow from mistakes (there will be many of these too). Make preparations where possible and try not to turn your gaze away when faced with the unfamiliar or unknown.

To Take Responsibility. Like others finding solace in sourdough starters, or gardening during global lockdowns, I, too, found a new pastime. My enthusiasm for amigurumi crocheting quickly waned. I had chosen a far too difficult first project. I could not read patterns and distinguishing stitches was impossible—the entire project was inside-out and backwards. With much stubbornness, I finished the character accessorized with cloak and scarf… eyes tired and hands cramped from inexperience. I started (re)Searching to gather materials, better tools and resources to learn new stitches and tricks. Sometimes there was even improvisation and creating from scratch instead of following existing patterns.

Parallels between learning to crochet and learning to be equity-minded can be drawn. In both, you must familiarize yourself with new vocabulary and concepts to notice things differently. Time is spent gathering tools and resources. Both processes are trying at times… patience and time are needed. But as nice as it would be to continue this analogy, ultimately, the two cannot and should not be equated no matter how alluring. On numerous occasions, I have been informed that anti-racism and reconciliation are my personal hobbies—special interests and passions others are neither expected nor required to share in. I realized the treatment of equity issues as a hobby detracts and distracts us from understanding social justice and equity-minded practices as responsibilities and duties we have to each other as educators and human beings.

We begin by taking responsibility for our actions and inactions in the classroom by interrogating our practices to ask how our pedagogies contribute to reinforcing and perpetuating the status quo. It means not making excuses or waiting for others to do all the heavy lifting. Taking responsibility means learning to have challenging conversations about injustice in schools and re-prioritizing our time to learn and unlearn how to teach and assess more equitably. Teachers are a part of institutions existing within social, historical and political contexts, and thus, must interrogate how we are upholding (in)justices when enacting curricula, policies, and procedures. It is our responsibility to advocate for equitable practices and policies. In the advent of provincial policy documents like *Mamàhtawisiwin* (Manitoba Education and Early Childhood Learning, 2022), educators are responsible for implementing the framework in classrooms and schools (even if imperfectly). It is also our responsibility to familiarize ourselves with support documents like *Creating Racism-Free Schools Through Critical/Courageous Conversations on Race* (Manitoba Education and Training, 2017) to better support all learners.

Pointing out this responsibility is not about placing blame or guilt. We all have many other responsibilities in our personal and professional lives, and we all have things we are ignorant of. Many teachers, including myself, are products of the same school system we are now complicit in. However, once made aware, choosing not to act because of inconvenience would be an abdication of our responsibilities as educators. I hope one day we might be able to finally live in a world where every person can live fully human lives—no longer would a special interest for ameliorating inequities in education be necessary. In this world, there would be more crocheted donut cats and fewer unfinished waffle stitch throws, but until then, we must turn simultaneously inward and towards a collective taking of responsibility.

Discussion. (re)Searching, (re)Connecting and (re)Positioning may be eased by (re)Entering from a Place of Preparedness, which is the final theme of the self-realizations tenet. As I have discussed earlier in this chapter, becoming as a justice-oriented science educator can be fraught with tensions; it is not easy to disrupt our existing ways of thinking and being. Absolon (2022) emphasizes the importance of preparation:

> *Preparation* is essential to any search and includes putting thought into the search prior to actually going on one. Bring an Offering. I use *asema* (tobacco). Prepare yourself: be of a good heart and mind, think about your route, wear the proper clothing, gather your tools, bring food and water and plan for the unexpected. Announce yourself and your intentions about your search; share this with others. (p. 37)

The vignettes reflect on preparing *To Persevere Through Discomfort* and *To Take Responsibility*. Knowing that experiences of discomfort are inevitable and (re)Entering with a responsibility mindset are helpful realizations for going into (or continuing along) this journey.

The vignette *To Persevere Through Discomfort*, is about realizing that discomfort is a common experience of learning to teach differently. As I reflected, *discomfort is part of the process of changing our thinking and actions; those who have not yet had to challenge or change their way of knowing and being in this world might pay heed to the realities and necessities of this work*. This is particularly salient for dominant group members whose comfort is often prioritized over that of marginalized groups. The vignette documents affective states teachers might experience: confusion, anxiety, nervousness, embarrassment, frustration, anger, sadness and disconnection. Working through these emotions is an important aspect of (un)learning and growing forward as an educator. Acknowledging and listening to what emotions can teach us is disrupting of traditionally masculine norms that value emotional restraint (Arao & Clemens,

2013). Other educators have similarly experienced intense emotions when learning to teach for social justice (e.g., about colonization) (Aitken & Radford, 2018; Chowdhuri & Archer, 2024). These moments of strong emotions, sometimes referred to as the *punctum*, can support shifts in worldview (Barthes, 1981, as cited in Chowdhuri & Archer, 2024), possibly leading to "greater humility, empathy, student-centred practice and a shift to seeing oneself as a social justice 'ally'" (Chowdhuri & Archer, 2024, p. 490). Normalizing discomfort has potential for creating openings that disrupt existing mindsets and practices.

(re)Entering this process with the mindset that social justice advocacy is a collective responsibility rather than the special interest of select individuals is important. The vignette *To Take Responsibility* suggests that recognizing and acknowledging the complicity of educators and schools in perpetuating injustices is a necessary step toward understanding our responsibilities. After all, "complicity is where responsibility begins" (Applebaum, 2010, p. 4). As the vignette notes, we can *begin by taking responsibility for our actions and inactions in the classroom… [and] interrogate how we are upholding (in)justices when enacting curricula, policies, and procedures*. This call to action is echoed by social justice (science) education scholars such as those in Azarmandi et al. (2024) who ask educators to reflect on whether or not "we are taking a risk to question structures that we might be entangled in or those we are upholding and benefitting from" (p. 193), reminding us that "anti-racist praxis is first and foremost about critically analyzing and dismantling the racist systems in which we are already complicit" (p. 191). Although it may feel uncomfortable, examining how our existing practices might currently reinforce hegemonic norms is critical. The element of risk points, again, to the importance of engaging in true allyship (Radke et al., 2020).

Of significance to the Canadian context is consideration of educators' responsibilities for reconciliation with Indigenous communities. As Sinclair (2014) writes about the responsibility of education systems in ameliorating injustices,

> it is precisely because education was the primary tool of oppression of Aboriginal people, and miseducation of all Canadians, that we have concluded that education holds the key to reconciliation… The educational systems of this country bear a large share of the responsibility for the current state of affairs. But it can fix what it has broken. (pp. 7-10)

Elsewhere, "he [has also] pointed out that reconciliation is about responsibility and obligation, not forgiveness" (Aitken & Radford, 2018, p. 42). The reflective vignette draws attention to educator responsibilities for Indigenous education: *In the advent of provincial policy documents like Mamàhtawisiwin… educators are responsible for implementing the framework in classrooms and schools*. Additionally, all kindergarten to grade twelve teachers in Manitoba are required to participate in Treaty Education training by the end of the year 2025 (Treaty Relations Commission of Manitoba & Manitoba Education and Early Childhood Learning, 2023). Thus, teachers need to (re)Enter with the understanding that, as treaty people, reconciliation is both a personal and professional responsibility. At the time of writing, the Manitoba Department of Education and Childhood Learning is reportedly working with stakeholders to develop and implement an anti-racism policy for schools (Chartrand, 2024). These actions point toward potential shifts in the education landscape where justice-oriented teaching and learning may be more explicitly incorporated within the scope of educator responsibilities.

Pedagogical Innovations Tenet: The Fruiting Bodies

This section documents the pedagogical innovations enacted as I explored socially just conceptualizations of science as an educator. In culturally disruptive pedagogy, pedagogical

innovations are new practices emerging from processes of grappling with tensions, disrupting our thinking, and coming to critical self-realizations (Litts et al., 2020b). This stage focuses on enacting transformations in the form of tangible actions (i.e., the innovations) that create the possibility of encounters for others around us. As before, a narrative and discussion framed by something we can learn from nature introduces this tenet:

While a guest teacher steered the helm from my classroom, I was off in the bush roaming in search of something interesting to observe. Beneath my feet, the forest floor rustled and cracked—the withered remnants of vegetation not yet overtaken by spring. I had intended to find a willing plant as my muse but, instead, found myself drawn to a cluster of snowy white fans protruding from the base of a lichen and moss-covered trunk. All around the base, dried wisps of grass coiled into entangled streamers shooting upward toward the sky. Sitting cross-legged on the ground with paper and pencil in hand, I sketched the smattering of polypore bodies. The small interspersed with the large… the rough grey bark from which they emerged… the long thin enveloping tendrils. Maybe one day, I will return with learners in tow to once again admire the fruits of Mother Earth and partake in the simple pleasures of noticing all that is around us.

Fungal fruiting bodies are visible multicellular reproductive structures growing from mycelium to continue the fungal life cycle through, for example, spores (Moore et al., 2008) spread by wind or animals (Borgmann-Winter et al., 2023). Mushrooms are an example of a fruiting body (Kües & Liu, 2000), or in the case of polypore fungi on trees, the fruiting body is a conk (Zjawiony, 2004, p. 300). Once necessary environmental conditions are met, the mycelial hyphae branch, grow and group together into fungal primordia (i.e., baby fruiting body) that continue developing into the mature fruiting body (Kües & Liu, 2000). Many primordia may form; only some become fully developed (Moore et al., 2008).

In collaboration with Knowledge Keepers, Turner and Cuerrier (2022) compiled uses of fungi for food, medicine, spiritual practices, and technologies in Indigenous cultures. For example, field mushrooms are eaten by the Haudenosaunee, cinder conk fungus is boiled into a beverage by the Denesuline, and pine mushroom—prized for its aroma—is eaten by the Salishan peoples. Medicinally, spores from ripe puffballs have been used by the Anishinaabe and Blackfoot for treating nosebleeds and wounds, and diamond willow fungus by the Cree and Dene to treat headaches or earaches. Tinder fungus has also been used as fire starter by the Woods Cree, mosquito repellent by the Métis, and in ceremonies by Cree and Denesuline peoples.

Just as fruiting fungal bodies develop from its mycelium, pedagogical innovations emerge from grappling with our tensions, disrupting existing beliefs, and coming to realizations about our teaching. Innovating involves experimentation, and like fruiting primordia, not all ideas develop into matured fruits for harvesting. Come time, the fruits of our labours are shared and spread—discharged pores dispersing into the wind and through the bodies with whom we come into contact. Will we commit to creating environments that nurture the growth of our own fruiting bodies to maturity, spend a lifetime picking mushrooms borne from the fungal colonies of another, or avoid the harvest all together? Maybe our innovations, like cinder conk and matsutake, can offer sustenance to science educators who continue engaging in justice-oriented teaching. Maybe, like tinder fungus and puffballs, they can start fires in the hearts of educators and begin the process of healing wounds long inflicted by colonization and oppression.

Innovating means developing new ideas to transform existing practices (e.g., strategies and tools, theories, institutional structures) (Serdyukov, 2017). Changing teaching materials is the easiest form of implementation; changing how we teach is harder because learning new skills takes time (Fullan, 1982). Even more difficult for educators is changing beliefs because “they

challenge the core values held by a person regarding the fundamental purposes of education and they are often not explicit or recognized but rather buried at the level of unconscious assumption" (Fullan, 1982, p. 247). Innovative educational practices are processes of change rooted in pedagogical knowledge and theory, not singular tokenistic events or spontaneous improvisations (Álvarez Álvarez, 2015; Fullan, 1982).

This is consistent with Cochran-Smith's (2010) premise that a theoretical framework is central to social justice teacher education:

> social justice is *not* merely activities, but a coherent and intellectual approach… that acknowledges the social and political contexts in which teaching, learning, schooling, and ideas about justice have been located historically as well as acknowledging the tensions among competing goals. (p. 447)

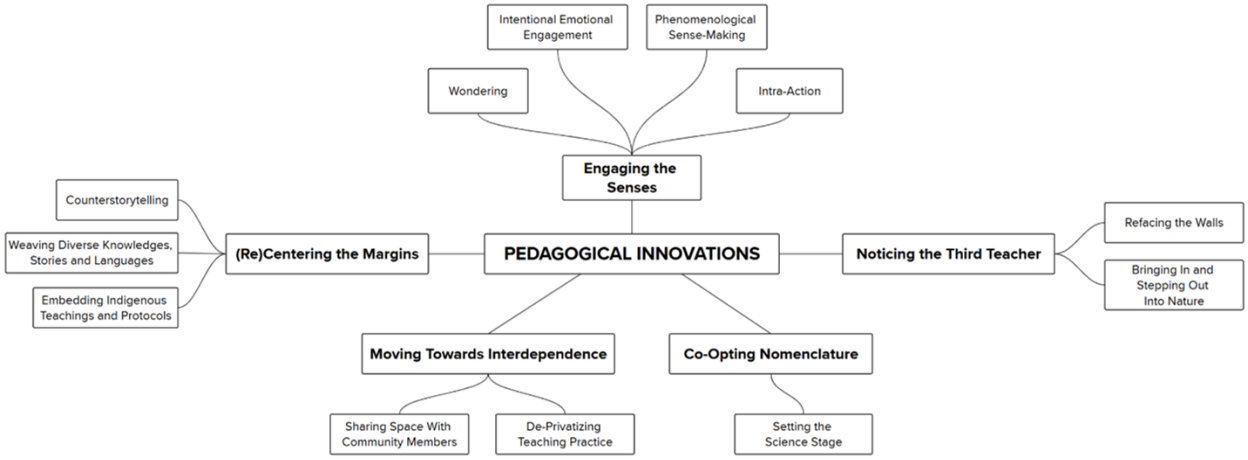
Pedagogical innovations for social justice teaching should be grounded in coherent frameworks that consider sociopolitical and historical contexts and not reduced to isolated classroom activities. Interestingly, Fullan (1982) offers the observation that changes in beliefs and teaching behaviours might be better thought of as reciprocal rather than linear (i.e., from beliefs to behaviours) because "trying new practices sometimes leads to questioning one's underlying beliefs; examining one's beliefs can lead to attempting new behaviour" (p. 247). In other words, even if you are not yet sure how to cultivate them, go into the bush, (respectfully) harvest a mushroom, and just get started.

