DAKOTA/LAKOTA MATH CONNECTIONS: APPLYING AN INDIGENOUS RESEARCH

PARADIGM TO RESEARCH IN UNDERGRADUATE MATH EDUCATION

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Dakota/Lakota Math Connections: Applying an Indigenous Research
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ABSTRACT

An Indigenous research paradigm collectively described by Wilson (2008), Archibald (2008), and Kovach (2009) has yet to be applied to research in undergraduate math education, and specifically at a Tribally Controlled College/University (TCU). Research at TCUs does not require the use of an Indigenous research paradigm, however at the outset, this study chose to center Indigenous values and ways of learning. Justification of one research paradigm from/through another research paradigm is not only unnecessary but could be viewed as decreasing academic rigor as well as devaluing Indigenous ways of knowing and learning. Applying an Indigenous research paradigm shifted the literature review from 'synthesizing the literature' to 'embodying the literature' (Ch. 2). Research questions were not developed in isolation by 'finding a gap' in the literature but through collaborative connection within a D/Lakota TCU, specifically at Sitting Bull College (SBC) between the math department and Wahóȟpi Kiŋ (the Lakota language immersion nest). Connections amongst D/Lakota math, language, and culture were collaboratively determined as the central idea to encircle, (that is, to study) meaning to strengthen the web of relations (Ch. 3 and 4).

In TCU math classrooms calls for local language/culture to be more integrated into the curriculum have been met with epistemological challenges as well as a dearth of math and local culture resources. The D/Lakota Math Connections study addresses both challenges at/with SBC in Standing Rock Nation. Following an Indigenous research paradigm focusing on relationality and relational accountability, groups of tribal college math instructors, Lakota language immersion teachers, and fluent elders experienced, confirmed, and refined the D/Lakota Math Connections framework (Ch. 5) as well as developed a community-based math resource for curriculum development at SBC and more broadly Očéthi Sakówiŋ (Ch.6).

This four-paper dissertation seeks to follow an Indigenous research paradigm in every possible way. This includes an emphasis on story, while also containing four distinct, peer-reviewed, published articles. Throughout the study, articulating D/Lakota math connections was both the process and the product. Further, qualitative and quantitative methods demonstrated that math and D/Lakota language fluency do grow together and for D/Lakota math to be a continued area of research.

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Many people have supported my dissertation journey and I am immensely thankful. But before that I thank Creator above all else, who "gives everyone life and breath and everything else" and from whom "we live and move and have our being."

My acknowledgements are broken into two parts. First, in this acknowledgements section I share only a short list of tremendously influential people in my life that I want to thank with a deep gratitude and reverence. Secondly in the literature review (Ch.2) subsection 'Relationships Inform Every Step of the Research Process', I discuss that all my relationships are essential and central to this entire research project. Thank you all!

To my family:

Kali, I love you. You have been amazingly supportive in this dissertation journey these past six years and I can't thank you enough. We will both celebrate the completion of my dissertation. I am abundantly thankful to be your teammate.

Kamila and Eliza, I love you both. Neither of you were a thought in our eyes when I begin my PhD journey and now Kali and I are so thankful for you both as our daughters.

My parents, siblings, cousins, aunts, uncles, and grandparents, I love you. Thank you for your love and support through this journey.

To my fellow Indigenous scholars – past, present and future:

Yakoke. Philámayapilo. Miigwech gakina gagoo. Thank you all for everything you have done and will do. And more importantly, thank you **not** for what you produce, but simply for who you are as an Indigenous person before you ever begin your scholarly journey.

Specifically, I want to thank you Dr. Hollie Mackey for your immeasurable impact on who I am as a researcher and as a person. Thank you for teaching me so much about research

with and in Indigenous communities and helping me further understand my own Indigenous identity. Thank you, Dr. Sweeney Windchief, for your inspirational edited book 'Applying Indigenous Research Methodologies' and first introducing me to Indigenous research methodologies through the work of Dr. Shawn Wilson. Even though, I have never met or talked with you, Shawn Wilson, thank for your book 'Research is Ceremony.' I too have faith in the ceremony.

Further, I want to thank my new friends and colleagues that are part of the Indigenous Mathematicians network. You all are such an encouragement to me whether we have met in person or not. Specifically, thank you Dr. Kamuela Yong as the unofficial leader of our network and Dr. David Austin as a Choctaw mathematician and constant encouragement to me in my identity and career.

Lastly, to all Tribal College/University (TCU) faculty, thank you! Thank you for what you have done that has brought the TCU system to this juncture in its first fifty years. May we continue to serve our respective communities and nations through the work we are doing in the next fifty.

Specifically, I want to thank Dr. Kathy Froelich, whom I now call Auntie, for always encouraging me, looking out for me, and connecting me with her colleagues and family. I also want to thank Anna Bahnson for consistent encouragement and securing funding for an initial book study on "Indigenous and Decolonizing Studies in Education" which opened multiple doors early in my research journey.

Further, I want to specifically thank Sunshine Carlow for taking a risk on me through initially forging the opportunity for me to partner with Wahóȟpi Kiŋ (the Lakota Language

Immersion Nest) at Sitting Bull College. None of this research would have been possible without you. Wóphila tȟáŋka.

Lastly, I want to thank all the faculty and students that were part of the TCU pre-engineering education collaborative. It has been an honor and joy to meet and work with so many great faculty and students across the TCUs within ND. Thank you all for being so generous to me and welcoming me into your TCU engineering community.

To the fluent elders and all my relationships developed before and within the research throughout Standing Rock Nation:

Philámayapilo. Líla wóphila tȟáŋka héčha lo. Many big thanks to you all. Truly, I can't thank you all enough. Without you all, none of this research nor my dissertation would have been possible. Thank you for being gracious to me and hosting me as I enter your community. The results of this research do not belong to me nor should be under my name, but rather all of us who collaboratively participated. Further, it has been my joy to know you and continue to get to know you beyond my PhD journey. I will not disappear after my PhD is completed. I have full confidence in saying that the relationships that began through this research are not solely about the research and will continue into the future.

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Thank you, Wahóȟpi Kiŋ (the Lakota Language Immersion Nest) at Sitting Bull College, for financially and logistically supporting every aspect of the project from its origins and into the future.

In conclusion:

I hope it's clear that I did not do this effort alone. Thank you to everyone who contributed. This is your work/results as much as it is mine. I pray this project can continue to be beneficial and actionable to math teachers, language teachers, and the D/Lakota community in general. I pray this project can continue to honor my ancestors, this place, my family, and Creator.

DEDICATION

To all my relations. Mitákuye Oyás’iŋ.

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LIST OF ABBREVIATIONS[1]

CCM ....Circulating Conversation Methodology

CRISP ....Culturally Relevant, Imbued, and Sustaining Pedagogy

DBER ....Discipline-Based Education Research

D/Lakota ....Dakota/Lakota

DLMC..Dakota/Lakota Math Connections

DLSI ....Dakota/Lakota [Language] Summer Institute

HBCU ....Historically Black College or University

HOMC ....Higher Order Math Concepts

IK-HABME ....Indigenous Knowledge has Always Been Mathematics Education

IRB ....Institutional Review Board

IRMs..Indigenous Research Methodologies

K-8...Kindergarten to Grade 8

K-12...Kindergarten to Grade 12

K-16...Kindergarten through Undergraduate

LMC ....Lakota Math Connections

L/N/Dakota ....Lakota/Nakota/Dakota

L/N/D...Lakota/Nakota/Dakota

MFD(s) ....Monday-Friday Drawing(s)

NDSU ....North Dakota State University

Nest..Wahóȟpi Kiŋ (the Lakota Language Immersion Nest) at Sitting Bull College

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[1] Abbreviations are in alphabetical order and omit common ones such as PDF, USA, PhD, etc.

LIST OF EQUATIONS

1. INTRODUCTION AND CONTEXT

1.1. A Formal Introduction

In following a Dakota/Lakota model of communication, I begin with a formal introduction to initiate context and attempt to build relationship (Long Feather, 2007). Further, from an Indigenous perspective "we know what we know from where we stand" (Kovach, 2009, p. 7) for "embedded in our places [is] where land, learning, identity, and education intersect" (Styres, 2018, p.24).

Háu mitákuyepi. Lé aŋpétu kiŋ čhaŋtéwašteya napéčhiyúzapi ló. Danny Luecke emáčiyapi. Turtle Mountain él wathí na Fargo emátaŋhaŋ. Iná Kathy Jo Dahlgren ečíyapi. Até Lenny Luecke ečíyapi. Wówiyawa waúŋspewičhawakhiye.

In Lakȟól'iyapi (the Lakota language) I said, hello my relatives. On this day, with a good heart I shake your hand. My name is Danny Luecke, I currently live in Turtle Mountain, and grew up in Fargo, North Dakota. Growing up in the Red River valley is interwoven with who I am and is also where I began my PhD journey. Now I am finishing my writing while living in Turtle Mountain (a two-hour drive from the Red River valley and four hours from Standing Rock). I share my parent's names as part of common protocol, to acknowledge that who I am comes from them, and to fulfill my desire to honor all my ancestors and Creator. My mother also grew up in Fargo and is of Scandinavian ancestry and my father grew up on a farm in South Dakota and is of Irish, German, and Choctaw ancestry. I am enrolled in Choctaw Nation of Oklahoma and often reflect on the tension of embracing or neglecting my Choctaw heritage because of my predominantly white background and experiences. Further, I am married and blessed to have two beautiful daughters. Lastly, I said that I am a math teacher. Currently, I am a math and math education faculty at Turtle Mountain Community College, an Anishinaabe tribal

college. I am a learner to embodying Indigenous knowledges, research, and ceremony and certainly am no expert (Fast & Kovach, 2019; Kovach, 2009; Wilson, 2008). I am honored that you even have an interest in reading my work. Even though I am Choctaw, am from multiple European nations, and am writing this dissertation in English, I introduced myself in Lakȟól'iyapi to honor the Nation, people, and land/place that this research is from. As I learn more of the D/Lakota language, perhaps someday I could translate more portions of this work into D/Lakota.

Long Feather states in her dissertation on D/Lakota oratory, "Communication for Native people then, as asserted here, is not the mere exchange of facts or messages. For Native people, communication involved primarily relationship building" (2007, p.51). Further in describing story, self-introductions, and subjectivity within research, Tuck(Unangax̂) and Yang explain that "Storywork practice is very different from Western commonsense notions of "universal stories," with presumed universal listeners and omniscient narrators who are never actually universal. In those stories, "universal" means unmarked; perspectives that are often masculinist, conquering, and Eurocentric are normalized as gender-neutral, timeless, and placeless. By contrast, storywork makes transparent the listener and the teller" (Tuck & Yang, 2019, p. x). The question is not if research is subjective, for everything a human does, writes, teaches, etc. is laden with personal values. Rather the question is if the subjectivities and assumptions of the researcher and research are known to the researcher and to others (Hampton, 1995; Kovach, 2009; Wilson, 2008).

1.2. An Indigenous Research Paradigm and My Writing Style

Each component of my dissertation and research are carefully crafted to meet the requirements of a PhD from the North Dakota State University math department and Discipline-Based Education Research program while using a research paradigm that is untraditional in

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academia (Gonzalez, 2020). Key aspects of a traditional dissertation in academia (literature review, theoretical framework, methods, results, discussion) are all included but all through the lens of an Indigenous research paradigm (Archibald, 2008; Kovach, 2009; Wilson 2008). Indigenous ways of doing research (as well as ways of knowing, learning, and being) have always been happening on and with this land, but it is only in the past decade or so that an Indigenous research paradigm is being accepted within academia (Smith, 2021; Wilson, 2008). "Indigenous epistemologies challenge the very core of knowledge production and purpose [within academia]. While this is not a matter of one worldview over another, how we make room to privilege both, while also bridging the epistemic differences, is not going to be easy" (Kovach, 2009, p. 29). I seek to follow an Indigenous research paradigm for every aspect of this research and dissertation while still meeting the doctoral requirements. Above all, I seek to honor all my relations.

One way to honor all my relations from the start is to make clear this research, the D/Lakota Math Connections project, does not belong to me. I am not an expert and certainly do not own any of this work or knowledge. In a reality formed by relationships, that is relationality, "the whole idea of 'discovering' something is not there, as what you are doing is just creating a new set of relationships. The idea belongs to the cosmos, to all of the relations that it has formed" (Wilson, 2008, p. 114). Instead of owning or mastering, rather I am now in greater responsibility and accountability to the relationships that I have formed with D/Lakota math, the people who have contributed to this effort, the D/Lakota Nation, the Standing Rock community, and this land. Therefore, the dissertation product is simply my attempts in sharing as many relationships, including D/Lakota math connections, that I can that were formed through this process. It is your responsibility to make the new connections for yourself that you are prepared

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for (Long Feather, 2007; Wilson, 2008). All the strengthened and newly formed relationships throughout the process by you, me, the contributors, the cosmos, etc. are the product. Wilson sometimes explains this strengthening web of relationships as "the process is the product." (Wilson, 2008, p.103).

Wilson (2008), Long Feather (2007), and many more Indigenous academics plainly admit their difficulty in decolonizing not only their research but also their writing. I feel very similar. Kovach warns of "the risk of tribal epistemologies being morphed into something that it is not, merely to become palatable to mainstream academic evaluation" (Kovach, 2009, p. 84). This caution of minimizing, essentializing, or shape-shifting Indigenous knowledges to appease whitestream academia is my greatest concern in doing any research, especially as it relates to research presentations and writings. Kovach learned for herself, and I seek to follow, that "It [a tribal epistemology of relationality] demanded that I 'write knowledge differently' than I had been instructed to do within previous Western research training… Once this tribal epistemology was visible, then all the research choices were considered against it [including writing]." (Kovach, 2009, p. 43).

An Indigenous paradigm for knowing and being, including holistic, relational, and subjective ways of knowing, reinforces the use of storytelling. Kovach sums up much of storying to me in saying "Stories are who we are. They are both method and meaning. Stories spring forth from a holistic epistemology and are the relational glue in a socially interdependent knowledge system" (Kovach, 2009, p. 108). Kovach speaks to identity here and expanded on her idea previously by saying "I knew from a Nêhiýaw point of view that knowledge and story are inseparable, and that interpretative knowing is highly valued, that story is purposeful" (Kovach, 2009, p. 98). The 'relational glue' Kovach speaks to describes the mutual responsibility, that is

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reciprocity, of both listener/reader and speaker/author. The power of story to encompass heart, mind, body, and spirit has led a growing number of Indigenous researchers, and now me, to use story in presenting their work. Kovach speaks directly when she says, "Story as methodology is decolonizing research" (Kovach, 2009, p. 103).

Even though I am a learner to research, ceremony, Indigenous knowledges, and the D/Lakota language, certain values in the literature from Indigenous education scholars have allowed me to continue with clarity, although not easily. Some of these values are reciprocal relationships, 'giving back' to the community (Kovach, 2009; Shirley & Angulo, 2019; Smith, 2021; Wilson, 2008) and intentional power shifts away from the individual researcher to the community sometimes described as self-determination or local control (Kovach, 2009; Sanders, 2011; Smith, 2021; Tuck, 2009; Wilson, 2008). Wilson elaborates that "As we Indigenous scholars have begun to assert our power, we are no longer allowing others to speak in our stead. We are beginning to articulate our own research paradigms and to demand that research conducted in our communities follows our codes of conduct and honors our systems of knowledge and worldviews" (Wilson, 2008, p. 8). My understanding of an Indigenous research paradigm began through books, an obvious limitation, and now through the process is transforming to be more and more relationship-centric, holistic, and synergistic (Archibald, 2008; Kovach, 2009; Wilson, 2008). My initial responses and continual reflection on critical questions from Indigenous scholars lead me away from colonial research of the past and present. "Was I doing anything different from earlier 'outsider' academics who created a legacy of mistrust among Frist Nations concerning academic research? How was my research going to benefit the education and wellbeing of Indigenous peoples and their communities? How would I

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address ethical issues related to respect and ownership of Indigenous intellectual property?" (Archibald, 2008, p. 36).