Shifts in my teaching beliefs have primarily been discussed as part of the other culturally disruptive pedagogy tenets (tensions, disruptions, self-realizations), so I now focus on highlighting materials and teaching approaches while continuing to weave relevant theoretical knowledge. Although evaluating the impact of teaching practices on student learning is also an

important aspect of innovation (Serdyukov, 2017), this reaches beyond the scope of this study. The pedagogical innovations documented in this study include: the explicit naming of (Western) Sciences, noticing the third teacher through a consideration of physical spaces as science pedagogy, (re)centering the margins by prioritizing ethnoracial and diverse cultural knowledges, engaging the senses through embodied and emotional learning, and moving towards interdependency. Once again, a discussion of the theme will take place after the sharing of reflective vignettes. An overview of the pedagogical innovations is shown in Figure 18.

Figure 18

Themes and Sub-themes Emerging from Pedagogical Innovations Tenet



Note. This graphic was created using digital tools from Mural.co. The pedagogical innovations tenet is shown in the center in bolded capitalized letters. The pedagogical innovations themes are shown in boxes with bolded text. Sub-themes are shown in boxes with plain text.

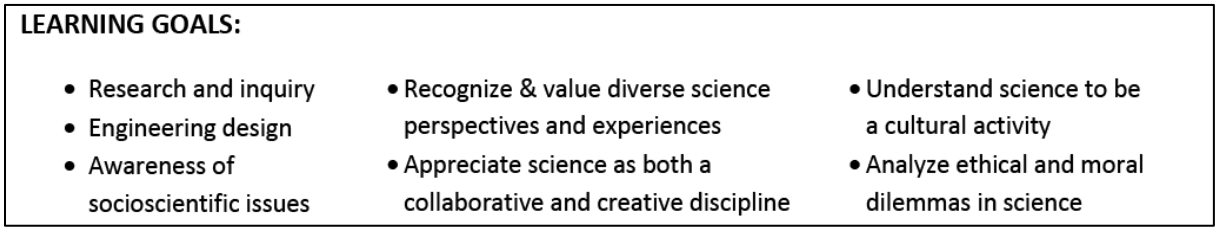
Pedagogical Innovations Theme 1: Co-opting Nomenclature—The Naming of (Western) Sciences

Setting the Science Stage. In addition to introductory activities like labelling popsicle sticks, name games and reviewing emergency procedures, we introduce the course learning plan.

Among goals such as developing inquiry and design skills, and appreciating science as collaborative and creative, the course outline artefact also explicitly stated that we will work toward valuing diverse science perspectives while coming to understand science as a cultural activity (see Figure 19). We chat about these ideas and how they might be new or unfamiliar. I share that it took time to realize Western Science is not the only lens, that I am still learning, but we will explore together. In efforts to teach transparently, all families will receive communications with introductory information and an invitation to review our learning plan, which is made available online should the paper copy disappear unceremoniously into the abyss.

Figure 19

Goals Section in Science Course Learning Plan Teaching Artefact



Note. A screenshot of the Learning Goals section from the Science Course Learning Plan teaching artefact.

Next, we introduce Etuaptmumk (Mi'kmaw), also known as Two-Eyed Seeing (as this concept has been elaborated on in detail previously in the literature review, I will not do so here). We talk about the concept's origins and what it means while explicitly naming Western Sciences and Indigenous Sciences, noting other perspectives exist as well. Then, we read the picture book, *Walking Together* (Marshall & Zimanyi, 2023). It is co-authored by Elder Albert Marshall, who brought forth the term Two-Eyed Seeing initially, and provides a beautiful introduction to the idea of "learn[ing] to know the world through two eyes" (Marshall & Zimanyi, 2023, p. 30).

Learners are invited to making observations from the illustrations, reflect on what they have learned from the story, and consider their wonderings. Their ideas are recorded in personal science journals prior to engaging in oral conversations as a class. Depending on the cohort and time remaining, we share from our spots or in a sharing circle (with additional conversations relating to circle protocols). I have had the privilege of hearing many insightful ideas (e.g., how the illustrations shift to different seasons), but one should also be prepared to mediate less savoury comments (e.g., the idea of learning *from* Frog seems to be triggering for many…).

In class materials, content and terminology for both Indigenous and Western Science perspectives are incorporated side-by-side. Those perspectives will continue to be explicitly named throughout the year. To explore key values of each lens, we read, reflect on, and discuss a short scholarly excerpt from Snively's (2016b) book chapter, *When Uncles Become Killer Whales: Bridging Indigenous Science, Western Science and Worldviews*. We also listen to a recording by the former Director of Indigenous Inclusion at the University of Winnipeg and now Manitoba Premier, Wab Kinew, explaining an Ojibwe perspective of living using rocks as an example (Bedoya, 2020). Learners are asked to reflect on and record their own perspective of science and consider similarities and differences between other worldviews and their own. On assessments later on, questions continue to be written in ways that explicitly name diverse perspectives. For example, students might be asked to demonstrate their understanding of the characteristics of living things from a Western Science perspective, while being able to explain why, from an Indigenous Sciences perspective, a rock could also be considered living.

Discussion. The first pedagogical innovation is Co-Opting Nomenclature: The Naming of (Western) Sciences, captured through the reflective vignette titled *Setting the Stage*. There exists a relationship between the language and values of different cultures and worldviews

(Snively, 2016b). Classification, from Indigenous worldviews, is based on cultural use and "views plants and animals, and all of creation as equals. Humans are not the controllers of nature, but coexist with nature, and can even be of lesser importance" (Snively, 2016b, p. 124). Western Sciences, instead, organizes life through a hierarchical Linnaean lens where humans are superior to the more-than-human world and "the world is assumed to be equally and neutrally classified… separated or removed from their derived cultural background" (Snively, 2016b, p. 124). In Western Sciences, binomial nomenclature has been used to identify species with Latin names. Carl von Linné, the originator of the system, also applied this process of naming to classifying humans based on skin colour (Yucesan, 2024). Using a system developed in France by Lavoisier, Guyton de Morveau, Berthollet, and de Fourcroy, nomenclature is also used in chemistry to systematically identify chemical compounds (Duveen & Klickstein, 1954).

It is ironic that a culture so enamoured with naming has, with regularity, neglected to clearly name and classify itself as one particular branch of science: the Western Sciences. Were it truly neutral, Western Science would be identified alongside all scientific worldviews rather than treated as the universal science. A pedagogical change in my teaching was emphasizing science as cultural and naming perspectives to make Western Science visible. The *Setting the Stage* vignette recounts introduction of these ideas in back-to-school science classes through science course outlines and introducing Two-Eyed Seeing as a guiding framework. Learning goals such as *valuing diverse science perspectives* and *understand science as a cultural activity* are documented in the vignette and Figure 19. The vignette reflected on how *we introduce Etuaptmumk (Mi'kmaw), also known as Two-Eyed Seeing… We talk about the concept's origins and what it means while explicitly naming Western Sciences and Indigenous Sciences*. The vignette also documented using several texts (e.g., picture book, excerpt from a scholarly text,

video) for exploring key ideas from each lens. Similar language is woven into assessments. As the vignette noted, *[on] assessments later on, questions continue to be written in ways that explicitly name diverse perspectives.* These enacted pedagogies set the stage for pluralistic science learning to occur within a cohesive framework rather than as tokenistic add-ons and thus, remains consistent with the premise that social justice education should be rooted in knowledge, theory and context (Álvarez Álvarez, 2015; Cochran-Smith, 2010).

Pedagogical Innovations Theme 2: Noticing the Third Teacher—Physical Spaces as Science Pedagogy

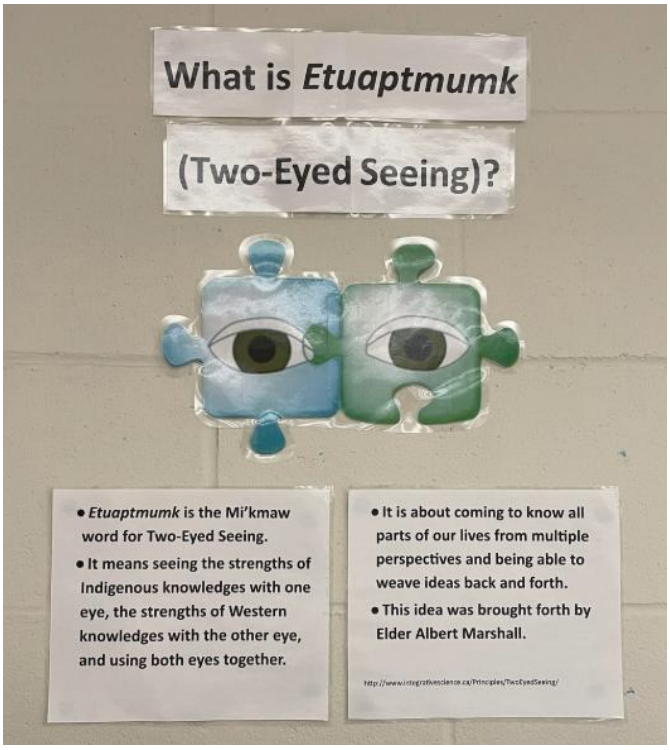
Refacing the Walls. Each August, I set aside one day specifically for attending to the physical classroom space. No planning or copying, just cleaning, organizing, and indulging in a little laminating. Turning the key, I open the door, check the light switch, and flail my arms wildly to trigger the energy saving sensor. With the exception of a terribly located immobile island to which all wiring must be funneled, I love this classroom with its ample tan wooden cabinetry, sinks, and generous windows filling the room with natural light. I am fortunate to teach in a physical space that mostly aligns with my pedagogical leanings, but also recognize there are pre-determined aspects we are not in control of like seating options or table types. However, there are always small things we can do to (co)create welcoming environments. I value leaving empty space for displaying student learning, maintaining a maker corner with loose parts, recyclables and tools for exploring and creating, as well as clearly organized supplies, materials and resources that students can access freely as needed.

Against this existing backdrop, I changed our physical learning space by displaying diverse books on the whiteboard ledge and removed several posters (so long, interactive periodic table… goodbye, Gandalf meme… farewell, charismatic frogs). Instead, a display outlining

Two-Eyed Seeing is now on the wall (see Figure 20). We also added a curated selection of intersectionally diverse scientist stories from the I Am a Scientist project (The Plenary, Co., 2024), which can be connected further to resources and lessons for exploring. Also new are inclusive space and seven teachings posters. While I do not believe any individual wall display, on its own, sufficiently addresses systemic issues in a meaningful way, when used as part of a broader assortment of equity-minded pedagogies, I do think conveys the values of a teaching space while inviting learners to interact with new ideas. For teachers who might be hesitant or nervous, this could be an accessible first step provided that it does not remain the only.

Figure 20

Two-Eyed Seeing Classroom Display



Note. This is an image of a Two-Eyed Seeing wall display. It was created using information and images from the Integrative Science website (Cape Breton University, n.d.).

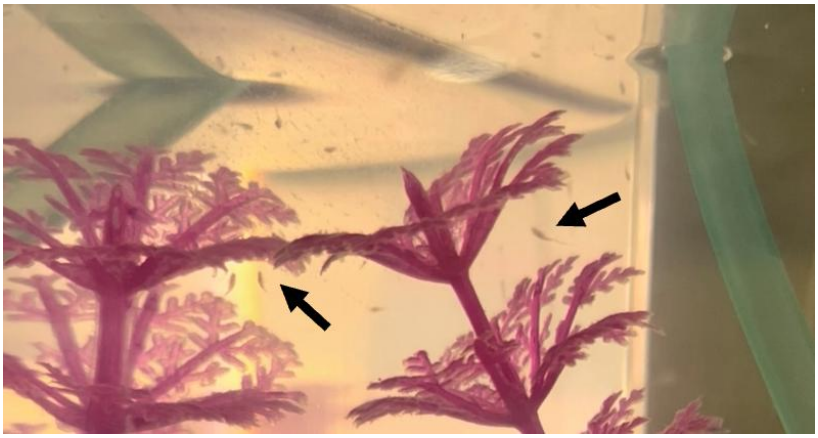
Bringing In and Stepping Out into Nature. In early summer, I looked around my home for the hardiest house plants I could find and started propagating them—the leaves of donkey's ear echeveria, jade plant stems, fleshy aloe vera pups. By September, they were ready to be transplanted into their new home. With a combination of artificial plant lamp and natural window light, they managed to stay alive. We take care of them together as a class and I have taught them to notice and feel for drying soil before watering. Informally, they often spark impromptu conversations about other plant species. As I reflected in my teaching journal, *the plants were able to serve as a provocation for conversation*. Aloe has even come to our aid during glue gun incidents. During science class, our plants have also aided us in practicing the art of making observations, sketches and wonderings; it is always a treat to highlight and celebrate the prior plant knowledge different learners bring to the conversation.

I am hesitant about class pets due to the long-term care required. However, potential pets—axolotls! Hermit crabs! Bettas!—were researched with such fervour that it compelled me to follow their leads. We agreed on brine shrimp, which I had previously attempted unsuccessfully. I approached a local store for guidance and supplies. Would a tank with conditioned water, aeration and heater help? We even measured the salinity with a hydrometer. First attempt: expired eggs, no hatching. Second attempt: new eggs, hatching. To our excitement, they grew and fed happily on yeast… at least until their post weekend demise. More food? Third attempt: The weekend is still our nemesis. Brine shrimp are typically hatched for feeding fish, so information on growing them to adulthood was limited. Posting details of our attempts to an online aquarium forum to solicit community help. Fourth attempt: Preventing ammonia accumulation via water changes finally leads to success (at least until an even more formidable nemesis: winter break) (see Figure 21). The shrimp initiated many great conversations on

homeostasis and microscopy. Their pink translucent bodies with visible egg sacs led to fascinating discussions on forms of reproduction. There were wonderings about other living things like Triops and horseshoe crabs. Most importantly, this adventure taught us that science is not a linear path free from difficulties, but a lesson in grit and perseverance.

Figure 21

Brine Shrimp in Tank

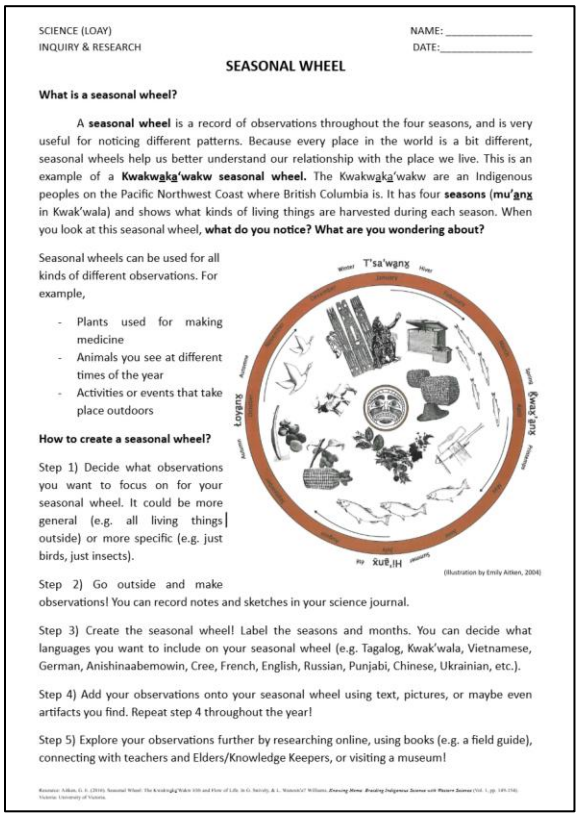


Note. This is a photograph of brine shrimp growing in a classroom tank. The arrows draw attention to two individual brine shrimp.

I also wondered how we might come to think of the outdoors as a classroom space. We have been trying to go outside regularly throughout the year to construct seasonal wheels (see Aitken, 2016 and Figure 22) with our observations. I noticed some groups can remain reflective and focused for upwards of 30-45 minutes, while others can become restless after 5-10 minutes. For this reason, actively teaching students how to make sustained, detailed observations is needed. It takes time to build stamina. I also found using sit spots (Strich, 2012) to be helpful for anchoring learners and encouraging attentiveness to their surroundings. Learners are encouraged to respectfully bring in outdoor elements like a leaf or blade of grass to add to their wheels.

Figure 22

Seasonal Wheel Teaching Artefact



SCIENCE (LOAY) NAME: _____
INQUIRY & RESEARCH DATE: _____

SEASONAL WHEEL

What is a seasonal wheel?

A **seasonal wheel** is a record of observations throughout the four seasons, and is very useful for noticing different patterns. Because every place in the world is a bit different, seasonal wheels help us better understand our relationship with the place we live. This is an example of a **Kwakwɣaka'wakw seasonal wheel.** The Kwakwɣaka'wakw are an Indigenous peoples on the Pacific Northwest Coast where British Columbia is. It has four **seasons (mu'ɣanx** in Kwak'wala) and shows what kinds of living things are harvested during each season. When you look at this seasonal wheel, **what do you notice? What are you wondering about?**

Seasonal wheels can be used for all kinds of different observations. For example,

- Plants used for making medicine
- Animals you see at different times of the year
- Activities or events that take place outdoors

(Illustration by Emily Aitken, 2004)

How to create a seasonal wheel?

Step 1) Decide what observations you want to focus on for your seasonal wheel. It could be more general (e.g. all living things outside) or more specific (e.g. just birds, just insects).

Step 2) Go outside and make observations! You can record notes and sketches in your science journal.

Step 3) Create the seasonal wheel! Label the seasons and months. You can decide what languages you want to include on your seasonal wheel (e.g. Tagalog, Kwak'wala, Vietnamese, German, Anishinaabemowin, Cree, French, English, Russian, Punjabi, Chinese, Ukrainian, etc.).

Step 4) Add your observations onto your seasonal wheel using text, pictures, or maybe even artifacts you find. Repeat step 4 throughout the year!

Step 5) Explore your observations further by researching online, using books (e.g. a field guide), connecting with teachers and Elders/Knowledge Keepers, or visiting a museum!

Note. This is the Seasonal Wheel handout for students created based on information in Aitken (2016). The circular diagram is from Aitken (2004), as cited in Aitken (2016), and was used in the lesson to prompt a discussion of what students noticed and might be wondering about.

Whenever possible, I also encourage my classes to spend time observing meteorological phenomena and have found many connections to, for example, our unit on optics. For example, sun dogs, which connects to concepts of refraction, appear during the daytime in the winter months and can frequently be viewed during class time. There have also been opportunities for students to view other phenomena outside of class like the northern lights during geomagnetic storms, a partial solar eclipse, or meteor showers. Whenever possible, I try to communicate with families so that they, too, can partake in such viewings together.

Discussion. The second pedagogical innovations theme is Noticing the Third Teacher: Physical Spaces as Science Pedagogy. This theme is framed by two reflective vignettes: *Refacing the Walls*, which is about changing what resources are displayed inside the classroom, and *Bringing In and Stepping Out into Nature*, which reflects on how we can blur boundaries between where we interact with/in nature.

The Reggio Emilia approach has been influential in early childhood education (Wexler, 2004). From this perspective, in addition to classroom teachers and families as educators of children, the environment is an important third, living teacher influencing learning:

> We do not usually think of the environment as alive, in the way that a person is; instead, we see it as coming about as a result of human imagination and work… that is, if we truly see it at all… By seeing the environment as an educator, as the Reggio Emilia approach does, we can begin to notice how our surroundings can take on a life of their own that contributes to children's learning. (Strong-Wilson & Ellis, 2007, p.40)

There are eight principles foundational to understanding the role of environment as third teacher. These include aesthetics (e.g., colours, lighting), flexibility (e.g., with time, how materials are used), collaboration of a child with both other children and adults, and relationships (i.e., between materials and people) (Fraser, 2012).

The remaining four principles (transparency, active learning, reciprocity, and bringing the outdoors in) closely align with the innovations relating to the physical space as pedagogy that came about from this (re)Search. Transparency, which refers to both the literal use of transparent materials and figurative meaning of being open to ideas or making children's learning visible (Fraser, 2012), can be found in the *Bringing In and Stepping Out into Nature* vignette, which documented a clear tank used for growing brine shrimp (see Figure 21). The *Refacing the Walls*

vignette also documented various posters (e.g., Two-Eyed Seeing display, diverse scientist stories, inclusive space posters, seven teachings posters), which reflect transparency of values (e.g., respecting diverse worldviews and identities), and although not necessarily a new innovation, there were also indications that bulletin board space was left for transparently displaying students' work in the future. The posters, in particular, serve to disrupt White, Western, heteropatriarchal science classroom spaces by celebrating counterstories of diverse scientists and elements of Indigenous cultural teachings.

In *Bringing In and Stepping Out into Nature*, the presence of indoor plants; the seasonal wheel learning experience where students went outdoors to make observations, record patterns, and gather leaves and grass; and invitations to observe meteorological phenomena exemplify the principle of bringing the outdoors in, which involves connecting with places, noticing patterns, and bringing outdoor materials inside (Fraser, 2012). The vignette also reflected on how *potential pets… were researched with such fervour that it compelled me to follow their leads. We agreed on brine shrimp… First attempt: expired eggs, no hatching… Fourth attempt: Preventing ammonia accumulation via water changes finally leads to success… The shrimp initiated many great conversations on homeostasis and microscopy*. This brine shrimp experience demonstrates reciprocity (openness to changing in response to learners) through my response to learners' desires for bringing animals into the classroom and active learning (inviting exploration and problem solving) through troubleshooting the process of raising shrimp to adulthood and engaging in conversations (Fraser, 2012).

Many of these innovations could be considered what has been termed, *provocations*, which are materials "meant to surprise children and spark discussion" (Strong-Wilson & Ellis, 2007, p. 42) and can be planned or happenstance (Freeman, 2021). A consideration of

terminology is put forth by Kashin (2017), who suggests provocations actually begin as *invitations* with potential for provoking a learner response, at which point the materials or experiences then become a *provocation*. This appears congruent with Freeman's (2021) study where not all science events teachers viewed as provocations led to children being provoked. Without further teacher interactions (e.g., guiding conversations), children became disinterested or did not produce meaningful responses to the materials. In this study, I facilitated conversations on topics arising from materials in the space, suggesting that the invitations did indeed become provocations. For example, the *Bringing In and Stepping Out into Nature* vignette showed how classroom plants *often spark impromptu conversations about other plant species*. Additionally, the *pink translucent bodies [of brine shrimp] with visible egg sacs led to fascinating discussions on forms of reproduction… [and] other living things like Triops and horseshoe crabs.*

Science educators may find the Reggio Emilia approach, including use of provocations, useful (Freeman, 2021; Stegelin, 2003). Interestingly, Reggio Emilia—mainly of interest in early childhood education—finds compatibility with a queer science pedagogy. The former views "the child as a gregarious and capable thinker and doer" (Stegelin, 2003, p. 164) who "will often find uses for objects and spaces that adults do not anticipate or intend" (Strong-Wilson & Ellis, 2007, p. 43) while "[q]ueering honors children as complete and real and fully human beings—albeit human beings who often do human being differently than older beings tend to do" (Leafgren & Sander, 2019, p. 238). As we work to queer science, I wonder how those of us working with adolescents might learn from early childhood educators, pedagogies and research. Afterall, as Gilbert and Gray (2019) remind us, "[q]ueer theories inform wonder by inviting teachers and other anxious parties to embrace, find joy in, and be inspired by the wondrous wildness of children and their unfettered imaginative possibilities" (p. 119). The raising brine shrimp activity

is reminiscent of Gunckel's (2009) suggested fruit fly experience for queering science, where jars of fruit flies could be kept in the classroom to invite learning about reproduction and life cycles. However, keeping brine shrimp as pets also demonstrates how a single learning experience can contribute to both disrupting and reinforcing hegemonic science practices, as it remains Western Science in flavour to subject living things to aquarium life and our anthropocentric desires to observe them.