Overall, my research project and this dissertation seek to follow Wilson's description of an Indigenous research paradigm where reality and ways of knowing/learning could be described by relationality (relationships from reality). Further, being accountable to all my relations describes the methodology, expected products, and the values that guide the research (Wilson, 2008). The strength, rigor, validity of this research is not in comparing an Indigenous research paradigm to a Western research paradigm, but rather comes from the alignment of all key aspects of a research paradigm with relationality and relational accountability. All research decisions were made to continually weave relationality and relational accountability together (Archibald, 2008; Kovach, 2009; Wilson, 2008).

1.3. Project Overview

"The process is the product" (Wilson, 2008, p.103) for this research project. The research questions were not pre-determined by locating a gap in the literature, common in Western research paradigms. Rather a set of values were determined through the literature and then the strengthened relationships (including intellectual, human-to-human, spiritual, with the land, etc.) that happened throughout the research process are the product. The research questions were both developed and answered through the process. I sought to do actionable and beneficial research for math instructors at Sitting Bull College and through the literature determined to apply an Indigenous research paradigm to research in undergraduate math education.

At Sitting Bull College in Standing Rock Nation, a portion of the mission statement reads, "Guided by Lakota/Dakota culture, values, and language, Sitting Bull College is committed to building intellectual capacity through academics" (Sitting Bull College, 2023).

This mission applies to all STEM courses and specifically math. This expands beyond Sitting Bull College as well. Across all TCUs and Indigenous communities, there are efforts to connect STEM with place-based, community-specific culture, language, and knowledge at the TCU as well as K-12 level (American Indian Science and Engineering Society, 2020; Boyer, 2011; Lipka et al., 2005; S. Meyer & Aikenhead, 2021a,b). Further, at the K-8 level, the Yup'ik in Alaska have demonstrated the many benefits of connecting language and culture with math in the classroom ranging from increased cultural identity for students to increased math exam scores (Kisker et al., 2012; Lipka & Adams, 2004; Lipka et al., 2007). Personally, the story "Coyote Searching for the Bone Needle" (Archibald, 2008, pp. 35–36) influenced me to 'do something different' than previous researchers at the intersection of research in math education with Indigenous communities. This story changed my heart and mind to further understand the seductive and destructive force of maintaining the colonial status quo of Western math superiority over D/Lakota math.

At the college level, calls for culture to be more integrated into the math classroom have been met with epistemological challenges as well as a dearth of math and local culture resources (S. Meyer & Aikenhead, 2021a,b; Ruef et al., 2020; Stevens, 2021; Webb et al., 2017). If Western mathematics is assumed to transcend culture, as it often is in mainstream Western education, then how can the TCU math classrooms connect with Indigenous culture? (Aikenhead, 2017; Bishop, 1990; Ernest, 2021; Stevens, 2021) More specifically, in what ways could Sitting Bull College math classrooms connect with Lakota/Dakota culture, values, and language? The Dakota/Lakota Math Connections research project addresses both challenges of epistemological misalignment and the scarcity of college math *and* Dakota/Lakota culture resources.

1.4. Dissertation Overview

This dissertation seeks to follow an Indigenous research paradigm in every possible way while also being a three-paper dissertation to earn my doctorate degree. The first paper was published in two places; therefore, this dissertation now contains four papers on three distinct topics. Chapter 3, 4, 5, and 6 are all distinct research papers that can stand on their own and are each published in distinct peer-reviewed research journals. Each distinct research paper is the entirety of chapter 3, 4, 5 and 6 respectively. Ch. 3, 4, and 5 have all been peer-reviewed and accepted. Ch.6 is in the peer-review process currently.

Although some details and context are repeated within the four stand-alone papers describing one research project, each paper spirals around the central idea (and title for the dissertation) "D/Lakota Math Connections: Applying an Indigenous Research Paradigm to Research in Undergraduate Math Education". Following the seminal piece on Indigenous storywork, Archibald (2008) quotes Hampton saying the story progresses "in a spiral that adds a little with each thematic repetition rather than building an Aristotelian argument step-by-step... I found new meaning in each turn of the spiral" (Hampton, 1995, p. 6). Further the seminal piece on an Indigenous research paradigm (2008), Wilson quotes Tafoya saying "Stories go in circles. They don't go in straight lines. It helps if you listen in circles because there are stories inside and between stories" (Tafoya, 1995, p.12). This three/four-paper dissertation could be read with these two quotes in mind.

In the book "Applying Indigenous Research Methods: Storying with Peoples and Communities" (2019), editors Windchief and San Pedro asked the following questions to contributors, whom they considered as academic elders. ""In applying IRMs to our lives and to our research, what particular methods are used? How are IRMs enacted with others? How do

relationships to place and to one another impact the application of IRMs?" (2019, p. xv). Reading the contributed chapters was part of my inspiration in applying an Indigenous research paradigm to research in undergraduate math education at Sitting Bull College. Further, these questions have help guide me in what to focus on in my writing of this dissertation in general and even more for chapter 1 and 7.

1.4.1. Chapter 1

Chapter 1 of this dissertation is an introduction to an Indigenous research paradigm and the project overall. It includes my formal introduction, an introduction to my writing style, a project overview, a dissertation overview, and lastly an introduction to storying and listening. This entire chapters seeks to fit the entire dissertation in context, including the context of me as author, math education, research with Indigenous communities, and the power of story as method and meaning. Chapter 1 was written after chapter 2, 3, 4, 5 and 6 were finalized.

1.4.2. Chapter 2

Chapter 2 of this dissertation is a four-part literature review. Chapter 2 is **not** a stand-alone paper but further sets the context and story of Ch.3, 4, 5 and 6.

Part 1 of Chapter 2 is excerpts from my initial literature review on Indigenous research methodologies/paradigms. This initial literature review was part of my qualifying exams for the NDSU Discipline-Based Education Research PhD Program. This initial literature review shifted from 'synthesizing the literature' as I was initially guided by my committee towards 'embodying the literature' as the Indigenous research methodology literature described. Cora Weber-Pillwax (Cree) shares a metaphor that has consistently aided me in understanding, applying, and living an Indigenous research paradigm. She says "until we live them [Indigenous research

methodologies/paradigms]… it's like writing 'bread' on a piece of paper and eating the paper instead of having the bread" (Wilson, 2008, p. 103).

Part 2 of Chapter 2 is my proposal letter to my PhD Committee to advance to candidacy. The letter/proposal is shared in nearly entirety. It defends the rigor and validity of an Indigenous research paradigm, but not by comparing an Indigenous research paradigm to Western research paradigms but rather through alignment of ontology, epistemology, methodology, and axiology. Wilson, in his seminal work, chose not to compare to (or build from) Western research paradigms. Rather, he demonstrated that Indigenous knowledges could stand on their own as distinct. No outside 'validation' is necessary or even appropriate (Wilson, 2008; Kovach, 2009). Further the proposal shared the literature and initial examples/results at the intersections of Indigenous communities, undergraduate math education, an Indigenous research paradigm, and local, place-based culture and language. Lastly, the proposal laid out the process for my research and dissertation expectations as they were known at that moment in the process.

Part 3 of Chapter 2 shares the relevant literature published or found during the dissertation process, that is after my proposal. This literature influenced the data synthesis process and also brought confirmation to the values and approach being followed from the lens of an Indigenous research paradigm. Gutiérrez's framework on rehumanizing mathematics specifically calls for research-based illustrations of mirrors where Indigenous, Latinx, and Black students see aspects of themselves reflected back to them in the math classroom and curriculum (Gutiérrez, 2018). Further, the Show Me Your Math project, event, and research in the Mi'kmaw and Maliseet nations for grades K-12 strongly corroborates with the D/Lakota Math Connections project in both process and results. Further, Phillip Stevens describes Apache mathematics and the Maori, Cree, and Ojibwe math dictionaries are explored. Lastly, all these examples of

corroborating research are viewed through math teacher professional development. Although this dissertation does not yet get to teacher professional development in forms of research, it is included as an aspect of the research as one way to stay accountable to all my relations.

Lastly, Part 4 of Chapter 2 shares my relationships with people before and during the research. It is not a literature review but rather describes how I am seeking to embody the literature by sharing my continual accountability to all my human relationships. Since relationships are not static but always changing, this written description is only a snapshot at a certain time. Further, this section allows readers not part of the dissertation process to get a glimpse of the relational web that was formed and to see the relational web that holds our collective understanding of the D/Lakota Math Connections project. These relationships are invaluable for the research. Not only do we all have our own unique relationships/understanding with the D/Lakota Math Connections project, but the research project could not have happened without them.

1.4.3. Chapter 3

The first paper of this four-paper dissertation is titled "Circulating Conversations Methodology: Co-Connecting Knowledge to Develop Research Questions at Sitting Bull College" (Luecke et al., 2022). It was co-authored with Sunshine Carlow, Josh Mattes, Warren Christensen, and Hollie Mackey and was published in the peer-reviewed, open-source journal titled "Philosophy of Mathematics Education Journal".

Circulating Conversations Methodology (CCM) is one approach within an Indigenous research paradigm to determine the research direction and research questions. This methodological paper shares both the process of developing Circulating Conversations Methodology and how the Circulating Conversations Methodology was specifically enacted at

Sitting Bull College to develop research questions for undergraduate math education. Through collaborative connecting via conversation and story, relationships were strengthened and formed amongst the co-authors as we co-connected knowledge. This paper is a story intertwining the process of developing the research questions, the resulting research questions, and the relationships formed through the process. Circulating Conversations Methodology and this paper follow an Indigenous research paradigm principle "the process is the product." (Wilson, 2008, p.103) and exemplify that "research is all about unanswered questions, but it also reveals our unquestioned answers" (Wilson, 2008, p.6).

Indigenous research paradigm/methodologies literature lays the foundational principles for the process and outcomes of research with Indigenous Peoples while leaving room to uniquely reflect place and community (Archibald, 2008; Kovach, 2009; Wilson, 2008). Sitting Bull College is a tribal college/university chartered by Standing Rock Nation and guided by Dakota/Lakota culture, values, and language. The co-authors included a Sitting Bull College math instructor, a Lakota language immersion instructor, an Indigenous research paradigm specialist, my co-advisor and me. This paper articulates how we experienced conceptual ideas related to Indigenous research and methodologies such as relationality, responsibility, and reciprocity within specific place-based math education research. The methodology is titled Circulating Conversations Methodology and implements what we came to describe as co-connecting knowledge. As far as we are aware, Indigenous research methodologies have not yet been applied to research in undergraduate math education. Circulating Conversations Methodology demonstrates both the possibilities and value for using Indigenous research methodologies to strengthen undergraduate math education.

The resulting research questions developed by co-connecting knowledge via the Circulating Conversations Methodology are:

In what ways can Western higher order math concepts be identified within Dakota/Lakota space, place, and language, to inform possible Sitting Bull College math curricular/pedagogical adjustments?

In what ways can Dakota/Lakota culture and language be identified within Western higher order math concepts, to inform possible Lakota Language Immersion Nest curricular adjustments?

In what ways can Dakota/Lakota space, place, and language represent non- Western higher order math concepts?

In what ways can Indigenous Research Methodologies lead an individual researcher towards more ethical and impactful (beneficial and actionable) research in undergraduate math education at tribal colleges and universities?

The first three questions are answered mostly in Chapter 6 with the process to answer them and the framework for answering them in Chapter 5. The last research question is partially answered through this first paper and even more through the whole process as I sought to follow the literature that described a spiritual, holistic, respectful, relationship-oriented, place-based, language and community-specific research. The answer to this last question is the specific actions taken throughout this research process giving concrete examples to the Indigenous research paradigm adage "the process is the product." (Wilson, 2008, p.103).

1.4.4. Chapter 4

The second paper of this four-paper dissertation is titled "The Story of Circulating Conversations Methodology towards RUME Research Questions" (Luecke, 2022). I am the sole

author on this paper, and it covers the same content as the first paper/Chapter 3 but is much shorter due to being a conference paper. It was peer-reviewed (double-blind) and accepted into the "SIGMAA (Special Interest Group of the Mathematical Association of American) on RUME (Research in Undergraduate Math Education) Conference 2022" in Boston, Massachusetts.

This paper shares similar content as Chapter 3 but synthesized down to a 7-page conference paper. Both the peer-review feedback and oral presentation question session gave feedback on applying an Indigenous research paradigm to research in undergraduate math education. Ch.7 (Discussion and Implications) will share some reflections to the peer-review feedback and conference experience.

1.4.5. Chapter 5

The third paper of this four-paper dissertation is titled "Dakota/Lakota Math Connections: An Epistemological Framework for Teaching and Learning Mathematics With Indigenous Communities and Students" (Luecke & Sanders, 2023). It was co-authored with David Sanders and is published in the peer-reviewed, open-source, and high impact journal titled "Frontiers in Education: Centering Humanism in STEM Education."

This paper will specifically focus on the challenge of epistemological misalignment between Sitting Bull College's mission of academics guided by D/Lakota culture, value, and language with the Western assumption of mathematics as universal and objective, meaning that math is the same for everyone with no influence from local culture but rather transcends local culture (Aikenhead, 2017; Bishop, 1990; Ernest, 2021; Stevens, 2021). As the Sitting Bull College mission mandates, D/Lakota culture, values, and language are place-based [not universal]; holistically include mind, heart, body, and spirit; and have a strong emphasis on

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relationship/context. In this tension of epistemological misalignment, the D/Lakota Math Connections project emerged.

Sanders and I co-facilitated a week-long course on D/Lakota Math Connections in summer 2021. Course participants/contributors included math teachers (middle school through college), language teachers (immersion elementary through middle school), fluent elders, and community members. In preparation for the course, Sanders and I co-developed the D/Lakota Math Connections framework. The framework is a four circle Venn diagram with each circle labeled as D/Lakota math, Western math, the English language, and the D/Lakota language. Seven initial assumptions were shared with the course participants and further understood through the course experience.

Each circle is distinct.

Each circle stands on its own.

Each circle (equally sized) is equally valuable.

Each circle is connected to all the other circles.

No pre-determined definition is needed.

Higher order mathematical concepts are embedded within the language and culture.

Math fluency and language fluency can grow together.

During the course, we collaboratively experienced, evaluated, and confirmed the D/Lakota Math Connections framework for teaching and learning mathematics in both the math and language classrooms at Sitting Bull College. The framework was initially confirmed through an intuitive synthesis of non-quantifiable relational outcomes.

After the course, this initial confirmation was brought into greater relationship, that is encircled, by the two following research questions developed and answered during the data synthesis/analysis stage.

In what ways did the framework impact the participants?

In what ways did the participants influence the framework?

To address how the framework impacted the participants, a quantitative analysis was conducted on participants' self-assessment of their change of knowledge from Monday to Friday. To address how the participants influence the framework, two additional methods were employed. First, a quantitative analysis was conducted on the participants' ratings on what circles and intersections were most/least emphasized during the course. Secondly, and arguably the most important, the knowledge keepers of the community (that is fluent elders) shared their perspectives on the course, framework, and project overall.

Altogether the results confirmed that math fluency and language fluency grow together. Further, they demonstrated the need for more work in D/Lakota Math. Quantitative results displayed that participants' greatest growth and increased connections was in D/Lakota Math **and** participants' rated D/Lakota Math as the least emphasized in the course. If the most change/learning came from the area with the least emphasis/teaching, then the combination is a strong indicator for further work in D/Lakota Math, both in researching D/Lakota math and in professional development for math and language instructors.

Lastly, the stories and insight from fluent and language learning elders re-defined the understanding of the D/Lakota Math Connections framework. The elders' validation of the research approach and framework is the strongest and most significant confirmation. No other endorsement or research validation is needed. Altogether math teachers, language teachers, and

elders influenced the framework, sometimes confirming initial assumptions and sometimes

expanding and adding new relationships to the framework.