Pedagogical Innovations Theme 3: (Re)Centering the Margins—Prioritizing Ethnoracial and Diverse Cultural Knowledges

Counterstorytelling. In my teaching, I have mobilized science stories that provide glimpses into the experiences of marginalized groups. The story of Dr. Patricia Bath, ophthalmologist and inventor of the Laserphaco Probe for treating cataracts, for example, creates opportunities for learners to reflect on racism, sexism and classism in science. In addition to the picture book, *The Doctor with an Eye for Eyes* (Mosca, 2017), we also watch online videos of Dr. Bath's interviews. However, as my teacher journal notes, I noticed the book *itself kind of reinforces binaries because it talked about White vs. Black. The text does mention "different shades" to imply everything in between, but it was mostly focused on the Black-White binary. It also reinforced gender binaries by continuously referring to "boys and girls" and "men". There was no mention of LGBTQ people.*

Prior to introducing the HeLa cell story, learners are invited to discuss how they feel about their body being used for research, who gets to decide, and any conditions that might influence their opinion (e.g., which body part(s), if the research is life changing for society or not, any forms of compensation). Then, we learn about Henrietta Lacks' story and how her cells were used for research without her knowledge or consent, and engage in further conversations

(e.g., thoughts about what happened, the exploitation of marginalized groups, wonderings they have). Yet another example, is reading from *Braiding Sweetgrass for Young Adults* (Kimmerer & Smith, 2022), which weaves Dr. Robin Wall Kimmerer's personal experiences together with botany teachings from Indigenous and Western Science perspectives. The Asters and Goldenrod chapter, for instance, connects beautifully to our optics unit and illustrates how the science academy has privileged Western Science while denigrating the worldviews of others.

Weaving Diverse Knowledges, Stories, and Languages. I detail the inquiry learning experience, Ode Min: An Exploration of the Heart as an example of how I have attempted to weave diverse knowledges, stories, and languages in my science teaching.

> *In the Haudenosaunee Creation story, Skywoman's beautiful daughter, whom she carried in her womb from Skyworld, grew on the good green earth, loving and loved by all the other beings. When she died, her final gifts—our most revered plants—grew from her body, and the strawberry arose from her heart.* (Kimmerer & Smith, 2022, p. 39)

Beginning with a read aloud from the Gift of Strawberries chapter from *Braiding Sweetgrass for Young Adults* (Kimmerer & Smith, 2022), botanist Robin Wall Kimmerer introduces the heart berry, ode min (Potawatomi), also known as *Fragaria virginiana* (Latin), the strawberry. As we learn about gift and market economies, readers are encouraged to reconsider what it might mean to "understand the earth as a gift again" (p. 47). We reflect on what we have learned and emerging wonderings—sharing ideas with one another in conversation.

The inquiry menu, which uses digital and physical materials, is then introduced. Learners engage with stations in a sequence of their choice at their own pace. I inform a few that they can complete three or four, as opposed to all six. The format of the menu lends itself well to differentiation. They can explore each activity independently or with a small group of peers. The

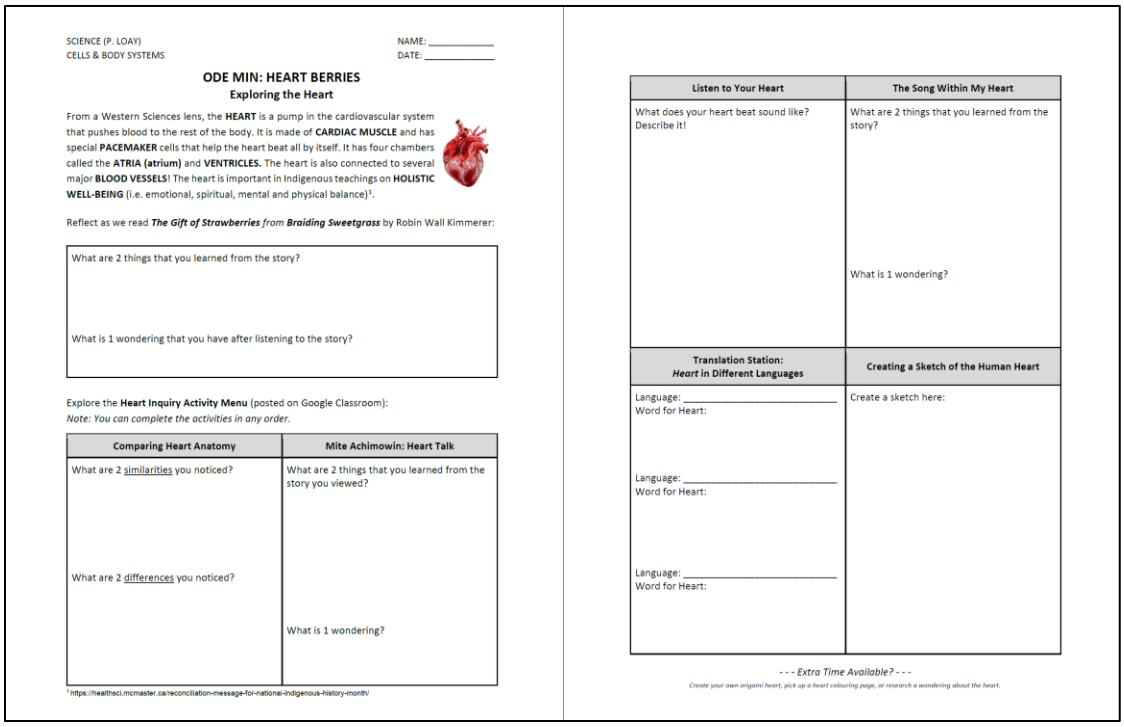
handout they used to record their reflections from the read aloud also has a graphic organizer for the inquiry menu with additional prompts (see Figure 23). I refer to each activity as a station because initially, they were set up around the classroom as physical stations that students rotated to. I liked this kinesthetic aspect, but because some stations involved digital media, it was logistically challenging to repeatedly log into multiple digital devices to load videos for each class section each day they worked on the inquiry. Thus, the stations were later converted into a hyperlinked digital menu students could access independently. Physical materials are stored together in a designated space where students could pick up and return as needed.

One station explores comparative heart anatomy between organisms using pictures and actual heart specimens embedded within an acrylic block, and a second station involves describing the sound of their hearts using stethoscopes. Digital stories from the *mite achimowin*: *Heart Talk—First Nations Women's Expressions of Heart Health Digital Story Research Project* (see National Collaborating Centre for Indigenous Health, 2019 and Fontaine et al., 2019), which involved participants from Manitoba, are explored in a third station. Themes from the digital stories related to social determinants of health (e.g., racism, access to medical care), residential school trauma, and tensions between Indigenous and Western approaches to lifestyle, diet, medicine and healthcare. In a fourth station, learners listen to audio recordings (with English and Cree options) or read a physical text of the picture book, *The Song Within My Heart* (Bouchard, 2002), which tells the story of drumming, heart beats, and pow wows. In these previous two stations, there are reflections on their main takeaways and wonderings. In the fifth station, learners make observations using three-dimensional heart models (digital and 3D printed) to create heart sketches. The remaining activity is the translation station, where students research the word for 'heart' in three different languages (one must be in an Indigenous language) by

searching online, using print dictionaries, asking classmates who know various languages, or tapping into their own language knowledge. Early finishers are invited to further explore resources from the inquiry, create an origami heart, or work on heart themed colouring pages.

Figure 23

Ode Min Rotation Stations Teaching Artefact



SCIENCE (P. LOAY)
CELLS & BODY SYSTEMS

NAME: _____
DATE: _____

ODE MIN: HEART BERRIES
Exploring the Heart

From a Western Sciences lens, the **HEART** is a pump in the cardiovascular system that pushes blood to the rest of the body. It is made of **CARDIAC MUSCLE** and has special **PACEMAKER** cells that help the heart beat all by itself. It has four chambers called the **ATRIA (atrium)** and **VENTRICLES.** The heart is also connected to several major **BLOOD VESSELS**! The heart is important in Indigenous teachings on **HOLISTIC WELL-BEING** (i.e. emotional, spiritual, mental and physical balance)[1].

Reflect as we read ***The Gift of Strawberries*** *from* ***Braiding Sweetgrass*** by Robin Wall Kimmerer:

What are 2 things that you learned from the story?

What is 1 wondering that you have after listening to the story?

Explore the **Heart Inquiry Activity Menu** (posted on Google Classroom):
Note: You can complete the activities in any order.

Comparing Heart Anatomy	Mite Achimowin: Heart Talk
What are 2 similarities you noticed? What are 2 differences you noticed?	What are 2 things that you learned from the story you viewed? What is 1 wondering?

[1] https://healthsci.mcmaster.ca/reconciliation-message-for-national-indigenous-history-month/

Listen to Your Heart	The Song Within My Heart
What does your heart beat sound like? Describe it!	What are 2 things that you learned from the story? What is 1 wondering?
Translation Station: *Heart* in Different Languages	**Creating a Sketch of the Human Heart**
Language: _____ Word for Heart: Language: _____ Word for Heart: Language: _____ Word for Heart:	Create a sketch here:

- - - Extra Time Available? - - -
Create your own origami heart, pick up a heart colouring page, or research a wondering about the heart.

Note. This is the accompanying student handout for the Ode Min: An Exploration of the Heart rotation stations activity.

Embedding Indigenous Teachings and Protocols. We hoped to return the ceremonial tobacco to water as instructed. For weeks, I searched my brain and poured over Google Maps for a nearby stream or pond within walking distance. Science class was thirty minutes: five for gathering, ten for travelling, at least five for placing the tobacco, and ten for the return trip (assuming all proceeds as planned). When the day arrived, we sauntered out to… a puddle on school property. Heavy rains flooded a long stretch of grass between the parking lot and bus loop

(basically a small pond). Sunlight peaked through early spring trees forming a loose, lacy canopy overhead. And so, into this picturesque pond-like puddle beneath a row of trees, we each returned a pinch of the crisp, sweetly aromatic, golden leaves to the land as we reflected on the teachings we were gifted on science and storytelling.

My knowledge of Indigenous cultural protocols is limited, but something I am learning more about. As I learn, I share with students. Educators need to appropriately introduce and normalize diverse cultural practices, especially in contexts where misconceptions and fears of protocols not from dominant cultures persist. Prior to the excursion, we had conversations about tobacco plants and where they grow, how to offer tobacco when seeking guidance, how climate might change what is appropriate (e.g., tea or something homemade), and when in doubt, ask. Student helpers are invited to participate in making territorial acknowledgements and offerings to guests. This process is supported by script outlines they can personalize and rehearsing together during recesses. We talk about what it means to host guests at our school in a good way. For many, it is their first time engaging with these protocols. I hope that by providing these small opportunities, they will be able to do so again in the future with confidence and respect.

Additionally, I try to embed teachings such as Two-Eared Listening (Archibald, 2008), being respectful by not taking more than what you need (Vukelich Kaagegaabaw, 2023) and minimizing harm when harvesting (Kimmerer, 2013). Two-Eared Listening manifests during discussions or the viewing of texts. Ideas introduced in class may be unfamiliar and have potential to elicit discomfort. Learners are reminded that these feelings are normal as we interrogate our existing worldviews. They are encouraged to find one thing that resonates even if their openness and understandings are still tentative and emerging. Not taking more than what you need is especially relevant when engaging in design challenges, which require physical

materials. Classes are reminded to leave some for others, not be wasteful, and to return what they no longer need for constructing prototypes. In my teacher journal, I also reflected on *not taking more than what you need and being respectful and responsible for the land when we go outside to make observations* or harvest for their seasonal wheels. This last one sometimes frustrates me; there remains unnecessary grass ripping, branch breaking and bug squashing, which I find disrespectful. Friendly insects minding their own business died because I decided to bring my class outside—something I still struggle to reconcile.

Discussion. This third pedagogical innovation is (re)Centering the Margins: Prioritizing Ethnoracial and Diverse Cultural Knowledges. This theme is framed by the following three reflective vignettes: *Counterstorytelling*; *Weaving Diverse Knowledges, Stories, and Languages*; and *Embedding Indigenous Teachings and Protocols*.

As discussed in the literature review, culturally disruptive pedagogy (San Pedro, 2018) originated from culturally relevant/responsive frameworks (Gay, 2010; Ladson-Billings, 1995) but differs in that culturally disruptive pedagogy aims to disrupt dominant (i.e., White) norms. The findings suggest that culturally responsive teaching supports the culturally disruptive pedagogical framework. Culturally responsive teaching, Gay (2010) writes, "is the behavioral expressions of knowledge, beliefs, and values that recognize the importance of racial and cultural diversity in learning" (p. 31). This recognition of racial and cultural diversity itself is disrupting of Whiteness because the dominant culture is seldom acknowledged as culture at all. Pedagogical innovations from this study point out science perspectives by naming *both* Indigenous and Western Sciences as cultural understandings while drawing attention to the subjugation of other worldviews by the dominant group. For example, in the *Counterstorytelling* vignette, learners are

introduced to *botany teachings from Indigenous and Western Science perspectives… [and] how the science academy has privileged Western Science while denigrating the worldviews of others.*

Culturally responsive teaching also involves valuing diverse cultural ways of knowing and being while using these knowledges to guide our teaching and interactions with learners (Gay, 2010). The following examples demonstrate how I created opportunities for students to participate in cultural meaning-making during science class. As documented in the *Weaving Diverse Knowledges, Stories, and Languages* vignette, the Ode Min inquiry menu involved exploring learning activities from both Western Science (e.g., using stethoscopes, comparative heart anatomy with models) and Indigenous Sciences (e.g., viewing stories about heartbeats and powwows, exploring First Nations women's understandings of heart health). Additionally, there was a *translation station, where students research the word for 'heart' in three different languages (one must be in an Indigenous language) by searching online, using print dictionaries, asking classmates who know various languages, or tapping into their own language knowledge*. These experiences introduced Indigenous Science knowledges through a Two-Eyed Seeing lens and also created opportunities for students to tap into their own funds of knowledge (Moll et al., 2005) relating to language, which is an aspect of culture.

As documented in the *Embedding Indigenous Teachings and Protocols* vignette, students were exposed cultural teachings and protocols. Embedded within various learning experiences were *teachings such as Two-Eared Listening (Archibald, 2008), being respectful by not taking more than what you need (Vukelich Kaagegaabaw, 2023) and minimizing harm when harvesting (Kimmerer, 2013)*. Students had opportunities to learn *what it means to host guests at our school in a good way*, which included *how to offer tobacco when seeking guidance [and] making territorial acknowledgements*. Together as a class, *we each returned a pinch of the crisp, sweetly*

aromatic, golden leaves to the land as we reflected on the teachings we were gifted on science and storytelling. When *all* students are able to learn cultural teachings and protocols (e.g., returning tobacco to the land, honouring teachings of respect, minimizing harm to plants and animals), the teacher is responding to the worldviews of Indigenous learners while creating opportunities for learners of other worldviews (including dominant ones) to disrupt their own.

Another aspect of culturally responsive teaching is "challenging racial and cultural stereotypes, prejudices, racism, and other forms of intolerance, injustice, and oppression" (Gay, 2010, p. 31). The *Counterstorytelling* vignette described how students learned about Henrietta Lacks, whose cells were used without consent. They also learned about the experiences of IBPOC scientists who faced institutional barriers and oppressions. One activity from the inquiry menu described in the *Weaving Diverse Knowledges, Stories, and Languages* vignette also included *digital stories related to social determinants of health (e.g., racism, access to medical care), residential school trauma, and tensions between Indigenous and Western approaches to lifestyle, diet, medicine and healthcare.* In highlighting the experiences of IBPOC scientists, First Nations women's experiences with healthcare systems, and the exploitation of marginalized communities by science, these activities provided opportunities for learners to disrupt the façade of science as free from complicity in perpetuating and reinforcing injustice and oppression. Other research has shown counterstorytelling can be used in classrooms through engagement with existing science stories (Riley & Mensah, 2023) or having learners tell their own science stories (Calabrese Barton & O'Neill, 2008). Stories, more generally, have also been used to raise awareness of environmental issues (Hadzigeorgiou, 2016). Mobilizing counterstorytelling, thus, contributes to fostering citizenship through science (Calabrese Barton & O'Neill, 2008).

Pedagogical Innovations Theme 4: Engaging the Senses—Embodied and Emotional Learning

Opportunities for Wondering. With the fortuitous convergence of a cloudless spring sky and geomagnetic storm, shades of jade and amethyst revealed themselves faintly overhead (see Figure 24). Within light polluted city limits, this glimpsing of the aurora was a special occasion indeed. Craning my neck upwards in the quiet, I realized I was alone, not lonely. As night cooled and sky darkened, arriving from places far from where I stood were messages and photographs from the vantage point of fellow observers. I had earlier hesitated… unsure if, hours having passed since I left our classroom, I desired to communicate with learners and families on the eve of a weekend. I was, ultimately, enchanted by the possibility of sharing in this moment of learning together under the classroom of the night sky. Months earlier, we had learned about the science and stories of this meteorological phenomenon through texts within our classroom; now, we would immerse our bodies and senses in the lights that have long been so captivating.

Figure 24

Observing the Northern Lights

Note. This is a photograph of the northern lights during a geomagnetic storm in May 2024.

We began our aurora borealis exploration with *SkySisters* (Bourdeau Waboose, 2000), a story about two Ojibwe sisters searching for the northern lights. While travelling, they remind each other to whisper when speaking. At the top of Coyote Hill, the SkySpirits finally arrive:

> We watch them sway and flicker in the four directions. Streamers of pink and purple swirl and flow across the sky. Twisting and turning, the SkySpirits join together. Around and around they spin. Faster and faster. Their shimmering parkas and scarves lift with the wind as they dance in the northern sky. (p. 25)

As we read the story, learners are invited to reflect on what they are learning from the story and wonderings that they might have. Afterwards, we share ideas in small groups and as a whole class. This protocol of reflecting, wondering, and sharing is a routine in our science class.

Next, we introduce the inquiry menu, Chasing Aurora: An Exploration of the Northern Lights (see Figure 25). The logistics are similar to the heart inquiry menu described in an earlier vignette. In one station, learners explore the aurora from a Western Sciences perspective to learn how fluorescent light is produced via the interaction of charged particles from the sun with gases in the Earth's atmosphere. In another activity, we access live and replay camera feeds from Canada and around the world to observe the northern lights in action. From our classroom, we can vicariously visit Churchill in northern Manitoba, Yellowknife in the Northwest Territories, and even Lapland in Finland. Students also consider a wondering during this process.

In two other stations, learners listen to various Indigenous stories of the northern lights and once again, record their learning and wonderings. For example, according to Wilfred Buck, from one Ininewuk perspective, the northern lights are dancing spirits:

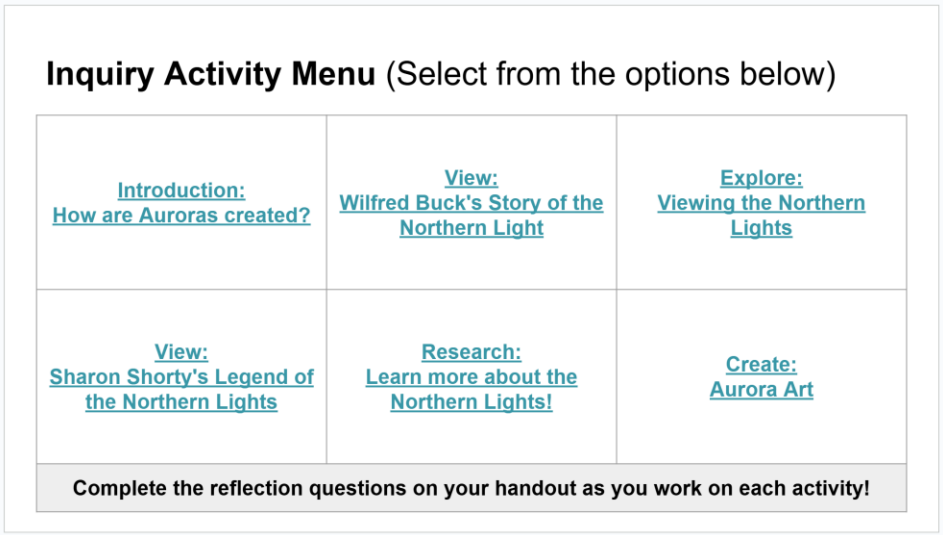
> As young people, we were told never to whistle at the Northern Lights because if we did, the spirits associated with these lights would come and take us away. Of course we had to test the validity of this warning. When we whistled, the lights moved, which inspired us to run and hide. (Buck, 2009, p. 72)

This was an important teaching, because in the winter when food for animals was scarce and the nights were dark, parents and Elders wanted children to stay indoors to avoid becoming a hungry animal's next meal (Manitoba First Nations Education Resource Centre, 2016).

The fifth station involves researching to learn more about auroras. They can either choose to learn about a personal wondering or select a question from an available list (e.g., What are the northern lights called in other languages? What are stories about the northern lights from different parts of the world? Why are auroras different colours?). Learners are encouraged to generate additional wonderings from their research. The last remaining station is creating aurora art, which is always a favourite. A variety of materials (e.g., chalk, pastels) are provided for creating the artwork. Early finishers can continue to explore resources in the inquiry menu, research another wondering, or work on a northern lights themed colouring page.

Figure 25

Chasing Aurora Inquiry Menu Teaching Artefact



Note. This is a screenshot of the main menu slide from the Chasing Aurora inquiry menu, which contains hyperlinks to slides with instructions and resources for each station activity.

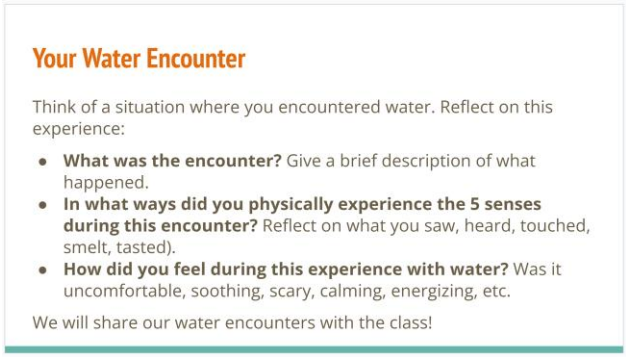
Opportunities for Intentional Emotional Engagement. I have also tried to be more intentional about supporting emotional engagement. Although science demonstrations have always been an aspect of my teaching, I had considered them as a fun way to introduce a phenomenon or support students in building conceptual understanding. As a provocation, I knew they generated positive feelings, but the emotional aspect was more byproduct than goal. After reading about emotional engagement, generating emotional energy and entrainment of behaviours through classroom rituals such as science demonstrations (see Olitsky & Milne, 2012) for a paper I wrote in my first graduate course, I saw demonstrations in a new light. As I reflected in my teacher journal, in September, I decided to open with jabbing pencil crayons through a bag of water overtop of a volunteer's head *to build rapport with the students… I think when they start off with a positive perception… they will be more willing to engage with new and unfamiliar ideas… There was a lot of cheering and clapping and laughter… I purposely pause after a few [pencil crayons] and suggest maybe we stop there… of course they want to keep going!* When I do science demonstrations now, I understand it as an intentional invitation to engage in embodied, emotional learning that disrupts the traditionally masculine, rational, restrained, and emotionless stereotypes surrounding science.

I also intentionally ask students to reflect not only on what they are thinking about, but also how a learning experience makes them feel emotionally and physically. They are invited to consider these ideas when, for example, we go outside for a nature scavenger hunt. When introducing concepts about water, I also ask students to write and share stories of their water encounters (e.g., swimming at the lake, jumping in a puddle, getting drenched in the rain, viewing a waterfall) (see Figure 26). They are invited to incorporate elements of the five senses (i.e., what did it sound, taste, feel, look, and smell like) as well as their emotions. Was it a scary

experience? Calming? Joyful? Additionally, I try to find science stories that capture and convey the emotions of scientists to remind us all, that science is a pursuit filled with emotions both positive and negative. The documentary, *Chasing Coral* (Orlowski, 2017) is one such story that I would recommend. It captures the passion and disappointment, joy and fear, excitement, sadness, and hope that the team of scientists, divers, and film-makers experience as they try to raise awareness of climate change and its effects on our ocean ecosystems.

Figure 26

Water Encounter Teaching Artefact



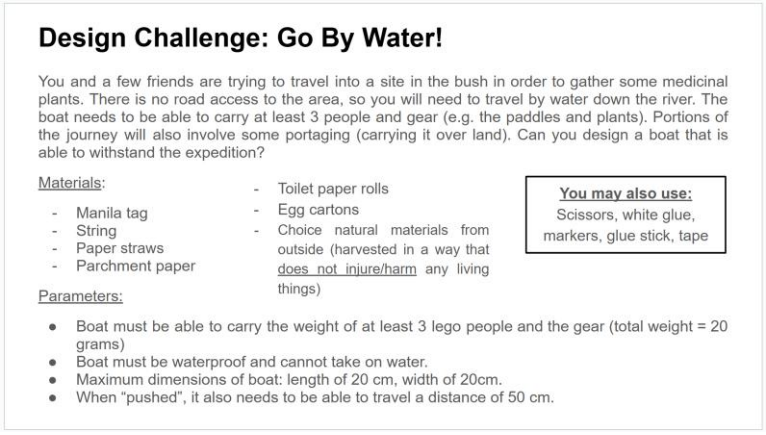
Note. This is a screenshot of a slide from the Water Encounter lesson where students reflected on emotions and physical sensations experienced during their water encounter.

Opportunities for Phenomenological Sense-Making. After watching an episode of Mi'kma'ki titled Gwitna'q (Go by Canoe) (Collier, 2022), which is about how birchbark canoes are being revived in Newfoundland by the Miawpukek First Nation, I wanted to try developing a design challenge around birchbark canoe building. I was unable to collaborate with an Elder or Knowledge Keeper on this (and hope that one day I will be able to do so firsthand) but still wanted to make a beginning effort that involved authentic Indigenous voices as much as possible. I spent a lot of time searching for additional resources to mobilize but found the process challenging. For example, there was an interesting CBC interview with Elder Marcel Labelle, but

it was entirely in French and the English subtitles, when displayed on the screen, were too small for students to read. Although I have since encountered the book *Indigenous Ingenuity* (Havrelock & Kay, 2023), which has a chapter on modes of transportation, including birchbark canoes, it had not yet been published at the time. Eventually, by using Gwitna'q and the resource document, *The Birchbark Canoe: Navigating a New World* (Broderick, 2014), which was developed in collaboration with Indigenous experts, I attempted to put together the following learning experience for students to experience, firsthand, the engineering design process.