1.4.6. Chapter 6

The fourth and final paper of this four-paper dissertation is titled "Dakota/Lakota Math

Connections: Results from Developing a Community-based Math Resource" (Luecke, in

review). I am the sole author on this paper and it is in the review process with the peer-reviewed,

open-source journal titled "Tribal College and University Research Journal."

This paper shares the process and results of developing a community-based math

resource. The content/examples of the math resource are the answers to the initial three research

questions developed in the Circulating Conversations Methodology. The examples are called

D/Lakota math connections and are partially shared in this paper for word count and data

sovereignty reasons. The full results can be found at www.othokahe.com, a web portal under the

Standing Rock Iyapi, a branch of the Standing Rock Sioux Tribe Department of Education.

Being hosted by Standing Rock Iyapi allows the language leaders in the community to have final

authority on what and how the D/Lakota Math Connections resource is shared.

The full results are displayed as a non-linear web to model both the interconnected nature

of math and the rich course conversations that meandered through many mathematical topics

making a variety of connections along the way. For example, nested sets in mathematical set

theory was discussed with buffalo circling up, odd and even numbers, family structure (tiwáhe,

tióšpaye, oyáte), and Ring theory categorization of domains. Series/partial sums connected to the

D/Lakota number system and conditional probability within Hand Game are both examples of

D/Lakota math connections that can inform possible Sitting Bull College math

curricular/pedagogical adjustments. Along with these two examples, a metaphor for adding

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fractions and continuing courses to develop words/phrases for math terms can inform possible Lakota language immersion Nest curricular adjustments. Lastly, the previous four examples plus the sun cycle and numbers as verbs are examples of D/Lakota math distinct from Western math. These six examples (and more examples on Othokahe) answer the first three research questions and are the results from developing a community-based math resource.

1.4.7. Chapter 7

The last chapter is not a synthesis of the most significant results but rather shares the most significant results to me. From an Indigenous perspective "we know what we know from where we stand" (Kovach, 2009, p. 7) and "embedded in our places [is] where land, learning, identity, and education intersect" (Styres, 2018, p.24). I do not pretend to tell you how this project will connect with your place, land, learning, and identity. I hope that as I share the relationships that have been strengthened or newly formed through this research for me, you will be able to make your own connections and draw your own conclusions.

The final chapter of my dissertation is presented in four sections and a conclusion. "Stories go in circles. They don't go in straight lines. It helps if you listen in circles because there are stories inside and between stories" (Tafoya, 1995, p.12). The four sections of this last chapter try to emphasize the stories between and throughout the four distinct papers/chapters. One subsection focuses on the process of this research in answering research question 4. Next, product of this research is shared in answering research question 1-3. The story inside and between the four published papers is the peer-review process of the papers and my comments in response. Lastly, implications for applying an Indigenous research paradigm to research in undergraduate math education, for the D/Lakota Math Connections project and for research in Indigenous math in general are shared.

1.5. Listening – An Introduction

In this final section of Chapter 1, I attempt to share my understanding and application of listening in this project. Long Feather's Medicine Wheel Diagram for a L/N/Dakota Model of Oratory (Long Feather, 2007, p.125) is built on a foundation of listening. She describes that the "orator who listens has the requisite human experience to speak authoritatively on the subject but, because of the cultural value of respect, will not make such an assertion" (Long Feather, 2007, p.126). I am not Dakota nor Lakota, nor grew up in an Oceti Sakowin community, and so listening to the self-stated goals of the community (leaders) seems even more important as an outsider. A spiritual moment of epiphany earlier in my graduate school training made me realize my desire is to 'follow the community' and not just 'follow the money.' This idea could similarly be stated as 'even though money [from outside granting agencies] talks loudly, listen to the community.' My desire for this entire project was to listen to the community leaders and their self-stated goals. In short, doing so led me from research in undergraduate math education solely to research in undergraduate math education intersected with language and self-determination in a more wholistic and relational way.

Figure 1

Long Feather's Medicine Wheel Diagram for "A Lakota/Nakota/Dakota Model of Oratory"
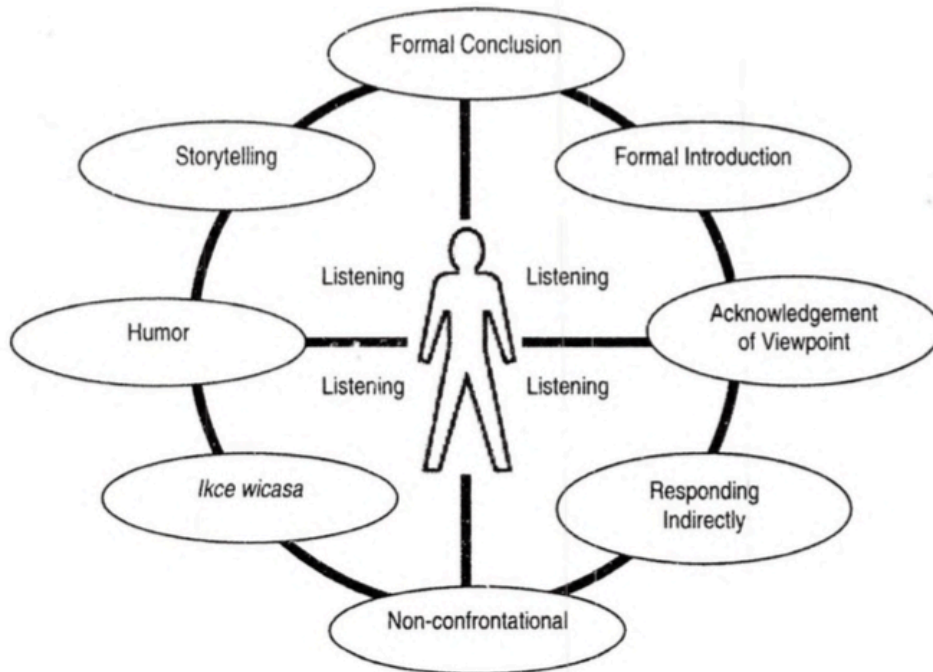
Note. Figure found in Long Feather, 2007, p.125

This type of listening is personal, connecting with both your mind and your heart. It is not merely an external process but an internal process. Long Feather says that:

The process of communication must necessarily connect mind and heart of both communicators or the intent and purpose of communication has not been met. In other words, the message may have been transmitted and received but, unless the listener/receiver internalized the message into heart and mind, the connection was not made. 'Talking heads' is a common term for the lack of connection and it can be argued that much of our communication in the modern world follows this pattern. Figure 5 illustrates the importance of connecting through relationship-building and that this connection must be made before communication can be considered successful or

complete. What this means in practical terms is that much of what contemporary society calls communication is not communication at all but a mere use of words. (p.51)

Figure 2

Long Feather's Figure 5. "Oratory as External vs Internal Process."
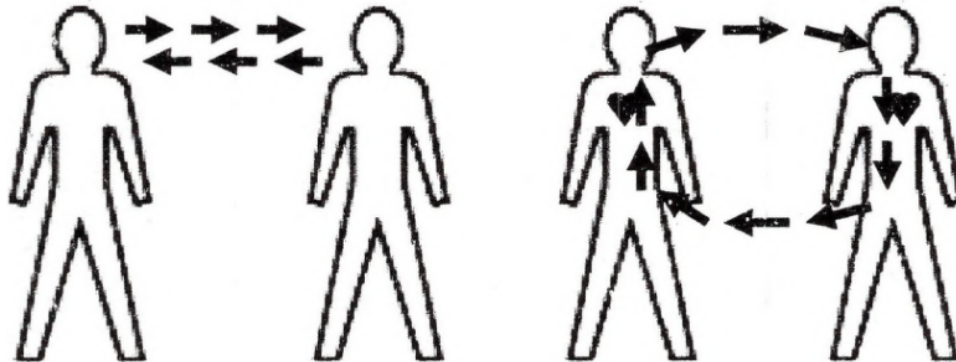
Note. Figure found in Long Feather, 2007, p.51

Archibald agrees in what the Elders had taught her. "As the Elders say, it is important to listen with 'three ears: two on the sides of our head and the one that is in our heart' "(Archibald, 2008, p. 8). Listening is wholistic and requires that one must have "enough wisdom and self-control to listen to all sides before making an informed decision about just what one was willing to believe" (Long Feather, 2007, p.134). Further, "Listening also plays an integral role in self-reflection and self-awareness, two fundamental attributes of wisdom… and for understanding relationships and their multiple meanings" (Long Feather, 2007, p.164). In order to learn, then observing and listening to nature, elders, spirits, self, etc. are a must.

Listening with three ears further allows lessons to be gleaned through the silence or indirect communication. Archibald added 'work' to create her term storywork because story as method and meaning was not being taken seriously within academia and Western audiences (2008). Nearly all of the seminal pieces of an Indigenous research paradigm were written as books and not research articles. The listening process for articles and books is different. Kovach

shares that "the choice of writing a book, as opposed to a series of separately published journal articles, was to ensure that this offering could, and would, be taken up as a holistic unit" (Kovach, 2009, p. 11). Additionally, Kovach recognizes "the pressure on Indigenous researchers to present research findings in a manner that does not radically contest established standards lest they risk entering into a publication void" (Kovach, 2009, p. 84). This is a difficult task when peer-reviewed journals entail "a discussion of findings extracted from context" (Kovach, 2009, p. 84). That is on top of story and self-location being considered indulgent instead of necessity. Both of these reasons increase "the risk of tribal epistemologies being morphed into something that it is not, merely to become palatable to mainstream academic evaluation" (Kovach, 2009, p. 84). This caution of minimizing, essentializing, or shape-shifting Indigenous knowledges to appease whitestream academia is my greatest concern in doing any research, especially as it relates to research presentations and writings.

Listening for me throughout this process also informs how I write and your role as a reader/listener. Certain cultural norms to listening/learning (a universal listener, an omniscient, objective narrator, direct communication, results isolated from method, etc.) are often expected within mainstream academia, however writing (and listening) in story is quite different.

When presenting to a L/N/Dakota audience, it is implicitly understood that the speaker (writer, in this case) will begin, progress and end according to their own personal understandings and insights. The role of the listener (reader, in this case) then is to open themselves up to the sharing of the information and follow along the path on which the speaker takes them. This type of listening/reading is difficult, oftentimes, for those who are used to a more structured approach in which we are taught to "tell them what you are going to tell them, tell them and then tell them what you told them". A patient and self-

reflective listening that is required in a Native-based approach is a practice that a fast-paced society often does not permit. In today's society, listeners/readers expect a speaker/writer to "get to the point". As a L/N/Dakota person, however, I am taught that getting to "the point" is impolite and arrogant. I am also taught that the manner in which a speaker proceeds along his or her verbal path tells us just as much (if not more) about a person and his or her life experiences than the actual words reveal. These are critical aspects of a culturally-based Native model of communication. (Long Feather, 2007, p.13-14).

I still have much to learn in the area of listening in my personal life as well as in my research. Collaborative research efforts and local control of the research in undergraduate math education will continue to push me towards listening with my heart.

2. FOUR PART LITERATURE REVIEW

The literature review for this dissertation will be presented in four distinct sections. The first three sections follow the timeline of the PhD process, and the last section describes the relationships with other people developed through the process. Although this may be unconventional compared to a standard dissertation with a chapter two literature review, the literature review presented here follows the Indigenous research paradigm/methodology that guided the entire research project from conception to completion.

Eve Tuck (Unangax̂), Indigenous education scholar, explains "Citation is political… in academic writing, especially within critical fields of education. In referencing a body of work to make an idea or argument, one is signaling which genealogies matter, and which can be de-emphasized." (Wemigwase & Tuck, 2019, p. 84) Therefore, the literature highlighted here is a political act. Both the research in and of itself is political, and the research is set within a political context. To pretend current education research has no influence on United States education politics is disconnected, colonized thinking (Brayboy, 2005; Grande, 2015; Smith, 2021). Historically and currently, the United States education system is not designed to benefit Indigenous Peoples and/or support Indigenous ways of knowing and being, teaching and learning (Brayboy, 2005; Grande, 2015; Mackey et al., 2020; M. A. Meyer, 2014; Smith et al., 2018). This research is political. Not Democrat/Republican political, but in the sense that an Indigenous research paradigm privileges and centers Indigenous continual presence on Indigenous land (Smith, 2021; Tuck, 2009).

In this context of a political literature review, and PhD research in its whole, the first two sections are written in first person following my research journey within an Indigenous research paradigm. The third section includes the most recent literature published during/after the data

collection for this project. Lastly, the fourth section is written in first person again. This final section attempts to describe the human relationships developed through the research process and describe how I begin and will continue my accountability to those relationships.

In a Western worldview, the written word is highly valued to the detriment or even erasure of the oral word. Standard citation practices in Western worldview research rarely, if ever, cite oral communication. The written word removes the fluidity that allows ideas to grow and change. Written discourse allows fixed words to be taken out of context and dissected. It minimizes the mutual responsibility that is inherent in oral communication (Wilson, 2008). In my journey, the written word from Indigenous scholars taught me to center relationship in this research. They taught me that listening to the Indigenous educators, elders, and community members in my community can and should be the greatest influence (Archibald, 2008; Kovach, 2009; Wilson, 2008). Thus, the conversations and relationships that took place within this research are equally if not a greater influence on the outcome of this research. To me, not citing these conversations and relationships goes against the grain of an Indigenous research paradigm.

I believe in the adage "knowledge is power." In the seminal work by Margaret Kovach (Plains Cree/Saulteaux), she succinctly lays out that if one believes that 'knowledge is power,' then inevitably choosing a research paradigm, including citation practices, to find new knowledge is a political act influenced by power dynamics (Kovach, 2009). The four sections that follow describe the literature and relationships that most influenced this PhD dissertation research.

2.1. Initial Literature Review for Indigenous Research Methodologies

In Fall of 2019, as I read the literature around Indigenous Research Methodologies, it became apparent that I the must change the goal and structure of my literature review to align

with the literature itself. The literature review began with a Western approach to "synthesize the literature" but needed to be transformed into "embodying the literature" holistically into my identity, the writing style, and the format in totality for the literature review. The literature review structure became a non-static 4-circle Venn Diagram, or perhaps, better thought of as a kaleidoscope.

Cora Weber-Pillwax (Cree), an academic elder, shares a metaphor that has consistently aided me in how I should talk about Indigenous Research Methodologies. She says "until we live them [IRMs]… it's like writing 'bread' on a piece of paper and eating the paper instead of having the bread" (Wilson, 2008, p. 103). This metaphor crystallizes my movement towards "embodying the literature" in writing my literature review.

Along with embodying the literature, my literature review followed Wilson's affirmation of the title *literature review,* not a *literature critique*. He says "critiquing others' work does not fit well within my cultural framework [including an epistemology based in relationality] because it does not follow the Indigenous axiology of relational accountability. Criticizing or judging would imply that I know more about someone else's work and the relationships that went into it than they do themselves" (Wilson, 2008, p. 43).

The final draft proposed to my PhD committee was over fifty pages single-space. It was my first attempt at writing in an academic setting following the guidance of Indigenous research paradigm. Much of the content has been synthesized and/or re-told in my PhD proposal and Paper 1/Chapter 3 of this dissertation. This section is excerpts from 'Circle 1: Introductory Relationships' of my initial literature review on Indigenous Research Methodologies that are not just a repeat in the proposal or Paper 1.

2.1.1. Cover Page for Indigenous Research Methodologies (IRMs) Literature Review

Danny Luecke

Fall 2020

STEM Education PhD Program

Written Preliminary Exam

Committee: Bill Martin (advisor), Warren Christensen (co-advisor),

Hollie Mackey, Jessica Striker, Jason Boynton, Robert Pieri

2.1.2. Circle 1: Introductory Relationships

Halito (Hello). My name is Danny Luecke. Thank you for taking the time to join me in learning about Indigenous research methodologies (IRMs). Even though I am thankful for the opportunity to share on some of what I have been learning, I am nervous to share this literature review.

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Standing on the shoulders of academic 'elders' of IRMs, I am grateful for their honesty and generosity in all they wrote. This learning and writing process has strengthened my relationships within myself, with others, with the Land, and with the content of IRMs itself. I pray that the same may happen to you through your reading. My desire for this writing is that you will have many opportunities to connect to Indigenous ways of knowing, being, and doing. Specifically, I desire for this work to connect with you intellectually but also connect emotionally and spiritually. A holistic engagement is exemplified in the title of seminal work "Indigenous Storywork: Educating the Heart, Mind, Body, and Spirit" (2008) by Jo-ann Archibald (Stó:lō and St'at'imc). Here is one teaching I have sought to embrace and hope you

may follow also. "As the Elders say, it is important to listen with 'three ears: two on the sides of our head and the one that is in our heart' "(Archibald, 2008, p. 8).

Therefore, each time I reworked the outline and drafts I pushed more towards storytelling. Archibald emphasizes the ability of storytelling in saying "Stories have the power to make our hearts, minds, bodies, and spirits work together. When we lose a part of ourselves, we lose balance and harmony" (Archibald, 2008, p. 12). Even though story as writing style, and Indigenous knowledges as a whole, are new to me, I have the responsibility to follow the academic "elders" guidance in how I learn, embody, and share my understanding of IRMs (Archibald, 2008; Hampton, 1995; Wilson, 2008). Further I join with these Indigenous authors and researchers in grappling with how to best honor Indigenous knowledges in a university setting (Kovach, 2009). Forcing Indigenous knowledges into a Western linear model of literacy and knowing would be considered disrespectful (Archibald, 2008). Therefore, I have attempted to structure this literature review non-linearly. The following quote by Terry Tafoya guides me. "Stories go in circles. They don't go in straight lines. If helps if you listen in circles because there are stories inside and between stories" (Tafoya, 1995, p. 12).

In this literature review, the four major circles are introductory relationships, contextual relationships, colonial relationships, and my Indigenous research paradigm story. Each major circle connects and interacts to the other major circles like a four-circle Venn diagram. However, my hope is that you view this four-circle Venn diagram as non-static, changing in shape like a kaleidoscope being turned back and forth. In this way, my desire is to write in a web-like format that connects to your web of relationships as you form new connections with the content. Each major circle is a story within itself and is interdependent and interrelated with each other circle

(Hampton, 1995; Kovach, 2009; Smith, 2021; Wilson, 2008). Circle 1-3 set the context for my Indigenous research paradigm story.

From the start I emphasize that this literature review is my understanding of these ideas. The story presented is *my* journey. Even if you and I read the same literature, because of our different relationships to research, education, and Indigenous Peoples and cultures, we would come to a different understanding of IRMs. That is, we would form a different relationship with the content. This demonstrates a relational way of knowing. In research specifically, "the whole idea of 'discovering' something is not there, as what you are doing is just creating a new set of relationships. The idea belongs to the cosmos, to all of the relations that it has formed" (Wilson, 2008, p. 114).

A relational way of knowing breaks any notion of 'expert', because nobody can possibly know all of another's relations. Further, I want to strongly dismiss any notions of me being an 'expert' (Fast & Kovach, 2019; Kovach, 2009; Wilson, 2008). When it comes to Indigenous knowledges and IRMs I feel like a very young child! Through this process, I have come to believe that I may always feel this way. Despite over the past year greatly strengthening my relationship with IRMs, there is so much more that remains vague and blurry. As I cyclically read the literature, major themes keep coming to the forefront and connect a little bit more to who I am and to my understanding. Thank you for joining me in unravelling this journey. Yakoke!

…

Research on Indigenous terms is described by Shawn Wilson (Opaskwayak Cree) in his seminal work 'Research is Ceremony: Indigenous Research Methods' (2008). Wilson claims that Indigenous research paradigms certainly do not need to be narrowed down to one or two ideas or

terms but if they were, the concepts would definitely be relationality and relational accountability. Relationality holds that all knowledge and research "needs to be seen within the context of the relationships it represents" (Wilson, 2008, p. 43). From there the methodology fixates on responsibility, respect, and reciprocity to be accountable to all these relationships. Thus, as I learn and write about IRMs, the responsibility to respect and honor the authors and Indigenous knowledges sits squarely on me. This is a form of reciprocity with the Indigenous scholars who have already demonstrated responsibility and respect towards Indigenous knowledges in their works (Wilson, 2008). This weight of accountability leads me to present this literature review on IRMs through an Indigenous writing style. It is my attempt to embody the learning into who I am and not stay intellectually fragmented. Additionally, I believe it to be most academically accurate and rigorous to present content through a framework and a presentation style that is congruent with that content (Archibald, 2008; Kovach, 2009; Smith, 2021; Wilson, 2008). I do not claim to have successfully reached or arrived at these goals (Kovach, 2009; Wilson, 2008), but that in my journey I am pursuing holistic, relational, and decolonizing ways of doing this literature review to the best of my ability.

My journey did not begin this way, however. Entering into the literature around IRMs, I did not expect holistic learning to include a spiritual component or this literature review to be written in a style I had yet to be exposed to in my U.S. education. My research journal documents that within the first handful of hours of writing my first outline it became evident to me that I needed to embody and apply Indigenous knowledges. Not only do Indigenous ways of knowing, being, and doing need to be honored but, to do that, the methodology and writing process must align with Indigenous knowledges (Kovach, 2009; Smith, 2021). So, before going

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any further, I self-locate myself within the web of relationships that are who I am (Wilson, 2008).

 …

  Within holistic ways of knowing, a researcher's purpose is found within personal story (Hampton, 1995; Kovach, 2009). Relating to my research, when I was finishing my Master's degree in mathematics determining if I should do research in pure math or math education, I recall telling my friends and family that "I would enjoy research in math, seeing the field of math advance, but I would really enjoy research in math education, using math to see people advance." This explanation to others and myself was based in the desire to love people as God loved me and leant towards an abstract altruistic motivation. Upon reading 'Research is Ceremony,' Wilson speaks the words of my heart when he says, "I feel as though there has been a gradual shift, subtle and perhaps long lasting, in my perception and view of the world" (Wilson, 2008, p. 136). This resonates with me as relationships with Native students at NDSU, Native students at TCUs (tribal colleges and universities) in ND, Native faculty and mentors, and the scholarship of Native authors with IRMs have altogether changed me as a person and my views of Indigenous knowledges. My research purpose now includes a very real responsibility to my ancestors, Land, Creator, and my growing networks of Native faculty, mentors, peers, and students. These two complementary motivation impetuses (using math to see people advance and relational accountability) exemplify the metaphor for my research journey; *learning to walk on both of my legs.*

  Learning to walk on both of my legs represents to me honoring all of my ancestors. For too long I neglected part of my ancestry to my own detriment. Now, I am learning about my Choctaw and Indigenous heritage and it is making me a stronger person and researcher. Further,

walking on both of my legs represents using two different epistemologies (that is, ways of knowing); an Indigenous knowledge leg and a Western knowledge leg. I humbly acknowledge those who do not have or cannot use two legs. I have wrestled with my able-bodied privilege and am still not sure if this metaphor is appropriate. Despite the appearance of a two-leg binary, both Western knowledges and Indigenous knowledges are extremely diverse in and of themselves. Further, both legs (epistemologies) in and of themselves can be stood upon distinct from the other (Archibald, 2008; Kovach, 2009; Wilson, 2008). To me personally, in my set of relations, I want to stand, walk, and run on both, however this is not a necessity for any person or researcher. Indigenous ways of knowing stood strong for thousands of years before any contact with the Western world (Smith, 2021; Wilson, 2008). Since contact, Western knowledge and power structures continually seek to dismiss, minimize, and/or illegitimatize Indigenous knowledges, therefore creating a hegemony of Western research methodologies in academia (Kovach, 2009; Smith, 2021; Wilson, 2008). Archibald shares two extremely powerful and personally transforming stories describing this. One of the lessons from 'Coyote's Eyes' (Archibald, 2008, p. 8–10) that I gleaned was the need for me to have a place for both epistemologies and to seek balance and harmony between them. Moreover, one of the lessons from 'Coyote Searching for the Bone Needle' (Archibald, 2008, p. 35–36) that I gleaned was the seductive and destructive force of maintaining the status quo of Western knowledge superiority. In her explanation of this story she says, "Many Elders have said many times that one must learn to 'live in two worlds.' " (Archibald, 2008, p. 40). My two research purposes stem from distinct epistemologies. Acknowledging both epistemologies is walking on both of my legs to me.

My metaphor, however, is *learning* to walk on both of my legs. Though the elders make space to value both knowledge systems (Archibald, 2008; Kovach, 2009), to me this is a huge

struggle! I have emphasized and strengthened the Western knowledge leg my entire life and completely ignored Indigenous ways of knowing, being, and doing entirely. Despite being part Choctaw, I have been conditioned to see Western knowledge as both the norm and superior. It has been a lifelong journey to even acknowledge the distinctiveness of Indigenous knowledges and begin to heal from this conditioning (Kovach, 2009). The decolonizing component is separating from this conditioning and standing against Western knowledge as superior or normal. The Indigenizing component is learning to follow the path of Chahta (autonym for Choctaw) ways of knowing, being, and doing. Learning to walk on both of my legs is my attempt to honor the Indigenous knowledges and respect the Indigenous scholars who wrote this literature. To me this literature review has been a process of learning to strengthen and stand on my Indigenous leg. Thank you for joining in this journey by reading and building your relationship with who I am (Wilson, 2008). Thank you! Yakoke!

 …

 Similar to sharing my web of relations through the self-location statement, I do not essentialize you as the reader to be monolithic or static. Attempting to write in story steers me to explicitly address you as the reader/listener. Tuck(Unangax̂) and Yang explain the story relationship between you and me by saying "Storywork practice is very different from Western commonsense notions of "universal stories," with presumed universal listeners and omniscient narrators who are never actually universal. In those stories, "universal" means unmarked; perspectives that are often masculinist, conquering, and Eurocentric are normalized as gender-neutral, timeless, and placeless. By contrast, storywork makes transparent the listener and the teller, and the dialogic nature of storying—that is, the way the story is created in the space

between teller and listener" (Tuck & Yang, 2019, p. x). Therefore, I take space to identify my potential readership and discuss knowledge ownership and my writing assumptions.

Indigenous knowledge systems view knowledge as relational and therefore without an individual owner (Grande, 2015; Kovach, 2009; Wilson, 2008). Instead, there is a joint ownership of IRMs and I am accountable in how I learn, embody, use, and share it (Kovach, 2009; Wilson, 2008). In this literature review, I am responsible for how I present IRMs as the author/storyteller. You as the reader are responsible for listening, learning, and being accountable to all your relations. Thus, I assume that each listener/reader will process and receive what their relationships have prepared them for (Archibald, 2008; Kovach, 2009; Wilson, 2008). Wilson describes the position of author/storyteller by saying "My role is not to draw conclusions for another or to make an argument. My role, based upon the guidelines of relationality and relational accountability, is to share information or to make connections with ideas… as many connections or relationships available as possible and to respect the reader's ability to take in what they are ready to receive" (Wilson, 2008, p. 133).

Some Western paradigms have made room for author positionalities, but still miss the relationship with the reader. Filtering this literature review through your own prior knowledge creates space for miscommunication and especially cross-cultural miscommunication (Wilson, 2008). Tafoya (1995) explains that "when speaking with people from another culture it often takes longer to explain the context, background, or meaning of a story than it does to actually tell the story. On the other hand, when communicating with people who share the same culture, too much explanation or background detailing can be seen as disrespectful of the intelligence of the listener" (Wilson, 2008, p. 7).

Since I grew up steeped in Whiteness, neglecting my Choctaw and Indigenous heritage and now am trying to learn and re-connect, please be gracious to me as I try to bridge cultures within myself and this literature review. It is difficult to maintain accountability simultaneously to all my relations (Whetung & Wakefield, 2018; Wilson, 2008). In my efforts to maintain accountability, I specifically address my PhD committee, TCU faculty in North Dakota, and future people interested in IRMs in the next three sections. My attempt to maintain accountability to each group, write in story, and embody Indigenous knowledges in myself and my work has taken more time and space than I initially anticipated. Mentor Hollie Mackey encouraged me to be gracious to myself by writing that "Indigenous storytelling can be long, but each word is precise and necessary, rarely redundant without purpose. It takes time and practice to effectively translate this to writing" (H. Mackey, personal communication, September 2020).

…

2.1.2.1. An Introduction to Articulating Western Knowledge and Education

Sandy Grande (Quechua) lays out five key beliefs in the Western knowledge system. Many of these beliefs stem from the Enlightenment period in Europe describing a modern worldview (Grande, 2015). As you read through these five beliefs, I encourage you to listen with your mind and heart by reflecting upon how much your heart and mind align with these beliefs (Archibald, 2008).

First, 'belief in progress as change and change as progress' (Grande, 2015, p. 69). This belief emphasizes that change is positive, and that humanity is moving forward. That is, as time moves forward in a linear manner, humanity is improving. This is measured, individual and collectively, through material gain, i.e. more education, more income, more status, and often in a set time frame to measure improved efficiency (Grande, 2015).

Second, 'belief in the effective separateness of faith and reason' (Grande, 2015, p. 69).

This effective separation leads to rationality, that the intellectual knowledge is the superior form of knowledge. This leads to the idea of objectivity and the ability to have an expert opinion. In research, this belief lays the foundation for positivism and empiricism. For research to be 'valid,' any emotions and motives must be removed. Establishing an appropriate separation or distance from research demonstrates objectivity. This belief in effective separation leads to the notion that the mind is not only superior in the realm of knowledge, but also has the authority over one's heart, life, and body (Grande, 2015).

Third, 'belief in the essential quality of the universe and of 'reality' as impersonal, secular, material, mechanistic, and relativistic' (Grande, 2015, p. 69).The essential quality means the universe is a singular reality and this reality as material is made of physical substance, or matter, that can be broken down and analyzed at the component level to determine the mechanisms, cause and effects, properties and laws (Grande, 2015).

Fourth, 'subscription to ontological individualism' (Grande, 2015, p. 69). This belief in an individualistic reality is often pinpointed to Rene Descartes' famous line "I think therefore I am." The individual is seen as the basic social unit and a productive member of society is viewed as an autonomous individual with no perceived dependence on anyone else. An emotionally or financially healthy individual is self-sufficient in themselves. Epistemologically, the individual is the source of knowledge as well as the owner of knowledge (Grande, 2015). Smith highlights this Western belief in research practices by saying "the most fundamental belief of all [Western research paradigms is] that individual researchers have an inherent right to knowledge and truth" (Smith, 2021, p. 173).

Fifth, 'belief in human beings as separate from and superior to the rest of nature' (Grande, 2015, p. 69). Thinking about the Land acknowledgment, this Western belief is an obvious contrast to viewing Land as a familial relative with which to connect spiritually.

When I first read these five, I was shocked to see how much my mind agreed with these beliefs. Even more than that I was stunned by how I was unable to articulate these cultural beliefs until I read them from Grande! To me, it is ok that I held these beliefs because none of them are inherently wrong. However, my lack of awareness to these deeply held beliefs demonstrates a major problem. Like my childhood of seeing White as normal, until this research journey, I viewed many of these beliefs as normal and standard for all cultures and humans. This is where the problem lies. Similarly, being white is not wrong. It is not wrong to be born into a white family, but a major problem exists as soon as White is viewed as normal, standard, universal, or superior. Part of colonialism is that it holds up these five Western beliefs as universal, superior, and the only option for the 'modern' human. This creates space to minimize, erase, assimilate, develop, and/or civilize the 'primitive' human. The notion of the 'modern' human has been used as a theoretical underpinning for centuries to justify assimilation and genocide (Smith, 2021). Grande summarizes by titling these five beliefs as 'the deep structures of colonialist consciousness' (Grande, 2015, p. 69).