Figure 27

Go By Water Design Challenge Teaching Artefact



Note. This is a screenshot of the instructions slide for the Go By Water Design Challenge. The image shows the scenario, available materials/tools and parameters.

Following an introduction to Western Science concepts on why objects float or sink in water, we watched the Gwitna'q episode to learn about the Indigenous innovation of birchbark canoes. Afterwards, the design challenge scenario was revealed (see Figure 27). They need to travel by water to a hypothetical location with no road access to gather medicinal plants. Their water vessel needed to transport at least three people and some gear (represented by Lego plants, Lego blocks and three Lego figures), be waterproof and not take on water, be less than the

maximum physical dimensions allowed, and be able to travel a specified distance. Although we did not use actual birchbark, we still discussed the importance of harvesting protocols that would minimize harm to the tree. In the spirit of bark and trees, beyond basic supplies (e.g., scissors, glue, masking tape), the prototype had to be constructed from paper-based, recyclable materials or natural elements gathered from outside in a way that minimized harm to living things.

I provided time for students to identify the problem, create a plan by sketching their prototype ideas, identify materials they planned to use, and understand the challenge parameters. I also encouraged my classes to consider what they learned from the documentary as they developed their designs. They could work in a small group up to a maximum of three people. Once a group had a plan, they could visit our class maker corner to gather materials and begin constructing prototypes. They were permitted to repeatedly test and improve prototypes as needed. For testing prototypes, we used a long rectangular storage tub filled with water to simulate the river. Groups could decide which three Lego figures they wanted to use when testing their designs. When building a bunch of Lego figures from the mix and match bins at the store, I made efforts to include a variety of hair colours/styles, facial features, etc. that could potentially represent diverse identities. Afterwards, students spent time reflecting on the process and prototypes, and early finishers could explore an inquiry menu on canoes, which included a variety of activities such as viewing short videos about traditional birchbark canoe building, exploring their wonderings about canoes, or learning the word for *canoe* in different languages.

I could really feel the anticipation and positive energy throughout this learning experience and did not need to speak with anyone about active participation. It was great to see different hull shapes and frames inspired by the documentary. Because there were many choice materials available, there were many opportunities for creative ideas to take root, but the

classroom also gets… messy. I teach multiple sections; there are many science students working on this simultaneously. Having special designated student volunteers to assist with tidying materials at the end of each design challenge class is helpful for staying sane. Despite moments of organized chaos, which really should come with no surprise seeing as fifty litres of water was involved (surely, it must have been some *other* science teacher who spilled all the water onto the floor while trying to empty the tub…), it has also been incredibly fun to enact.

Opportunities for Intra-Action. Although there are different reasons for group work (e.g., sharing limited resources, learning collaboration skills, time savings), it is interesting to consider collaborative work from the perspective of sacred truth spaces where learners encounter knowledges and experiences of others (San Pedro, 2018). The scope of this study does not allow for the discussion of how students might be affected by one another in their interactions or their physical body positions and movements, but the primary field texts documented instances where opportunities were created for students to enter into such spaces. For example, many discussions and conversations took place using protocols like sharing circles or think-pair-share. Sometimes these revolved around observations of phenomena or images (e.g., a picture of a dentalium mollusc), and at other times, about more complex topics like inequality (e.g., various -isms) or challenging life experiences involving illness and disease (e.g., cancer). Additionally, there was documentation of activities or projects involving collaborative work between learners, such as design challenges (e.g., constructing “birch bark” canoes or dentalium harvesters) and end of unit inquiry projects (e.g., water systems exploration where students selected essential questions of interest and carried out a number of open-ended project options).

In addition to designing, enacting and facilitating these experiences, the primary field texts also documented many instances where I responded to and further engaged in ideas that

were student initiated. Sometimes this resulted in impromptu conversations relating to science or inequity. Sometimes this resulted in changes to the classroom environment or the direction and parameters of a particular science lesson. As the teacher, I also exist within sacred truth spaces with my students and can choose to participate in responding to their invitations to learn from their knowledges and experiences. Finally, the primary field texts also documented a number of communications between myself and families where, as the teacher, I invited them to engage in their child's science learning or to participate with their child in observing science phenomena. Again, while this project cannot speak to how families and students might have interacted with one another or provide specifics regarding their interactions with myself, it does suggest that teachers can create opportunities for science interaction beyond the classroom itself.

Discussion. Enacting opportunities for embodied and emotional learning is another pedagogical innovation resulting from this (re)Search. To learn science is to engage in "an enacted and embodied process, one that is lived in the practice" (Siry & Brendel, 2016, p. 805) and the acts of teaching and learning science are necessarily entangled with emotions (Siry & Brendel, 2016). This theme is framed by four reflective vignettes: *Opportunities for Wondering*; *Opportunities for Intentional Emotional Engagement*; *Opportunities for Phenomenological Sense-Making*; and *Opportunities for Intra-Action*.

Opportunities for wondering were documented in the findings of this (re)Search. For example, the *Opportunities for Wondering* vignette writes that after a read aloud, *learners are invited to reflect on what they are learning from the story and wonderings that they might have. Afterwards, we share ideas in small groups and as a whole class. This protocol of reflecting, wondering, and sharing is a routine in our science class.* Also embedded throughout the northern lights inquiry menu described in the vignette were prompts to reflect, wonder and further

research those wonderings. These pedagogical moves that engage "students in science classrooms with their feelings, and specifically the sensation of wonder, may allow us to break away from binaries—namely, simplistic right-and-wrong depictions of previously discovered science 'facts'—toward an emotionally embodied doing of science" (Gilbert & Gray, 2019, p. 118). Providing opportunities for wondering engages learners in a science pedagogy that is embodied and emotional, queer, and disrupting.

Additionally, shared science experiences where students anticipate something interesting contributes to building emotional energy (Olitsky & Milne, 2012). As I reflected in the *Opportunities for Intentional Emotional Engagement* vignette, *I saw demonstrations in a new light… an intentional invitation to engage in embodied, emotional learning that disrupts the traditionally masculine, rational, restrained, and emotionless stereotypes surrounding science*. In addition to enacting a science demonstration with the intent of generating emotional energy, I created learning experiences emphasizing sensations experienced by the physical body (e.g., reflecting on the five senses while outside or emotions experienced during water encounters). The vignette also noted how I wanted *to find science stories that capture and convey the emotions of scientists to remind us all, that science is a pursuit filled with emotions*. For example, viewing a documentary provided opportunity for gaining insight into the complement of emotions experienced when doing science. Both positive and negative emotions are important in learning science, as confusion, surprise, frustration or uneasiness has potential for motivating learners to ask questions and seek solutions to science problems (Jaber & Hammer, 2016; Matthews & Snowden, 2007). These examples demonstrated commitments to queering science.

But what is embodied learning exactly? Kersting et al. (2021) outlines four senses of embodied learning: physical, ecological, phenomenological, and interactionist. Of interest to this

study are phenomenological and interactionist senses of embodiment. *Phenomenological embodiment*—learning through lived experiences like experimenting, observing, or becoming a concept with your body—is evidenced in the vignettes. For example, The *Opportunities for Wondering* vignette noted a learning experience where students were invited to view the northern lights using live camera feeds or firsthand during a geomagnetic storm. As reflected in the vignette, *we had learned about the science and stories of this meteorological phenomenon through texts within our classroom; now, we would immerse our bodies and senses in the lights that have long been so captivating.* Carrying out such an experience would involve using the body to make observations of the phenomenon. Phenomenological embodiment was also found in the birchbark canoe learning experience where students were invited to experience the design process. This was documented in the *Opportunities for Phenomenological Sense-Making* vignette: *I provided time for students to identify the problem, create a plan by sketching their prototype ideas, identify materials they planned to use, and understand the challenge parameters... they could visit our class maker corner to gather materials and begin constructing prototypes. They were permitted to repeatedly test and improve prototypes as needed*.

The *Opportunities for Intra-Action* vignette demonstrated examples of *interactionist embodiment*, where bodies interact with one another to problem solve and make decisions about science (Kersting et al., 2021). Interactionist embodiment is similar to Bronwyn Davies' (2014) idea of *intra-action*—"an encounter where each participant affects, and is open to being affected by, the other" (Siry & Brendel, 2016, p. 812). Though beyond this study's scope to comment on whether individuals were actually open to and affected by one another, the findings did show that as the teacher, I had attempted to create opportunities for interactionist embodiment or intra-action through collaborative learning experiences (e.g., inquiry group projects). In the vignette, I

reflected on how the primary field texts provided *documentation of activities or projects involving collaborative work between learners, such as design challenges (e.g., constructing "birch bark" canoes or dentalium harvesters) and end of unit inquiry projects (e.g., water systems exploration where students selected essential questions of interest and carried out a number of open-ended project options).* For example, in the birch bark canoe design challenge, students *could work in a small group up to a maximum of three people*.

The vignette also wrote that *many discussions and conversations took place using protocols like sharing circles or think-pair-share. Sometimes these revolved around observations of phenomena or images (e.g., a picture of a dentalium mollusc), and at other times, about more complex topics like inequality (e.g., various -isms) or challenging life experiences involving illness and disease (e.g., cancer)*. These explorations of science phenomena, inequality, illness and disease were invitations to enter into sacred truth spaces (San Pedro, 2018) where learners could potentially learn from one another's experiences and knowledges. The *Opportunities for Intra-Action* vignette also reflected on how *I responded to and further engaged in ideas that were student initiated. Sometimes this resulted in impromptu conversations relating to science or inequity. Sometimes this resulted in changes to the classroom environment or the direction and parameters of a particular science lesson.* This suggested that teachers can participate in these same sacred truth spaces by demonstrating their own openness and willingness to listen and be influenced by learners. Lastly, as the vignette writes, there were *communications between myself and families where, as the teacher, I invited them to engage in their child's science learning or to participate with their child in observing science phenomena*. Beyond the classroom walls, teachers can attempt to invite families into embodied learning experiences by encouraging families and student learners to jointly participate in observing science phenomena.

Pedagogical Innovations Theme 5: Moving Towards Interdependence—No Teacher~Researcher is an Island

Sharing Space with Community Members. This process has involved reconnecting with aspects of the teacher I once was, so this might be better thought of as a (re)innovation involving new lenses and learnings. During my informal teaching experiences, I had organized many opportunities for learners to interact with scientists and organizations. Sometimes, we invited and hosted guest presenters; other times, we visited spaces we were graciously invited into. After formally becoming an educator, I continued making efforts to invite speakers into my classes and schools. There are more challenges in formal school settings (e.g. budgets, schedules, more students and classes to organize) but still manageable.

Due to world and personal circumstances, there had been a pause on these engagements. When re-visiting the idea of sharing space again, I knew I wanted to approach from a different lens. What I learned from my graduate work prompted a re-examination of how previous invitations inadvertently reinforced Western Science norms, and on some occasions, even stereotypical images of scientists (e.g., lab coat wearing mad scientists). I am unfamiliar with many science topics and perspectives—teachers do not know everything. Maybe I could invite those with expertise in areas I lack, so both my students and I can learn new knowledges together. Maybe we could be thoughtful and intentional about representing diverse counterstories and experiences. Instead of parachuting in pre-made workshops, we could collaborate to create learning experiences rooted in places and contexts relevant to a particular group of learners.

The process of creating such spaces took much planning, but it was so worth it. Despite the aforementioned logistical challenges, from my perspective, the workshops went very well. I am so grateful to those who have had patience with me as the host. I liked how many sessions

were embedded into the regular science schedule and sometimes even extended over a period of time. Oftentimes in schools, hosting guest speakers becomes one-and-done events never mentioned again, but I hope we can normalize the idea of learning from and alongside community and industry experts regularly; it takes a village to nurture science minds. For me, sharing space is not about offloading responsibilities we have as teachers for doing our own learning, especially on complex and challenging topics. Rather, it is about humbling ourselves, acknowledging that no single individual can know everything, and endeavouring to create spaces where encountering diverse ideas and perspectives is just another day in the science classroom.

De-Privatizing Teaching Practice. With a deadline looming, I sat with my computer at a local sushi joint over spring break, frantically trying to manifest ideas that might be spun into some semblance of words and phrases for an article about counterstorytelling in science (see Loay, 2024). As I reflected in my teacher journal, I was *getting a bit nervous… anxious about backlash… just thinking about the possibility [was] very unsettling*. After procrastinating for two-and-a-half months, I could no longer avoid these unpleasant feelings. Even the act of reaching into my memories for ideas was a painful act, just as it has been when reaching back to reflect on tensions from this (re)Search. Writing about our pedagogical innovations is fun; writing about the moments and processes that brought us there is less so.