…

Grande keenly observes and articulates this insistent conditioning through implications on schooling stemming from the five beliefs of Western knowledge. She says the five beliefs, also named as the colonialist consciousness, have five implications for education (Grande, 2015). Again, as you read through these five implications, I encourage you to listen with your mind and

heart by reflecting upon how much your education experiences, as a student or educator, align

with these ideas about schooling (Archibald, 2008)

First is "Independence. Children are expected to be self-reliant" (Grande, 2015, p. 70).

Students have internalized these expectations that any cooperative/communal effort among other

students is viewed with suspicion and as a potential barrier to personal success. The classroom

behavior expected demonstrates the value of self-reliant independence. "'Appropriate,' on-task

behavior is measured by the degree to which students behave as if they were in solitude, even

though they are not. A good student acts is if he or she is 'alone in a crowd' "(Grande, 2015, p.

71).

Second is "Achievement…Success and individual worth are measured by abstract and

impersonal standards of excellence" (Grande, 2015, p. 71). This puts students in direct

competition with one another and pushes students to see the process as only a means to the end

product.

Third is "Humanism" (Grande, 2015, p. 71). This implication encourages students to

believe they are the master of their own destinies and have complete individual control over

every situation. Further, humanism boasts that through human effort, technology, and science all

of nature can be understood and predictable. This implicitly, and often explicitly, rejects any

form of spirituality in individual cognition and worldviews.

Fourth is the "Detachment from sources of local and personal knowledge" (Grande, 2015,

p. 71) that is found spiritually within, through family and community leaders, and through

ceremony. This detachment implies that 'book' knowledge is the more valuable and worthwhile

knowledge.

Fifth is the "Detachment from nature" (Grande, 2015, p. 71) implying that 'real' learning occurs indoors. Even when the subject matter is earth, animals, or plants, a majority of the learning is done sitting in rows of desks inside a building. Through these five implications of the colonizing consciousness within education, the Western knowledge beliefs are reproduced by leading students "to develop as progressive, competitive, rational, material, consumeristic, and anthropocentric individuals" (Grande, 2015, p. 71).

The process of education through these Western beliefs inevitable leads to students learning these Western beliefs as the unspoken norm. The process is the product and therefore to disrupt colonialism not just the content must change but also the process (Wilson, 2008). As I mull over these implications for schooling from the colonizing consciousness, my deep, deep conditioning to Western knowledge and ways of doing and viewing education become evident. I am learning to no longer neglect my Choctaw/Indigenous heritage, but it is a huge struggle to un-learn the ways of doing and viewing education I have been trained into. What about you? Especially if you are an educator, how do you see the five Western beliefs and five implications for schooling in your work?

Colonial education is still the dominant form of our education system (Deloria & Wildcat, 2001; Cummins, 2019; Grande, 2015). Grande (2015) states that Indian Education in the US sets out to continually "reinvent Native American people in the likeness of white people" (p. vii). Deloria and Wildcat (2001) agree and share that "the thing that has always been missing from Indian education, and is still missing today, is Indians" (p. 152). In response, Indigenous researchers and educators have recently begun using the term "Indigenous Education" which centers Indigenous Peoples, Land, and Indigenous visions for the future (Mackey, 2020).

2.2. Proposal Letter to Graduate Committee

The written proposal approved by my PhD Committee in May of 2021 will be shared in nearly complete entirety below in contrast to the excerpts from my literature review above. Only redundancies that will be better described in the following chapters of the dissertation are removed.

2.2.1. Cover Page for Proposal Letter

Danny Luecke

April/May 2021

Mathematics Department

STEM Education PhD Program

Written Proposal for Oral Exam

Committee: Bill Martin (advisor), Warren Christensen (co-advisor),

Hollie Mackey, Jessica Striker, Jason Boynton, Robert Pieri

2.2.2. Table of Contents

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Thank you! Yakoke!

Appendix of Literature

2.2.3. Hello Supervisory Committee

Hello Supervisory Committee,

I am thankful for each of you as part of my PhD Supervisory Committee. You each have a specific and significant role in my journey. Yakoke! For this proposal/oral exam, I have chosen to write you a letter. Similar to the IRMs (Indigenous Research Methodologies) Literature Review, within this letter I will give the justification for writing my proposal in this format. After discussions with Bill and Warren, I came to realize that the goal of this proposal is to demonstrate to you that I am "prepared to carry out reasonable research that if completed is worthy to achieve a PhD" (W. Martin, personal communication, March 11, 2021). I believe a letter will be able to communicate that preparation story well to you. But you get to decide *if* I have achieved this goal.

Personally, my goal for this PhD research is multi-faceted. Through the literature review process, my identity journey of no longer neglecting my Choctaw/Indigenous heritage influenced my research process. I am guided by the desire to keep growing/learning about myself and seeking to honor all my ancestors, Creator God, and all the relationships that have formed during this research process. My original goal to do research that is beneficial and actionable has not faded but only become clearer as relationships with self, place, Creator, and instructors at Sitting Bull College and the Lakota Language Immersion Nest strengthen. I pray that my good

intentions actually become a positive impact towards nation-building for/with the Standing Rock Nation.

2.2.4. Relationship to Self and Place

Since each of you know me already as a student and through the IRMs Literature Review, I want to share something new with you. I decided to share with you my relationship to self, place, and the public through my speaking opportunities this semester. It has been a definite honor to be asked to share the land acknowledgement I have written at three public events: NDSU Talkback to Racism event, the Black Student Association Open Mic, and the Tri-College Native American Graduation Ceremony. For each event, I modified some wording by my discretion to best fit the audience. Overall, I share the full version here. I did not give citations during these oral public presentations but now in writing, I will share them.

"Hello. My name is Danny Luecke. My wife's name is Kali and we have the cutest daughter named Kamila. I am a graduate student here at NDSU in math education and am enrolled in Choctaw Nation of Oklahoma.

A land acknowledgement is full of politics. It can easily be seen as just words without action, further reinforcing that good intentions are enough even when the impact is negative. Too often it can become a performance without substantial change to policies, funding habits, and/or cultural norms (Mackey, 2020). With that, there are some ideas in the NDSU official land acknowledgement that I appreciate and some ideas that I believe are blatantly missing. So tonight, I will introduce myself more fully, share the NDSU official land acknowledgement, and finally give a few of my own comments.

I was born in Fargo, ND, yet I do consider myself a settler to this land. My mom is of Danish, Swedish, and Norwegian heritage. My dad is of Irish, German, and Choctaw

heritage. This is my ancestry, both European and Indigenous. I am from both colonizer and colonized. I also acknowledge that in our society today I basically have every privilege marker including white, male, cis-gender, heterosexual, able-bodied, first language as English, tall, athletic, Christian, parents are well-connected, and I grew up with both of them. Now, I'm not guilty for having these privileges. This means I haven't done something wrong in having them. Most of them I didn't choose but came by birth. So, I am not guilty.

However, I do have a *responsibility* to handle/hold them. Further, I don't like to admit this but far too often I don't handle them well. I fall into thinking I've earned these privileges or merited them in some way. I minimize their power and even sometimes just straight up use them for my personal gain. It's so common for me to think that because I don't think this particular political idea, or take this particular moral stance, that I am better than the person who does. For this, I am very guilty and in need of forgiveness. For me, this leads me to repentance as Jesus called me too and a desire to live differently (Acts 3:19).

So now that you know me a little better, I will read the official NDSU land acknowledgement and then after I'll share a few of my personal thoughts on it.

We collectively acknowledge that we gather at NDSU, a land grant institution, on the traditional lands of the Oceti Sakowin (Dakota, Lakota, Nakoda) and Anishinaabe Peoples in addition to many diverse Indigenous Peoples still connected to these lands. We honor with gratitude Mother Earth and the Indigenous Peoples who have walked with her throughout generations. We will continue to learn how to live in unity with Mother

Earth and build strong, mutually beneficial, trusting relationships with Indigenous

Peoples of our region. (North Dakota State University, 2023)

My thoughts are three-fold. There is something in here I want to emphasize, something assumed, and something missing.

The something I want to emphasize is the phrases "Mother Earth," "walked with her," and "live in unity with." We can see the contrast in how one views the land. Living in unity with Mother Earth helps explain this idea that Land is a living relative to be in relationship with. This is stark contrast to Western view where land is property, to be owned and done with as pleased. Famous Lakota activist and scholar, Vine Deloria Jr says this differing orientation towards land is one the primary distinctions between Western and Indigenous cultures (Grande, 2015).

Something assumed or normalized by this land acknowledgement is that it is in the English language. You may chuckle at that feeling like it is the only option. That is because it has been normalized. Since we are on Indigenous land, then English is a foreign language. This year 2021 actually marks the 150-year founding of Fargo as a railroad town and helps us see that English is not native to this area. English has been brought here to this land and then normalized to feel like the only option.

This brings me to the third point that something is missing. In my opinion, there is a glaring absence from the land acknowledgement. It's not the fault of the writers as they were surrounded in an ocean of politics. What I think is missing is **how**! How did the Land get to be this way? How did NDSU get to be on this land? There are two different grand narratives to answer this question. From Western perspective, the narrative flows as discovery, population decline, empty land, wilderness to be tamed, and land to be

claimed from sea to shining sea. From an Indigenous perspective, the narrative flows as invasion, war, stolen lands, broken treaties, genocide, and assimilation (Grande, 2015). These are obviously divergent narratives.

Specifically, at NDSU, as a land grant institution, I think we need to acknowledge in part how NDSU is here today. In part, it comes from the 130,000+ acres of land across ND given to NDSU by the federal government through the 1890 Morrill Act. These lands were taken from Indigenous Peoples for just under $1,200 in total. During the following 10 years, NDSU sold a majority of this land raising over $900,000 as capital. It is a ratio of 781:1 return on payments to the tribal nations. This outlandish rate of return pushes one to see the land as stolen (R. Lee, 2020).

So overall, the how that is missing is settler colonialism. Eve Tuck, an Unangax̂ education researcher and scholar, strongly emphasizes the triad of settler colonialism as settler, native, slave. To quickly hit the key ideas, there is the destruction of Indigenous Peoples to acquire land. For the land to produce excessively as desired, excess amount of labor is demanded. Here enters the enslavement of African peoples. In our country's history of settler colonialism, so much today has become normalized and expected because of original settler-native-slave triad. Indigenous Peoples on reservations. Black and Hispanic landlessness. Racial injustice is the current norm and status quo on this land (Tuck & Yang, 2012).

In closing, I connect back to my introduction. I do not share this land acknowledgment to say you are personally guilty or wrong for being here at NDSU or on this land. No. I didn't choose to be born in Fargo or in the United States. Nobody chose their birth. So instead of an irrational guilt for being born into a certain family or place,

rather I close by encouraging you to ask yourself a few questions. What is the responsibility I have because of what I have been given? What is my responsibility to the Land that I am on currently? Ask yourself. What is my responsibility to the silenced voices on this land? Indigenous, Black, Hispanic peoples on this land have a societal system that is stacked against them (Smith et al., 2018).

Further, what is my responsibility to my ancestors? We all have different ancestors but what does it look like to honor them on this land today? For me, I think about both my European and Indigenous ancestors. Take a moment to think about this for you, personally, how did you come to be on this land? Where were you 1 year ago, or 10 years ago, and your ancestors 100 or 500 years ago? (Smith et al., 2018).

So, ask yourself. How have you personally, and us collectively as NDSU, come to be on this land? What is my responsibility in response to that? This land acknowledgment is just words, so think about what action will we and you take?

Thank you for letting me share! Thank you! And in Choctaw, Yakoke!"

2.2.5. Proposal Introduction

The goal of this proposal is to demonstrate to you that I am "prepared to carry out reasonable research that if completed is worthy to achieve a PhD" (W. Martin, personal communication, March 11, 2021). This written proposal as a letter attempts to show how I have connected with the literature, what I plan to study, how I plan to do the research, and that I am capable of completing the work in a timely manner. All of this can be accomplished through sharing portions of my story.

This research journey is unique for there is no 'one way' to apply (or even define) IRMs since each of us are (and are accountable to) a different web of relations (Wilson, 2008). I am

responsible to all my ancestors, my God, the Oceti Sakowin, as well as all my relations as I walk this research journey and share it with you (M. A. Meyer, 2014; Smith et al., 2018; Wilson, 2008). For me, I am seek to no longer neglect my Choctaw heritage, but seek balance and harmony between my Indigenous and European ancestors within me and my research. I am in the process of learning not only to stand on the Western knowledge and culture I have been trained and conditioned into but also to stand on Indigenous ways of knowing, being, and doing (Archibald, 2008).

The term Western in its simplest form describes the Western world distinct from the Far East, Middle East, African, and Indigenous. Western vs Indigenous is not to propagate an unhelpful dichotomy but to make clear the distinctiveness between these two very diverse categories. Within each of them there is great diversity. Other terminology may include dominant, Euro-centric, mainstream, malestream, whitestream (Wilson, 2008; Kovach, 2009; Grande, 2015). The term Indigenous is my preference when addressing the collective diversity of those who face colonialism denying their past and present sovereignty. In general, connection to the land unifies the huge variation in language, spirituality, place, culture, and ethnic groups (Kovach, 2009; MHTTC, 2020; Smith, 2021; Wilson, 2008).

I pray that I can honor the Indigenous scholars who generously shared themselves and their work with me. I pray that I can reciprocate at the level of respect, generosity, and humility they demonstrate (Archibald, 2008). I pray that I honor the Dakota/Lakota knowledges as I walk the tension of holding these knowledges in reverence and applying them to research and living them every day (Kovach, 2009). There is much to continue learning. The depth of Margaret Kovach's words about IRMs continues to teach and inspire me. "The sacredness of Indigenous research [and knowledge] is bound in ceremony, spirit, land, place, nature, relationships,

language, dreams, humor, purpose, and stories in an inexplicable, holistic, non-fragmented way" (Kovach, 2009, p. 140).

In my journey using IRMs, I have the honor of co-facilitating a course at the Dakota/Lakota [Language] Summer Institute (DLSI) titled "Lakota Math Connections" this coming June. My co-facilitator Dave Sanders (Oglala Lakota) currently is the VP for research, evaluation, and faculty development at the American Indian College Fund. I reached out to him since his dissertation is one of the foundational building blocks from my PhD research (Sanders, 2011). Ten years ago, in his home community on Pine Ridge, Sanders "investigated potential connections between mathematics and the Lakota language at a K-8 school and how Bishop's framework of six universal math activities: counting, designing, measuring, locating, playing, and explaining (Bishop, 2012) could lead to further development of these connections assisting supplemental Lakota language fluency and mathematical understanding" (part of Lakota Math Connections course description). The goal is for all course participants and co-researchers "to develop LMC that can be brought into their work as language/immersion or [high school and undergraduate] math instructors" (part of LMC course description).

Sanders' PhD research journey and publications (Sanders, 2011, 2013) are the foundation for both the Lakota Math Connections (LMC) course as well as my research. Building from his work at the K-8 level, the LMC course and follow-up interviews are going to be the main data collection for my study at the undergraduate level. The Higher Order Math Concepts (HOMC) Authentic Cultural Connections model will be developed and used by all course participants and co-researchers. Paper 2 of my proposed three-paper dissertation will be on the development of the HOMC Authentic Cultural Connections model. Paper 1 of my dissertation will be the story of

how I experienced my IRMs theoretical framework of Circulating Conversations Methodology

(CCM) and how CCM led me to the particular research questions for this study.

This co-facilitating opportunity with Dave Sanders was a spiritual

experience/confirmation for me (M. A. Meyer, 2014). In November/December 2020, I felt

completely stuck in my research and spent much time in prayer for the unknown future. No clear

direction was emerging, and I had zero inkling of an LMC course. As I look back now, the

research literature on IRMs, the community book study I co-facilitated, the relationships I was

forming within myself and with others, the development of the research questions, and the

research questions themselves all precisely prepared me for the LMC course without knowing

this opportunity even existed! Even if I did know the LMC course opportunity existed in

November/December, there is near nothing I would have changed in my research preparation! It

feels like the research questions and design process were developed directly for the LMC course

before I even knew this opportunity existed!

Following the research methodology set forth by my 'academic elders' within IRMs, this

idyllic alignment of my research questions with DLSI LMC course before I knew that DLSI

LMC course could be a reality is a major spiritual confirmation to me. Sunshine Carlow, an

instructor and the finance manager of the Lakota Language Immersion NEST and the one who

invited me to teach a course at DLSI, often shared with me multiple times that "everything,

including timing, happens for a reason" (S. Carlow, personal communication, April 30, 2021). I

agree and believe Creator is leading my path into holistic (Kovach, 2009; M. A. Meyer, 2014),

relational (Wilson, 2008), respectful (Archibald, 2008), and reciprocal research (Archibald,

2008; Kovach, 2009; Wilson, 2008; Windchief & Pedro, 2019). Creator is giving me the path

and graciously enabling me to take the next step even when I do not see the next step or final

result. "He makes my feet like the feet of a deer, he causes me to stand on the heights" (2 Samuel 22:34, Psalm 18:33, Habakkuk 3:19).

2.2.6. Why a Letter?

Through discussions with my advisors Bill and Warren, I came to realize the audience for this proposal is you, my committee. More than any other piece of writing in my PhD process, this proposal is directed towards you. You, as my committee, determine via this proposal and the oral preliminary exam if I am able to advance to candidacy. As I prayed about the structure for this proposal, the idea of a letter came to me. To me, it is the best way I can honor all my relationships for a written proposal and an oral preliminary exam. Therefore, I began this written proposal/letter with the salutation "Hello Supervisory Committee."

Even though the common proposal structure within Western research [in undergraduate math education] methods may be the first few chapters of a dissertation, this felt premature as I do not yet know the precise structure of the dissertation. The final product will seek to be accountable to all of its relationships including the process and results (Wilson, 2008). Until more of these relationships are formed the story and its structure will remain undetermined. Some relationships for the dissertation include NDSU formatting confirmed (Windchief & Pedro, 2019), you as the committee (Windchief & Pedro, 2019), IRMs, the use of story (Archibald, 2008; Kovach, 2009), and the research results themselves (Wilson, 2008). The knowledge sharing is dependent upon the knowledge itself. All of these distinct relationships have a direct and specific impact on what the final dissertation will look (Wilson, 2008).

Similar to the process of writing the literature review, as I read the literature it became apparent that I the must change the goal and structure of the proposal to align with the literature itself. The literature review began with a Western approach to "synthesize the literature" but

needed to be transformed into "embodying the literature" holistically into my identity, the writing style, and the format in totality for the literature review. The literature review structure became a non-static 4-circle Venn Diagram, or perhaps, better thought of as a kaleidoscope. I trust that each reader will experience what they need to within their level of connections to Indigenous ways of knowing, being, and doing (Wilson, 2008).

IRMs are alive with experiential holistic knowledge that does not separate the experience from the knowledge, the mind from the body or spirit, and the researcher from their location/position. The temptation to intellectualize IRMs (to dis-member the mind from the heart, body, and spirit) is incessant because of my Western social training and conditioning, being in Western research environments, and my Western education. Cora Weber-Pillwax (Cree), an academic elder, shares an idea that has helped me continually push towards seeing this research and every piece of knowledge and knowledge sharing as a living relational web. She says "until we live them [IRMs]… it's like writing 'bread' on a piece of paper and eating the paper instead of having the bread" (Wilson, 2008, p. 103). Despite this holistic/embodied epistemology being new to me, it has been alive since time immemorial within Indigenous Peoples and the Land. So, as I do research with Indigenous Peoples on Indigenous Land, I have chosen to center an Indigenous epistemology.

I write this proposal with the idea that this letter is a living relational web accountable to all of its relations. Specifically in relation to one of my advisors, Bill, he shared two ideas about a proposal. First that it can be seen as a contract to say what you will do, then do it, and then write what you did. Further, that a proposal is to demonstrate that I am "prepared to carry out reasonable research that if completed is worthy to achieve a PhD" (W. Martin, personal communication, March 11, 2021). The wording of this quote reminds me of the two NSF grant

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proposals I have been part of. However, instead of achieving a PhD, the NSF grant proposal is to achieve the specific desired results of the solicitation. In the solicitation, specific guidelines are given on goals and how to submit said proposal but within the PhD process, the goals and application (proposal) are not as clear as an NSF solicitation. The goal of this proposal is to show you that I am prepared to do PhD level research.

If a contract had to be written up, I could say I will do my best to honor the Oceti Sakowin through nation-building (Brayboy et al., 2012), the Land through learning from her (Smith et al., 2018), and the knowledges carried with them through my research. I will do my best to follow IRMs with my heart, mind, body, and spirit in every step and stage of this research (Archibald, 2008; Kovach, 2009; Wilson, 2008). This easily connects with my desire to follow the words of Jesus that say "Love the Lord your God with all of your heart, all of your soul, all of you mind, and all of your strength" (Matthew 22:37, Luke 10:27) and incorporate this love and faith into every aspect of who I am. I will seek to 'give back' to the community (Kovach, 2009; Shirley & Angulo, 2019). As some researchers may 'follow the money,' I attempt to 'follow the community.' I will attempt to be accountable to all my relations as best as possible (Wilson, 2008). I purposefully choose the words 'seek to,' 'do my best to', 'attempt' because I know I will fail at these in their fullness. I am not a perfect person (Romans 3:23), nor a perfect researcher (Smith, 2021). So, in conclusion, I cannot give greater detail to what precisely will be done. I can lay out my current plan for my PhD research and dissertation but fully admit they are accountable to all their relationships which is constantly changing with time like any living entity (Wilson, 2008).

I anticipate my dissertation to be a three-paper dissertation in story format. My goal is to publish at least two of the three papers in RUME journals. Some have suggested looking at more

social, cultural, or political journals. Two possibilities could be the "Math Education and Society" journal or the "Journal for American Indian Education." Others have suggested looking at middle/high school math education journals such as the "Journal for Research in Mathematics Education". This is something I could do. However, I do not believe IRMs or research at TCUs (Tribal Colleges/Universities) should be pushed to the outskirts of mainstream research. Rather I believe the work I am doing using IRMs at SBC is fully legitimate research in undergraduate math education (RUME).

2.2.7. IRMs in the Literature

Indigenous ways of knowing have sustained Indigenous Peoples and their communities' research needs since time immemorial (Smith, 2021; Wilson, 2008). Since contact, Western knowledge and power structures have continually sought to dismiss and minimize Indigenous knowledges, therefore creating a hegemony of Western research methodologies in academia (Grande, 2015; Kovach, 2009; Smith, 2021; Wilson, 2008). The different epistemologies can stand on their own. Further, both Western knowledges and Indigenous knowledges are extremely diverse in and of themselves. Framing a dichotomy of Western versus Indigenous is already a Western binary approach emphasizing conflict and separation. Learning to highlight where relationship and reciprocal partnership can happen amongst Western and Indigenous ways of knowing is a way to show how they can be in synergy with each another (Cajete, 1999, 2021). They do not need to be in conflict but can work together in a balanced movement.

A book that is extremely influential on me and the research that I am conducting is "Research is Ceremony: Indigenous Research Methods" by Shawn Wilson (Opaskwayak Cree). Wilson shares that "If Indigenous ways of knowing have to be narrowed through one particular lens (which it certainly does not), then surely that lens would be relationality. All things are

related and therefore relevant" (Wilson, 2008, p. 58). For the math professors, relationality can be seen as the singular axiom. However, by its very nature, it cannot be defined as the one and only axiom because that would contradict itself. Wilson (2008), among others such as Hollie through personal communication (Fall 2020) and Kovach through her book (2009), is strong in his denunciation of a single definition or application of relationality.

"I also need to be clear that I am not promoting this book as a model of Indigenous research or data analysis; it is only one presentation of the view shared by my friends and myself as co-researchers… With an acceptance of relationality comes the realization that models do not work outside of specific contexts, and following relational accountability, I cannot presume to know the context of other people's research… This study is not intended to impose conclusions on other people or to be a manual of techniques for their research. This would narrow their thinking. I hope that an Indigenous research paradigm provides a foundation from which to work but not a ceiling or walls to enclose or encage others… What is presented in this book is only one version of an Indigenous research paradigm. The very nature of our epistemology is that it will be different in other contexts." (p. 136)

It is possible that the lack of precise definitions and/or axioms might be perceived as lacking objectivity/universality or without rigor from a Western perspective. I will share how I have come to process these concerns within an Indigenous research paradigm. Truly, Wilson taught me a new way (2008). I am changed (and changing) in my heart, spirit, and mind because of the knowledge he shared. In particular, the marriage metaphor brought me to tears. Wilson (2008) says, "gaining knowledge is more like being married to someone - you don't own your spouse or children, but you do share a special relationship. It is a relationship that you are accountable to… For someone else to come along and use this knowledge in an inappropriate

manner is [abuse]. You know that sexual exploitation and total denigration of our humanity was a big part of colonialism. Now that is taking place with our ideas and knowledge. Our knowledge is being stripped of its relationships and being used without accountability" (p. 114). This metaphor not only helped me crystalize knowledge as relational (instead of individual and object-focused) but carried with it a weight of responsibility and accountability towards Indigenous knowledges and Indigenous Peoples.

He humbly taught me throughout his work four big words: ontology [what is real?], epistemology [how do I know what is real? what is not?], axiology [what moral beliefs will guide the search for reality?], methodology [how do I find out more and explore this reality?]. He lays out that "the shared aspect of an Indigenous ontology and epistemology is relationality. The shared aspect of an Indigenous axiology and methodology that research must maintain accountability to all the relationships that it forms" (Wilson, 2008, p. 137). Through this, academic/scientific rigor is demonstrated through the alignment of ontology, epistemology, methodology, and axiology (Wilson, 2001, 2008).

This understanding for rigor for me stems from an early experience at NDSU STEM Education Journal Club in Fall 2019. At the time I had no idea how much this would impact my understanding of IRMs. I had not even heard of IRMs at this time yet! The Journal Club was discussing qualitative methodologies from multiple seminal works. It was all so new to me. I was attempting to soak it in like a sponge but words such as research paradigm, theoretical framework, epistemology were all swirling in (or more likely above) my head. Was a methodology a method or something else? Was it distinct from the theory behind it or was it both the theory and practice? However, in this milieu, I made connections with what I could at the time. Now, I can look back and see the foundation being set for my understanding of research

paradigms and methodologies. One of the PowerPoint slides for the discussion is below. It presents the following table from "Doing Qualitative Research in Education Settings" (Hatch, 2002, p. 13).

Figure 3

Table by Hatch of Various Research Paradigms and Their Significant Components

PARADIGM	ONTOLOGY *Nature of reality*	EPISTEMOLOGY *What can be known;* *Relationship of knower &* *known*	METHODOLOGY *How knowledge is gained*	PRODUCTS *Forms of knowledge* *produced*
Positivist	Reality is out there to be studied, captured, and understood	How the world is really ordered; Knower is distinct from known	Experiments, quasi-experiments, surveys, correlational studies	Facts, theories, laws, predictions
Postpositivist	Reality exists but is never fully apprehended, only approximated	Approximations of reality; Researcher is data collection instrument	Rigorously defined qualitative methods, frequency counts, low-level statistics	Generalization, descriptions, patterns, grounded theory
Constructivist	Multiple realities are constructed	Knowledge as a human construction; Researcher and participant co-construct understandings	Naturalistic qualitative methods	Case studies, narratives, interpretations, reconstructions
Critical/Feminist	The apprehended world makes a material difference in terms of race, gender, and class	Knowledge as subjective and political; Researchers' values frame inquiry	Transformative inquiry	Value mediated critiques that challenge existing power structures and promote resistance
Poststructuralist	Order is created within individual minds to ascribe meaning to a meaningless universe	There is no "Truth" to be known; Researchers examine the world through textual representations of it	Deconstruction; Genealogy; Data-based, multivoiced studies	Deconstructions; Genealogies; Reflexive, polyvocal texts

Note. Figure found in Hatch, 2002, p.13

Scientific rigor seems to be the alignment within each row to me. The following PowerPoint slide shared a quote that solidifies my thinking that rigor to me is the alignment within a particular research paradigm. "As Kuhn (1970) made clear, when you are standing withing the circle of logic created by the assumptions of your paradigm, the positions taken by those working in other paradigms simply do not make sense" (Hatch, 2002, p. 269). Thank you, Jeff Boyer, for putting this slideshow together and the impact you and all those at NDSU STEM Education Journal Club have had on me. Yakoke!

In specifically centering Indigenous knowledges, I am seeking to fight the tendency to compare, rank, assimilate, and subsume Indigenous research paradigms (in)to Western research. Wilson says, "The language, tone and focus of research [that is, Western research on Indigenous Peoples] reflects this comparison, with the inevitable consequences of rating one over the other" (Wilson, 2008, p. 17). Thus, Wilson explicitly chose not to compare to (or build from) Western research paradigms. Rather, he demonstrated to me that Indigenous knowledges could stand on their own as distinct. No outside 'validation' is necessary or even appropriate. As I continue in learning, my recognition grows of the distinctiveness, value, and necessity of all ways of thinking to me. Both Western research paradigms and IRMs are invaluable in specific contexts.

Relationality and relational accountability are the desired frame for every aspect of my research. Even if my research project meets the Western standards of judgement, like validity and reliability, but does not show respect to the relationships between researcher, participants, topic, Land, and community it would be considered inauthentic or non-credible within Indigenous research paradigms. Wilson explains, "we don't need externally imposed measures or tests of whether or not something is 'true,' we have our own ways of ensuring this. We have our own ways or questions to ask, so that we know that what we are saying is strong enough to say, 'Yes, we can go ahead and design a program for our children or our community based on what we have learned from this research.' And we have trust or faith enough so that we are willing to use this in our communities, for our own people" (Wilson, 2008, p. 102).

Distinct ontologies and epistemologies give way to distinct validity practices. No outside validation is necessary or even appropriate within an Indigenous research paradigm. "As with most researchers, those operating under an Indigenous paradigm recognize patterns that transcend the local and particular. However, the difference is that those ascribing to tribal

methodology will likely return to the particular and local to validate claims because our truths are found in our places" (Kovach, 2009, p. 140).

Further, the ontology and epistemology of relationality, often including tribal-specific epistemologies with knowledge bound to place through ancestors, language, and Land, make IRMs unique from Western frameworks. "Indigenous epistemologies challenge the very core of [Western] knowledge production and purpose. While this is not a matter of one worldview over another, how we make room to privilege both, while also bridging the epistemic differences, is not going to be easy" (Kovach, 2009, p. 29). Sometimes particular methods are specifically applied with Indigenous communities that seem identical in an Indigenous or Western worldview. However, since methodologies and particular methods are built upon epistemology, to maintain framework congruency, seemingly similar methods are distinct because of their epistemological differences. Some allied frameworks (in research or education) include feminism, critical race theory, tribal critical race theory, participatory action research, community engaged research, ethnography, auto-ethnography, phenomenology, ethnomathematics, and culturally relevant/responsive/sustaining pedagogies. IRMs is distinct from each of these and yet the similarities can allow for reciprocal partnership in various ways. Sandy Grande (Quechua) emphasizes in her book "Red Pedagogy" the specific tensions and intersections between critical (revolutionary) theory, feminism, and IRMs (2015). Bryan Brayboy (Lumbee) addresses the growing field of critical race scholars by developing Tribal Critical Race Theory and found difficulty fitting Indigenous ways of knowing and being into a Western framework, even an allied framework like critical race theory (Brayboy, 2005).