In teaching and in life, I am a private person. But I am trying more to share my learning, stories and teaching with others around me. I have shared my counterstories with learners in my classrooms, revealed my teaching practices to a few trusted colleagues, collaborated (sometimes serendipitously) with like-minded colleagues in solidarity and even provided guidance to those beginning to embark on their own journeys. Sharing your experiences with strangers feels like

losing control of who does what with your words and stories. Like with this critical autoethnography, I reflected cautiously on what might be too personal… too vulnerable.

Even though sharing feels risky, these moments can create possibilities for new encounters—connecting us to others who choose to walk alongside us as we create new disruptions and innovations. I realized that sharing my experiences also feels like freedom. There is something liberating about your ideas, teaching and values just existing out in the world somewhere. Maybe this is what it means to live, teach and (re)Search cleanly. Once I finished my draft, a generous gratuity in an act of reciprocity—for food and service, for unabashedly taking up space for hours in their establishment, and for reminding me that from our moments of vulnerability, beautifully disruptive acts can begin to take root in the very places we once might have thought impossible.

Discussion. In the afterword of *Walking Together* (Marshall & Zimanyi, 2023), Elder Albert Marshall provides the following insight:

> Whenever there is a need for two energies to connect, they will come together. It's the ability of an individual to detect a certain energy that brings peace and openness to get to know this person. We do not question how it was meant to happen. We accept it and honor how we came together. (p. 32)

As educators, we have the privilege of meeting, working with, and learning alongside many diverse peoples. The final theme of the pedagogical innovations tenet was Moving Towards Interdependence: No Teacher~Researcher is an Island and was framed by the reflective vignettes, *Sharing Space with Community Members* and *De-Privatizing Teaching Practice*.

Social interdependence theory involves two or more people being "motivated by states of tension that arise as desired goals are perceived… [and] *[s]ocial interdependence* exists when

the accomplishment of each individual's goals is affected by the actions of others" (Johnson & Johnson, 2008, p. 11). Although this (re)Search is unable to comment on the degree to which interdependency might have occurred from the perspective of all potentially involved individuals, the findings do suggest that in my own role as a teacher, there were moves towards establishing positive interdependence in the area of justice-oriented teaching practices. *Positive interdependence* is when goals can be reached "if and only if the other individuals with whom they are cooperatively linked also reach their goals. They therefore promote each others' efforts to achieve the goals" (Johnson & Johnson, 2008, p. 12).

The *Sharing Space with Community Members* vignette reflected on my desire to engage community members differently by *invit[ing] those with expertise in areas I lack, so both my students and I can learn new knowledges together. Maybe we could be thoughtful and intentional about representing diverse counterstories and experiences. Instead of parachuting in pre-made workshops, we could collaborate to create learning experiences rooted in places and contexts relevant to a particular group of learners*. This snapshot demonstrates a shift in mindset from transactional isolated interactions towards one that is reciprocal, rooted in relationships and disrupting of dominant science norms. The vignette also reflected on how *sharing space is not about offloading responsibilities we have as teachers for doing our own learning, especially on complex and challenging topics. Rather, it is about humbling ourselves, acknowledging that no single individual can know everything, and endeavouring to create spaces where encountering diverse ideas and perspectives is just another day in the science classroom.* This speaks to the importance of not putting the burden of teaching about diverse ways of knowing and being on our guests—particularly those who might be members of marginalized communities. It also points to how schools might consider normalizing the practice of learning with community.

The *De-Privatizing Teaching Practice* vignette described efforts to share my teaching practice beyond the classroom despite perceived risks: *I am trying more to share my learning, stories and teaching with others around me. I have… collaborated (sometimes serendipitously) with like-minded colleagues in solidarity and even provided guidance to those beginning to embark on their own journeys.* As I reflected on the experience of writing an article on counterstorytelling, *[s]haring your experiences with strangers feels like losing control of who does what with your words and stories. Like with this critical autoethnography, I reflected cautiously on what might be too personal… too vulnerable.* Counterstories are so named for being counter to the experiences of dominant cultural group members. For IBPOC members especially, sharing our lived experiences may feel particularly vulnerable. However, as the vignette also writes, *these moments can create possibilities for new encounters—connecting us to others who choose to walk alongside us as we create new disruptions and innovations. I realized that sharing my experiences also feels like freedom. There is something liberating about your ideas, teaching and values just existing out in the world somewhere. Maybe this is what it means to live, teach and (re)Search cleanly.* De-privatizing my own teaching practices has been a way to invite other educators into the interdependent work of justice-oriented science teaching.

As Horn (2008) writes, "despite the norms of privacy that pervade teacher culture and the assumptions of our behind-closed doors independence, we actually need our colleagues… Acknowledging this interdependence is especially urgent when we consider issues of equity" (p. 752). Addressing deep-rooted systemic inequities in science education is a complex act that would be supported by the benefits of positive interdependency (e.g., greater achievement and engagement, improved attitudes, positive social support, more sophisticated perspective taking) (Johnson & Johnson, 2008). However, formal school structures also challenge collective action.

As I reflected in *Sharing Space with Community Members*, when hosting guests, there are *challenges in formal school settings (e.g., budgets, schedules, more students and classes to organize)*. Consistent with barriers identified by Horn (2008), the study findings suggest that access to funds, school schedules, and school size can make the process more difficult. Also, teacher collaboration is generally not prioritized in schools, which means that, in addition to not having their workloads offset for engaging in social justice education, teachers who desire to collaborate on such matters must do so during preparation or personal time (Horn, 2008).

Summary

In this section, the (re)Search findings were presented and discussed in relation to the broader social context of science teaching and scholarly literature. Emerging themes were organized around the four tenets of culturally disruptive pedagogy (tensions, disruptions, self-realizations and pedagogical innovations) (Litts et al., 2020b; San Pedro, 2018) and sub-themes were explicated through reflective vignettes. The tensions tenet focused on interrogating dominant norms in schools and society more broadly, while the disruptions tenet began connecting theory and action to disrupt norms. The self-realizations tenet emphasized how insights gathered contributed to internal self-transformation. This transformation continued into the pedagogical innovations tenet, which demonstrated how changing our beliefs and values also changes our teaching materials and practices. The findings showed how the culturally disruptive pedagogical framework can be useful for making sense of how to become as a science educator working to enact more socially just conceptualizations of science. Though there are many tensions to grapple with, the findings also demonstrated it is possible to disrupt existing teaching beliefs and apply new insights to enacting tangible actions in our teaching practice. Implications and recommendations from this (re)Search will be discussed in the following final chapter.

Chapter 5: Conclusion

The purpose of this (re)Search was to disrupt existing hegemonic science practices by exploring how culturally disruptive pedagogy informs my becoming as a middle years science educator desiring to enact pedagogies that support students' conceptualizations of science in more equitable ways. Additionally, I explored how I can support gender equity and students' coming to know science from both Indigenous and Western Science lenses, while honouring students' ethnoracial diversities. Critical autoethnography has allowed me, as the researcher~participant, to critically examine my science teaching through an intersectional lens, make connections between my own individual stories and wider cultural patterns, and challenge hegemonic science standards (Boylorn & Orbe, 2021b). As a methodology, "critical autoethnography asks how personal narrative can both represent and challenge culture" (Boylorn & Orbe, 2021b, p. 6); it is "the refusal of a silenced identity" (Sparkes, 2024, p. 131). In this chapter, I consider the findings in the context of addressing my (re)Search question, discuss their implications, provide recommendations for future actions and end with concluding thoughts.

Culturally Disruptive Pedagogy for More Equitable and Socially Just Science Teaching

The process of my becoming as a more equity-minded and justice-oriented middle years science educator is supported by culturally disruptive pedagogy. Glimpses into this journey can be located in the (re)Search findings, where moments of tension, disruption, self-realization and pedagogical innovation (the tenets of culturally disruptive pedagogy) are captured by reflective vignettes from my teaching. This autoethnographic study also documents emerging themes relating to each tenet of the framework. The process involved grappling with numerous tensions such as reconciling my membership in different spaces of (non)belonging, enacting my teacher agency in consideration of student agency and within institutional structures, needing to

negotiate diverse values in the roles of educator and advocate, as well as working through the joys and discomforts of this journey. The findings additionally documented how my existing understandings of science and research, motivations for allyship, and teacher identity as a change agent were in various states of disruption as moments of courageous sharing and encounters with new knowledges and worldviews took place.

A number of self-realizations also emerged from the findings. Coming to enact equitable and socially just pedagogies valuing a plurality of perspectives involves (re)Searching through gathering knowledge, sense-making, an openness to seeing my teaching practices differently, as well as having patience for learning. It is a process that also involves (re)Connecting with people, places, the more-than-human world, and myself as a teacher and learner. Another realization is that it is important to (re)Position as an educator~advocate willing to name, interrogate and bring to light stories of injustice for ourselves, our schools, and broader communities. Additionally, this process is supported by (re)Entering from a place of preparedness, which involves recognizing our own complicity in perpetuating oppressive structures, understanding the inevitability of discomfort, and being of the mind that educators have a responsibility to engage in anti-oppressive practices.

The pedagogical innovations tenet of culturally disruptive pedagogy documents tangible actions taken in my teaching. There is much overlap between different strategies that may be used in efforts to address various forms of oppression. Each may be supported by forms of embodied and emotional learning such as opportunities for phenomenological and interactionist sense making and being intentional about planning learning tasks that involve opportunities for wondering and becoming attuned to bodily sensations. The findings also document the ways physical materials and learning spaces may support the valuing of diverse perspectives, racial

equity, and diverse gender identifications by, for example, considering classroom displays or bringing more-than-human elements indoors and ourselves outdoors. Efforts were made to (re)center marginalized voices through counterstorytelling, and the honouring of Indigenous Science perspectives was additionally supported through explicit naming of different science lenses along with respectful embedding of cultural teachings and protocols for all students to learn from. A final pedagogical innovation arising from this study is moves toward interdependence. The findings documented efforts made to share classroom space with and value the knowledges of community members while also de-privatizing my teaching practices.