So, I share my experience with IRMs in humble recognition of being in joint stewardship with IRMs via relationality. As I experience and share my understanding with others, I am

accountable to IRMs and all those who (will) use and experience them (Kovach, 2009; Wilson, 2008). Like Kovach, Wilson, and Archibald, what I share is only my understanding and approach to IRMs. I do not think a standardized framework for IRMs with universal and specific methods, rules, and procedures can exist. I am learning to live out and experience a relational, place-based, personal, spiritual, and holistic way of knowing.

2.2.8. Indigenous Undergraduate Math Education – Another Literature Journey

Like the very best stories, alongside one journey (IRMs literature), there is another intertwining and unique journey (the literature around Indigenous undergraduate math education). Like my favorite novels/movies (Lord of the Rings) and tv show (This is Us), there are multiple intertwining stories all happening at the same time coming together to form one larger narrative. This is my experience in the seemingly disjointed (yet relentlessly overlapping and connected) literature around the idea of Indigenous research in undergraduate math education. My hope is to share intertwining substories like a movie or tv show to form one larger story. Sub-stories to look out for are culturally relevant/sustaining pedagogy, native science, Indigenous education, personally inspiring articles, connections with RUME, relationships with TCU math instructors, Lakota/Nakota/Dakota (L/N/D) communication, ethnomathematics, and Lakota mathematics.

My general research topic was clear, undergraduate math education and honoring Indigenous communities. I could share that with anyone, but when my friends, instructors, or wife asked about further details it was difficult to have a precise answer. Superseding a specific topic, I had chosen values of honoring the community and doing research that was beneficial and actionable for TCU math instructors. Until I learned from the TCU math instructors what they

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wanted, my specific topic would remain undetermined. Further, it has been a difficult journey to find research literature done precisely in the area of Indigenous undergraduate math education.

I use the term *Indigenous* undergraduate math education in the sense similar to the term 'Indigenous education' instead of the term 'Indian education' that is often used in government settings. Colonial education is still the dominant form of our education system (Deloria & Wildcat, 2001; Cummins, 2019; Grande, 2015). Grande (2015) states that Indian Education in the US sets out to continually "reinvent Native American people in the likeness of white people" (p. vii). Deloria and Wildcat (2001) agree and share that "the thing that has always been missing from Indian education, and is still missing today, is Indians" (p. 152). In response Indigenous education centers Indigenous Peoples, Land, and Indigenous visions for the future (Mackey, 2020).

Despite minimal research literature in the area of Indigenous undergraduate math education, there is, however, much literature surrounding that central focus. I found literature around K-12 culturally relevant pedagogy (see Appendix A.1). I found antiracism / racial justice (education) theories (see Appendix A.2). I found ethnomathematics literature (see Appendix A.3). I found literature on Native Science (see Appendix A.4). I found literature honoring Indigenous communities through education and research (see Appendix A.5). I found literature honoring Indigenous communities through culturally relevant K-12 math education (see Appendix A.6). I found literature that had an Indigenous connection to RUME (see Appendix A.7). The general area of Indigenous undergraduate math education was clear, but literature in this area is minimal. Before I finish this paragraph however, a necessary caveat with all of these 'I found' statements is that I believe that nothing happened by accident. Rather, through

literature searches, mentors' suggestions, and friends' social media suggestions, all the literature came to me at the exact time Creator wanted it to appear.

Despite struggling to find the precise literature I was looking for in Indigenous undergraduate math education and the discouragement that came with that (reflective journal entry 9/15/2020), I was forming relationships with people who were doing the work. Thankfully through the PEEC (Pre-Engineering Educational Collaborative) program and Dr. Bob, I was (and am) introduced to the pre-engineering instructors at all five TCUs in North Dakota. The relationships with TCU math instructors became the literature to learn from, connect with, and depend on. Whatever I was reading got filtered implicitly or explicitly (through talking with one or multiple of these pre-engineering instructors) through their experience as engineering and math educators at their respective TCU. These relationships are invaluable.

2.2.8.1. Two Initial Guiding/Inspiring Articles

I did, however, eventually receive two research articles that thrilled me. I was eager to re-read them, share them, and finally have concrete research examples for me to learn from. So, I directly shared "Why indigenous languages matter for mathematics education: a case study of Ichishkíin" (Ruef et al., 2020) and "Conceptualizing a Mathematics Curriculum: Indigenous Knowledge has Always Been Mathematics Education" (Garcia-Olp et al., 2019) with the PEEC instructors in hopes my PhD could capture their essence.

These articles were so exciting to me because the assumptions that I was already working from were the same used in these articles. First was that I do not need to re-demonstrate the benefits of culturally relevant/sustaining pedagogy and curriculum. Their value has already been shown as I will share in the next section titled "CRISP: culturally relevant, imbued, and sustaining pedagogy". Further as I implicitly sift all literature via the experiences of the pre-

engineering/math instructors at TCUs in ND, nearly all of them have a specific required portion of their syllabi about cultural relevancy. In the Sitting Bull College syllabus template I received, the order went course description, course objectives, and then cultural relevancy. It has never been a matter of *if* but *how* to incorporate/center Oceti Sakowin identity/culture within the math curriculum as part of the mission of Sitting Bull College (Sitting Bull College, 2020). Both these articles work from the assumption of privileging Indigenous cultures, languages, and ways of knowing.

Garcia-Olp et al. (2019) shares about a K-12/inter-generational math summer camp in Denver and was the first (and perhaps only) example of IRMs in math education. The camp curriculum centered "on the fact that Indigenous Knowledge has Always Been Mathematics Education (IK-HABME). Through IK-HABME, we honor our relations with Elders, Community Partners, Indigenous youth, the natural world and real-life experiences, all while avoiding colonial constructs and measures of success" (Garcia-Olp et al., 2019, p. 1). The researcher's methodology developed as the study progressed and was termed Heart Work and Talking Story. "The practice of Heart Work and Talking Story allow us to always begin and end with Indigenous knowledge. Our Indigenous youth need to know that our ancestors have always engaged in high-level critical thinking" (Garcia-Olp et al., 2019, p. 14).

Ruef et al. (2020) shares the story of four co-authors: a Cherokee undergraduate (graduate by the end of the project) student, a non-Native professor, a Yakama Tribal member, and a Yakama Tribal Elder. They sought to develop a mathematics curriculum in Ichishkíin, an Indigenous Yakama language, specifically developing language for fractions in a fictious Ichishkíin immersion mathematics class. "Our work flows from broader Indigenous language and cultural revitalization projects, and is situated within the context of teaching and learning

mathematics" (p. 2). However, they experienced that word development is extremely difficult culturally.

After reading "Why indigenous languages matter for mathematics education: a case study of Ichishkíin" (Ruef et al., 2020), my reflective journal on 9/15/2020 is loaded with new excitement.

"Yesterday I was a little discouraged exploring papers at the intersection of math and race… **Today I read it. WOW!!! There was undoubtedly a spiritual moment when the first two sentences have been what I have saying for years!** Since my return from India. ... The paper excites me and hits the intersection of what I'm most interested in!! Reading the paper stirred my heart and brought great excitement to me for the future! This could be what I do for my PhD… Don't need more Western research to say Native students should improve in math/STEM, but rather change [my PhD research] to say working respectfully with Standing Rock community to actually see [math improvements] happen in reality." {bold emphasis original} (reflective journal entry 9/15/2020).

The first two sentences in the article read "Mathematics is often represented as abstract and culture-free (c.f., Bishop, 1988). But the learning and teaching of mathematics is a human endeavor, and by this definition, cultural" (Ruef et al., 2020, p. 313). This aligns with two common sayings for me, "Some people argue math is not cultural, either way, teaching and learning are certainly cultural" and "I do not teach math. I teach *people* mathematics." My six-month teaching experience in India first exposed me to this knowledge.

2.2.8.2. CRISP (personal acronym for Culturally Relevant, Imbued, and Sustaining Pedagogy

Some of the research literature I was able to find came under the terms culturally relevant, culturally responsive, culturally based, or culturally sustaining. Gloria Ladson-Billings first developed/published the term 'culturally relevant pedagogy' in 1995 daring to ask, "what was right with these students and what happened in the classrooms of teachers who seemed to experience pedagogical success with them?" (Ladson-Billings, 1995). Unfortunately, at times the term has been co-opted (perhaps unwittingly) to mean just adding a few 'diverse' images or holiday celebrations to the classroom or slyly asking another question. In undergraduate math education it may sound like 'what aspect of the [under-achieving] culture can be used/appropriated to hook students to learn the more important math content?' (Ladson-Billings, 2014). Paris (2012)/Paris and Alim (2014) respond by coining "culturally sustaining pedagogy" which seeks to center the culture for its own inherent value and not just as a hook for Western hegemonic curriculum (Ladson-Billings, 2014). McCarty and Lee emphasize tribal sovereignty and self-determination in Indigenous education by exploring the term 'culturally sustaining/revitalizing pedagogy' through two ethnographic case studies (McCarty & Lee, 2014).

Variations of the term culturally relevant/sustaining pedagogy are used and strongly supported by Indigenous scholars such as Hollie Mackey in her co-edited special issue of the Journal of School Leadership (Mackey et al., 2020). Further, the literature review by American Indian Science and Engineering Society (2020) fully confirmed for me the value of culturally relevant/sustaining pedagogy.

> "Throughout the literature on the topic of STEM education for Native learners is
> the pervasive notion of science education as devoid of culture, a set of universal
> principals to be memorized, and removed from context (Aikenhead, 2018). It is the

promoting of Eurocentric science as the acultural, ultimate truth, based on empirical data, that excludes individual experiences, different ways of knowing, and histories (Bang & Medin, 2010; Brandt, 2008)" (American Indian Science and Engineering Society, 2020, p. 5)

Aikenhead (1997) argues that failing to recognize teaching and learning as cultural transmission and acquisition, prevents viewing science education as a tool for Western prestige, power, and progress threatening Indigenous cultures." (American Indian Science and Engineering Society, 2020, p. 5)

"In regard to mathematics, Aikenhead (2018) found most Indigenous students' worldviews and the dominant worldview of mathematics was an obstacle for those students. For example, conventional mathematics deals with thinking only of content, whereas indigenous mathematizing deals with thinking, doing, living, and being with the content (Aikenhead, 2018)." (American Indian Science and Engineering Society, 2020, p. 5)

The [research] group also discussed the importance of… confronting epistemological differences rather than letting these differences go unsaid or unidentified." (American Indian Science and Engineering Society, 2020, p. 11)

Although never stated, many of the cited articles are more focused at K-12 STEM. Similarly, other books/teacher resource guides such as "Living Culturally Responsive Mathematics Education With/In Indigenous Communities" (Nicol et al., 2020), "Math First Peoples Teacher Resource Guide" (First Nations Education Steering Committee, 2020), and "Creating a Sacred Place for Students in Math K-12" (Sgarlotti & National Indian School Board Association, 2004) all focus at the K-12 level.

The American Indian Science and Engineering Society Literature Review (2020) and these books confirmed what I had already been thinking. Months earlier in my reflective journal on 10/16/2020, I reflected on the coming together moment for the "I" in the acronym CRISP. CRISP represents culturally relevant, imbued, sustaining pedagogy. This acronym for personal use helps me focus on balance and reciprocity and giving explicit weight to all three perspectives. Culturally relevant pedagogy looks at using the culture to encourage math proficiency as defined by the National Research Council (National Research Council et al., 2001). Culturally sustaining pedagogy looks at using the math content, classroom, and education system as a whole to sustain and build the students' culture. In this research, I am focusing on D/Lakota culture. CRISP reminds me to work towards the balance between learning math content determined by academia (or state standards for K-12) and the call of every TCU towards strengthening Native identity. SBC begins their 'student success definition' by saying "To be a successful student at Sitting Bull College, you do not forget who you are and where you come from" (Sitting Bull College, 2020). The journal entry for this coming together moment finishes in explaining that 'I' stands for imbued.

> "All curriculum and pedagogy are imbued with culture. By not naming white, male, materialistic culture of the US education system, it still gives white male, middle-class and upper-class students the best opportunities for success. Education outcome data demonstrate this. Claiming culture-less education system only continues to keep the current dominant culture as dominant when there is nothing biologically intellectually superior to people fitting the demographic of white, male, and wealthy. Pedagogy ALWAYS sits within a culture and some set of normative cultural practices. Who they are 'normative' to is the question?" (reflective journal entry 10/16/2020)

The idea of imbued culture within every aspect of our education and knowledge systems connects with Sandy Grande's articulation of the five Western beliefs and their five implications for education (Grande, 2015). Since I shared those directly in the IRMs Literature Review, instead I will share perhaps the anti-thesis to the five Western implications for education. This poster came to me through the book study I co-facilitated with Hollie Mackey and Anna Bahnson on "Indigenous and Decolonizing Studies in Education" (Smith et al., 2018) and is from the First Nations Education Steering Committee (2020). I am thankful for the discussion over each of these principles in the book study with other Native and non-Native educators.

Figure 4

Poster of First Peoples Principles of Learning by the First Nations Education Steering Committee
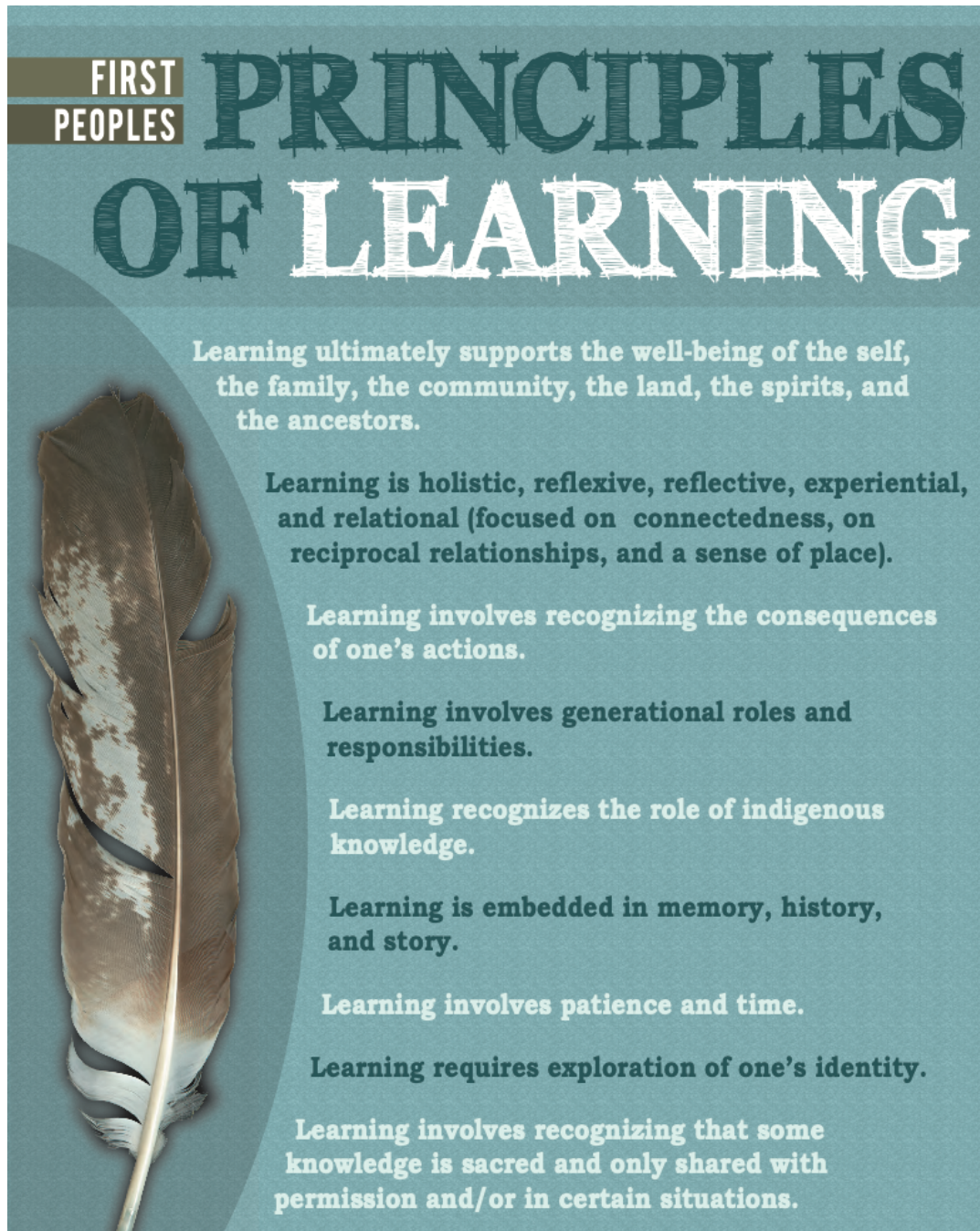
2.2.8.3. Connections to the RUME Community/Conference

Culturally relevant pedagogy and its impact on student outcomes and attitudes was specifically looked at and presented by Gregory Downing at the RUME Conference 2020. At an HBCU in southeast US, Downing investigated student outcomes and attitudes to four culturally relevant lesson plans, that is lesson plans that had a superficial hook within Black culture to teach the mathematical content. The lessons were the same mathematically but with different surface features laid on top (Downing, 2019).