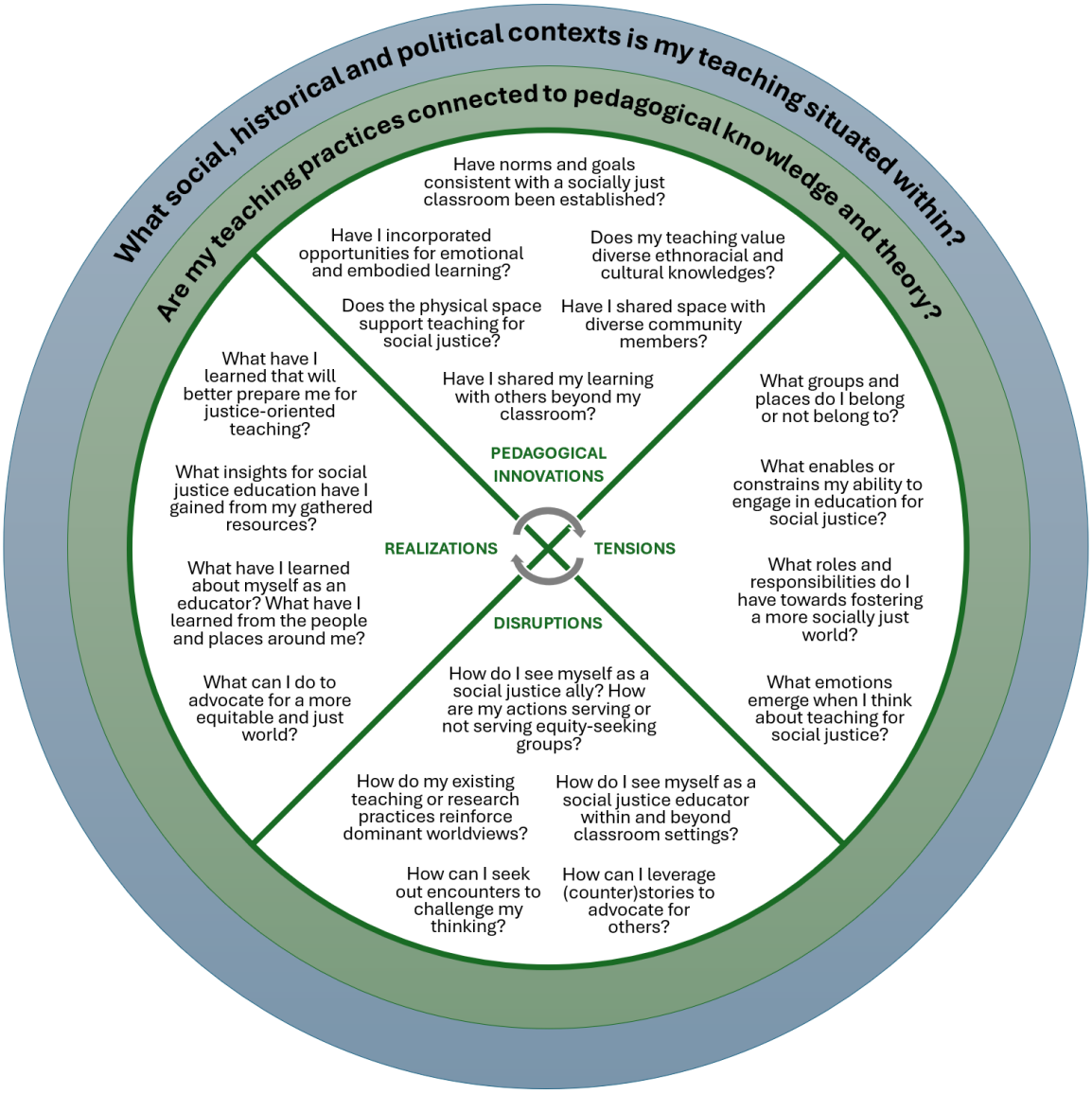
Implications of the Study

The findings resulting from this study contribute to the knowledge base on social justice science education using culturally disruptive pedagogy, as well as how science educators can interrogate their teaching practices through critical autoethnography. As other scholars have noted, disrupting teacher beliefs or conceptual ecologies can be very difficult processes (Fullan, 1982; Larkin et al., 2016). However, the culturally disruptive pedagogical framework has potential for supporting educators interested in learning to enact justice-oriented science pedagogies with their own self-transformation. The four tenets (tensions, disruptions, self-realizations and pedagogical innovations) provided a structure that I, as the researcher~participant, could use while engaging with the complexities of this process. The framework encourages engagement in a deeper long-term reflective learning process over the, perhaps, more immediately gratifying aspects of teaching such as implementation of lesson activities. Within the pluralism of classrooms, becoming more conscious of our own ideologies and social positioning enables educators to better respond to diverse students and support them in understanding their own values and beliefs (Starr, 2010).

Although my existing understandings of science, teaching and (re)Search are in various states of disruption, this study demonstrates that, while difficult, it is possible to begin disrupting existing beliefs over time. This process of disruption necessarily involves grappling with arising tensions. The culturally disruptive pedagogical framework both normalizes and embraces these tensions as a critical part of this journey. When interrogating how our identities intersect with social justice, educators are encouraged to face their tensions (Nganga, 2013)—leveraging them as "catalysts for learning" (Ahmed, 2020, p. 255). Grappling with tensions has allowed me to (begin) disrupt(ing) my existing understandings of science teaching and come to insightful realizations supporting my continued growth as a teacher. This (re)Search encouraged and allowed me to reach educators beyond my school in the time since field text collection ended. By sharing my learning on culturally disruptive pedagogy, anti-racism, and treaty education in science, I have been able to walk alongside other educators (e.g., facilitating workshops during our divisional Treaty Learning Days and guest speaking with teacher leaders in Indigenous Education from across the province). My involvement in this area also led to a collaboration resulting in the creation of a divisional teacher-led learning team for Indigenous Education slated for implementation in fall 2025. These are just a few examples of how transformation of self as educator has created possibilities and encounters for others beyond my immediate context. Other science educators could similarly look to the culturally disruptive pedagogical framework as a guide for transforming their own teaching practices (see Figure 28). This is especially relevant in light of the upcoming Manitoba science curriculum renewal, which includes learning about Indigenous Science perspectives and is slated for full implementation in the 2026-2027 school year (Manitoba Education and Early Childhood Learning, 2024, Summer).

Figure 28

Culturally Disruptive Pedagogical Framework Tool for (Science) Educators



Note. This tool adapts the culturally disruptive pedagogical framework (Litts et al., 2020b; San Pedro, 2018) to include questions for educators to consider when enacting justice-oriented teaching practices. The questions for each tenet relate to emerging themes from this study. Invitations to consider how teaching practices connect to pedagogical knowledge and theory (Cochran-Smith, 2010), as well as their social, historical and political contexts are also included.

While this study initially sought to separately address science teaching that values both Indigenous and Western Science perspectives, supports gender equity, and honours ethnoracial diversity, this (re)Search illuminated their entangled nature. The findings suggest that the process of enacting justice-oriented pedagogies may be supported by addressing various forms of oppression together. The emerging realizations of (re)Searching, (re)Connecting, (re)Positioning self as educator~advocate and (re)Entering from a place of preparedness are cross-cutting actions applicable across the oppressions of interest to this study. The pedagogical innovations, similarly, could be applied to tackle multiple forms of oppression. Counterstories, for example, may be leveraged to (re)center voices that have been relegated to the margins due to ethnoracial, gender and other cultural identifications. In describing a middle school course where students explore social identifications through discussion and inquiry, Caldwell (2012) observes how, despite separating units based on race, gender and class, "the recursive nature of the curriculum allows students to draw parallels and see intersections between different kinds of oppression" (p. 11). Case (2017) also encourages educators to consider a model of intersectionality in their teaching, including in "courses not typically associated with diversity content" (p. 9), which science, I would argue, falls into. The insights gained from the realizations and pedagogical innovations of this study also have potential to inform the teaching of other educators interested in approaching justice-oriented science teaching from intersectional lenses.

Engaging in this (re)Search also grounds my teaching practice in both classroom experiences *and* educational theory. Throughout this project, theory has influenced and informed my classroom practice. These teaching actions are then further connected to theoretical knowledge, which continues giving rise to new practices. Both theory and classroom experiences are important as changes to educational practices are innovated in the spaces between where both

aspects are mobilized (Álvarez Álvarez, 2015). Although the theoretical aspect of teaching is often undervalued in classrooms, it is important that educators work toward coherence between theory and practice (Álvarez Álvarez, 2015; Siry & Brendel, 2016). Without cultivating our theoretical knowledge, which often occurs through academic and scholarly activities, it may be difficult for educators to distance ourselves from the hegemonic school (science) traditions that we have been assimilated into (Álvarez Álvarez, 2015). Through "studying, reflecting, and acting, all of which must take place together, something that demands effort, passion, and courage" (Álvarez Álvarez, 2015, p. 243), the theory-practice gap—or rather, *dis*entanglement of theory and practice—may then be *re*-entangled. A better grasp of the theories underlying my science pedagogies supports both my classroom teaching and my work with educators in the broader teaching community.

Recommendations

For My Teaching

The tenets of culturally disruptive pedagogy can continue serving as a framework for my science teaching. As new tensions arise and disruptions take place, I will reflect on emerging realizations and commit to enacting new pedagogies in my classroom. I must continually examine how I might be upholding hegemonic science practices and ask myself how, as both an educator and researcher, I can contribute to dismantling these structures. The framework can also be mobilized as I further explore and come to know additional science worldviews, which could then be braided into my teaching. Additionally, as a middle school teacher, I can further explore how the culturally disruptive pedagogical framework and theoretical lenses of this (re)Search might be applicable to other disciplines, such as mathematics or language arts. Imagine if anti-oppressive practices were embedded in all aspects of our learners' educational experiences. I also

endeavour to continue growing into the internalization stage (Hardiman & Jackson, 1997, as cited in Goodman, 2011) as a justice-oriented science educator through continued efforts to interrogate my teaching practices, gather new knowledges, grow my relationships with diverse communities, and engage in advocacy through my teaching and scholarship. How I can grow as a coalition builder and support fellow educators in navigating this process is a question I have been increasingly wondering about.

For Schools

I recommend that schools, as an institution, interrogate and critically reflect on how they may (un)intentionally create spaces of (non)belonging not only for student learners, but staff who work in those spaces. As this (re)Search has demonstrated, the process of engaging in justice-oriented teaching and reconciliation is fraught with tensions rooted in our social identifications and contexts. In what ways are educators, especially those who may belong to marginalized groups, being supported or hindered in navigating these complexities? How are the risks and challenges of combating injustice and teaching for reconciliation distributed amongst *all* educators rather than being shouldered by those who, due to the very nature of their existence, must already be brave every day? Educators leading efforts and initiatives relating to equity and diversity need to be valued not only at personal levels, but through formal structures recognizing and providing compensation for such work. This study demonstrates that coming to teach in justice-oriented ways requires significant and sustained investments in time and resources beyond pre-existing teacher responsibilities. If schools and, by extension, divisions, genuinely wish to prioritize equitable teaching practices and education for reconciliation, then tangible expressions valuing this learning must be made. Embedding time for sustained reflective, theoretical, and collaborative learning within teaching timetables and courseloads is needed.

Related to this point is the need for reconceptualizing how teacher professional learning opportunities are structured. Typically, traditional professional development models involve large groups of teachers congregating on a few days throughout the year for short sessions led by presenters with expertise in specific areas, which leads to a preference for quick tips and easily implemented lesson activities (Chowdhuri & Archer, 2024; Picower, 2011). While this may still contribute to creating invitations that might become encounters, I also join other scholars in arguing that this model is at odds with the vulnerability, relationship building, and critical reflection required as demonstrated by the study findings. Such changes may be supported, more broadly, through increased funding for school staffing and release time, as well as for purchasing relevant teaching/learning materials and compensation for guest speakers.

As discussed earlier, this study documented moves towards collaboration and positive interdependence. However, positive interdependence relies on each person reaching their own goals (Johnson & Johnson, 2008), which means alignment on what those goals are is needed. Thus, in support of educator moves toward interdependence, I recommend that school members (e.g., administrators, teachers, support staff and students) come together as a community to dialogue, learn about and set school goals for social justice and reconciliation. Might we, as an interdependent community, come to see the absence of equity and diversity related school goals as strange and the presence of collective goals in schools for reconciliation with Indigenous Peoples as normal? How might we become with one another differently if educational institutions and everyone in them decided to normalize growth in these areas and start making concerted efforts towards eradicating injustices in our schools and broader community?

For Future Research

As educators continue grappling with social justice pedagogies and reconciliation with Indigenous communities, Asian Canadian educators such as myself may find ourselves in spaces of tension between privileges and marginalizations as documented in the study findings. Through the mobilization of multiple theoretical lenses for this research, I realized how different forms of oppression are interconnected. However, the study also showed how moving between intersecting identifications, whether as a teacher or scholar, can be a fraught process. For these reasons, I recommend additional research with intersecting lenses, as well as further exploration of the relationships between intraminority relations, allyship and motivations for justice-oriented teaching behaviours. Further research exploring the experiences and emotions of other science educators working on teaching for social justice and reconciliation could provide additional insights that align with the tenets of culturally disruptive pedagogy. Though it was beyond the scope of this particular research study, it would also be interesting to investigate the impacts of this teacher learning on student learners in the classroom.

Final Thoughts

> In science,
>
> a social justice perspective shifts the focus from science as a body of knowledge and skills to be learned on its own merits, to a social activity that students, teachers, teacher educators, and science education researchers engage in for the purpose of personal and community understanding and transformation. (Rivera Maulucci, 2012, p. 593)

This study contributes to advancing equity and diversity in science education by critically reflecting on the ways in which school science currently reinforces and perpetuates injustices (Morales-Doyle, 2017). Additionally, this research addresses existing gaps in the literature by

contributing to emerging, but limited, scholarly work in science education using culturally disruptive pedagogy as a framework. Science scholars have also articulated the need for further research in the areas of queering science (Fifield & Letts, 2019), anti-racist science pedagogy (Sheth, 2019; Walls, 2022; Watkins, 2022), and the role of racially marginalized scholars in advancing reconciliation with Indigenous communities (McGuire & Denis, 2019).

Although critical social justice work in science education is a collective effort, this change begins with each individual making concerted efforts to challenge the status quo (Rodriguez, 2001). Gazing inward to unpack our own teaching practices and assumptions is no easy feat. The process of becoming as anti-oppressive science educators is one that is ongoing and lifelong (Tolbert et al., 2018), vulnerable, challenging, and emotional (Rodriguez, 2001). When faced with the question of how we can challenge dominant norms in science education, Rodriguez (2001) responds,

> 'with courage.' Courage has been the missing element in education reform in general, and in science education reform in particular… by (re)defining our roles as cultural warriors, we will find the courage to manage the risks and the resistance to change we will most certainly encounter. (p. 278)
>
> [This journey] will take the collective effort of our research community, but it must start at the individual level. To have the courage to escape the entrapment of our own privilege is to take a step closer to understanding how our actions and inactions make us either pawns for the status quo or effective agents for transformative social justice. (p. 290)

And so, it is with courage borne from a deep love for science, teaching and learning that I have interrogated and critiqued my teaching practices alongside the beliefs and contexts in which

they are situated. It is a courage fueled by the unwavering hope that a socially just world can—no, must—become not only a possibility, but a reality for us all. From the early conceptions of this (re)Search till now, I have found myself coming to know science differently and becoming as an educator in unexpected, but profound ways. I can sense this stirring also in the hearts of the people and places with/in which I am interconnected—a disrupting, even if not yet dismantling, tremor arising on the spider's threads.

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