Figure 5

Screenshot of Downing's Slides Showing the Specific Superficial Overlay of Culture in Experimental Section

The Intervention

Mathematical Content	Experimental Section Guiding Question	Control Section Guiding Question
(Unit 3) Linear Functions	1. What does incarceration look like in this county and the US? Does race play a role?	1. How have gas prices changed over time?
(Unit 4) Quadratic Functions	2. How are sexually transmitted diseases and cuffing season related to each other?	2. How do pharmaceutical companies decide what to sell their drugs for?
(Unit 5) Exponential Functions	3. How do poor people bank? What does college loans debt look like at HBCUs?	3. What is the true price of a loan?
(Unit 5) Logarithmic Functions	4. How are demographics of the US changing?	4. Where do logarithms show up in the real-world?

Note. Found in RUME Conference Proceedings 2020

With n=55, Downing found that there were positive correlations (of varying strength) amongst the culturally relevant lesson plans, student outcomes, and student attitudes (Downing, 2019). Leaving the RUME conference in February 2020 right before the COVID pandemic began, I was wrestling with what, if any, research and research paradigms fit my pre-determined

research goals of being beneficial to the community? Or was there another research paradigm, an Indigenous research paradigm that better fit me and the work I wanted to do?

Within IRMs, direct benefit to an Indigenous community as determined by that Indigenous community is a critical component often framed as 'giving back' to the community (Kovach, 2009; Wilson, 2008; Windchief & Pedro, 2019). I want to be clear here that both Kovach and Wilson share that all research done with Indigenous communities does not need to be using IRMs. Further, every Indigenous research does not need to work with Indigenous communities nor use IRMs. Rather, from an Indigenous perspective, both the research and the researcher are responsible to all their relationships and wherever that may lead them (Kovach, 2009; Wilson, 2008).

As I look at my relationships with math instructors at TCUs in ND, and more specifically at SBC, I turned to them for research guidance. Medin and Bang (2014) and Tuck (2009) both challenge their readers with the question 'who is research for?'. If my research is for the SBC math department and Standing Rock community, then again, they are not asking *if* CRISP is the way, but *how* to live out CRISP within each subject and class. Further, the American Indian Science and Engineering Society literature review shares that "STEM instruction must at least include, if not center, Indigenous ways of knowing and Indigenous science" (2020, p. 11) and Aikenhead (2002) "explicitly called for Indigenous science to be included not as a token addition but a meaningful asset to curricula" (American Indian Science and Engineering Society, 2020, p. 8). Lastly, to me, it seemed most appropriate that if I was looking at culture and Indigenous ways of knowing for undergraduate math education, then using an Indigenous way of research for undergraduate math education would be most fitting.

Further, at the Joint Math Meetings 2020, Belin Tsinnijinnie called the community away from the conversation on how diversity can advance the field of mathematics towards the question "How will diversity and inclusion in mathematics directly empower marginalized communities?" (Tsinnajinnie, 2020)

2.2.8.4. Story and L/N/Dakota Communication

One way I seek to be part of empowering Indigenous communities is through how I share knowledge from this study. Kovach (Plains Cree/Saulteaux) shares "Indigenous researchers are grappling with how to present meaning in a way that honors tribal knowledges… Presenting findings congruent with Indigenous inquiry holds much promise in bringing Indigenous epistemologies into Western sites of research (Kovach, 2009, p. 140). Eve Tuck (Unangax̂) reminds us that the power of language can be used for different purposes. "Language is never neutral – it can teach us, inform us, entertain us, persuade us, and manipulate us – it can misguide and misdirect truths, thereby perpetuating colonial myths and stereotypical representations, or it can disrupt normalizing and hegemonic dominant discourses and liberate critical thought" (Smith et al., 2018). If language can do all of that, then the language (English and also the specific word choice) I use and do not use in this written proposal and oral exam is highly significant. My word choices/structure can land on a spectrum from (inadvertently) reinforcing colonialism to achieving a decolonizing and Indigenizing result (Smith, 2021).

Currently the plan is to write my dissertation in story. Hollie Mackey was able to locate a "Story Based Dissertation Abstract" (2019) and I found a dissertation titled "Indigenizing the Academy: A Story-Telling Journey to Determine Pathways for Native Student Success In Engineering" (T. D. Smith, 2019). These both give helpful concrete examples of a dissertation in story format.

However, likely even more impactful on my dissertation and really all knowledge sharing from my research journey is Cheryl Long Feather's dissertation titled "A Lakota/Nakota/Dakota Model of Oratory" (2007). When I found this dissertation, I was giddy with excitement to have a model of oratory and communication that can align directly with the L/N/Dakota epistemology and mathematical content. Long Feather shares the results of her research to be a L/N/D Model of Oratory. "The model is constructed upon the medicine wheel and the individual is at the center of the sacred circle" (Long Feather, 2007, p. 125)

Figure 6

Long Feather's Medicine Wheel Diagram for "A L/N/Dakota Model of Oratory"
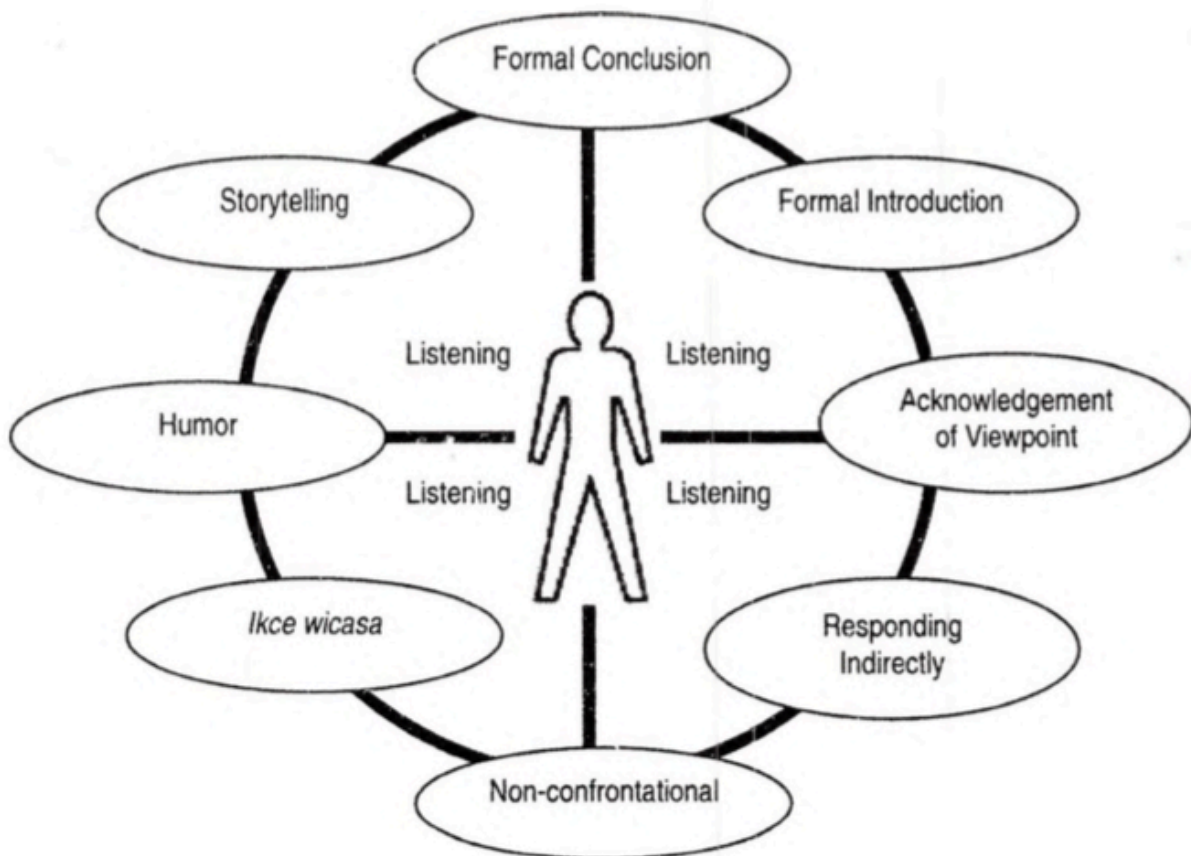
Note. Found at Long Feather, 2007, p.125

A portion of Long Feather's description of the model shares,

"In Figure 6, the lines of the medicine wheel serve as the foundation for the model but also illustrate the paths of movement possible in any given oration. The formal introduction and the formal conclusion are the only aspects of the model that could be considered linear or static. In every other aspect of the model, the orator has the flexibility to travel outward and inward as his or her personal experiences, attempts at relationship-building and intent allows.

The inner circle is characterized by the foundation of listening. A Native orator who listens has the requisite human experience to speak authoritatively on the subject but, because of the cultural value of respect, will not make such an assertion" (Long Feather, 2007, p. 126).

2.2.8.5. Lakota Mathematics and Ethnomathematics

Alongside the giddiness of connecting with a L/N/D model of oratory, I again wiggled with excitement upon receiving a dissertation titled "Mathematical Views within a Lakota Community: Towards a Mathematics for Tribal Self-Determination" (Sanders, 2011). The alignment of Lakota epistemology, methodology, communication style, and math content is spiritual to me and I give praise to Creator for it. At just the right time, Creator chose for me to connect with this dissertation through a Google scholar literature search in February 2021. At this moment in time, I was discussing with Sunshine Carlow about my research direction and the possibility of teaching a course at the Dakota/Lakota Language Summer Institute emerged. Now this dissertation will be a piece of foundational literature to build upon.

I found the dissertation through Bishop's framework (2012) of six universal mathematical activities: counting, measuring, locating, designing, playing, and explaining.

Searching Google scholar through this work and the "search within citing articles" feature for 'Lakota' brought Sanders' dissertation to the top. His research builds directly on Bishop's framework and Jerry Lipka's work with Yup'ik educators and culture. "Lipka's work eventually settles on learning mathematics through Yup'ik Eskimo survival/subsistence practices and remains one of the only, if not *the* only, look at the continual development of mathematics teaching and learning within a specific Native community" (Sanders, 2011, p. 56). After talking with Sanders, he shared that although Lipka and the Yup'ik are certainly the first to develop extensive culturally based mathematics, now Navajo Nation has taken major strides. However, because the work of Navajo Nation is embedded within Diné ceremony, it is not published in academia or even available at all to those outside the community (D. Sanders, personal communication, May 7, 2021).

Brazilian mathematician, Ubiratan D'Ambrosio, coined the term ethnomathematics and has heavily influenced the research of Indigenous mathematics worldwide. The field of ethnomathematics looking at the intersection of mathematics and anthropology is relatively new, beginning only in the late 1970s. "Culturally based mathematics programs and mathematics defined by local Indian contexts were non-existent prior to the mid-1980s" (Sanders, 2011, p. 58). Sanders (2011) elaborates on ethnomathematics with Native communities.

> "Ethnomathematics helped change the perception of mathematics from one that was centered on certain processes (algorithm, proof, and structure) to one that is embedded in all cultures and as such is present in cultural activities the world over. These are important to note since mathematics has had the perception of being 'above culture' and therefore accessible only in certain ways – this seems to be a major reason why

mathematics continues to be the least impacted content area [by self-determination] in Indian education" (p. 59).

Sanders' ethnographic research at Isna-Wica Owayawa (Loneman Day School) took place in academic school year of 2009-2010. His three research questions were:

What does Lakota mathematics look like?

How do local educators express self-determination in the educational process of their students?

What aspects of Lakota culture and self-determination principles are present in the middle-school mathematics classroom?

To answer research question 1, Sanders utilized Bishop's ethnomathematics framework (2021) of six universal math activities. Sanders "compared activities and content found within the middle-school and elementary mathematics classrooms to mathematical activities found in Lakota culture [via research question 1]." (Sanders, 2011, p. iii). This is nearly exactly what I am doing at the collegiate level! My work is building directly from his looking at how connections can be made between collegiate mathematics and cultural knowledge / the language. Overall, in answering his research questions, he demonstrates that self-determination as an education philosophy for Lakota mathematics had no impact in the middle school math classroom. Answering what Lakota mathematics looks like, however, Sanders spend six chapters of his dissertation, one chapter per universal math activity of Bishop's framework (2021). Sanders (2011) shares:

"With the aid of local Oglala elders, educators and anthropological sources written in the past hundred and sixty years and by applying Bishop's (1991) six universal mathematical activities I was able to describe some aspects of each of the following

activities found in Lakota culture: counting, designing, measuring, locating, playing and explaining. None of these descriptions are complete by any means, however, they, as a whole, can be used as a springboard for further discussion about what constitutes the intersection between Lakota culture and mathematics… It is also my hope, that in the future, this framework can be used by Lakota educators to aid in the development of mathematical curriculum in the Lakota language" (p. 321-322).

Looking directly at what Lakota Mathematics is according to Sanders (2011), I share the following quote as an overview and the following table as an example.

"I have tried to find how the Lakota approach some of these activities within their own culture. Measuring is done in Lakota culture, albeit, minus the high degree of precision deemed necessary by Western culture. It has a counting system minus negative numbers and most fractions. It has names for geometric shapes, uses symmetry in almost all artistic creations - so much so that we can apply the notion that what is above is below in the design of bead and quill work. They had a very sophisticated system of locating from place to place and understood time in a very complex manner. Spiritually they were in tune with various spheres of influence. And they played to such a degree that one might wonder how so many Lakota games went by the wayside" (p. 316-317)

Figure 7

An Example Table from Sanders (2011) Sharing Some of the Results

Table 6-2		
Distance Measurements		
English Word	Lakota Word	English Translation
Mile	makhiyutȟapi (NLD, p. 328)	makȟa = earth, iyutȟapi = to measure
Yard	Čae'glepi (NLD, p. 71) Čaiyuhtapi	Čae'glepi = 1 step, iyutȟapi = to measure
Foot	siiyutȟapi (NLD, p.888)	si = foot, iyutȟapi = to measure
Inch	siiyutȟapi čik'ala Oiyuthe ciscila (NLD, 921)	si = foot, iyutȟapi = to measure, čik'ala
Kilometer	makhiyutȟapi lečhala	makȟa = earth, iyutȟapi = to measure, lečhala = new
Meter	Čae'glepi lečhala? Čaiyutȟapi lečhala	Čae'glepi = I step, lečhala = new
Centimeter	?	?

Note. Found in Sanders, 2011, p.218

Sanders also suggested a couple suggestions for future work. "All arithmetic operations are expressible in the Lakota language, however, not all results of these operations are. The next step to demystify the mathematics, from a cultural perspective, is to find contexts for such things as the answer to 3 - 9… Thus the completion of the Lakota number line and the invention of names to deal with concepts that have not yet been dealt with is imperative" (Sanders, 2011, p. 317-318). Further, "It is time, I think, for the Lakota language to tackle the issue of mathematics, to bring into the Lakota way of looking at things mathematical concepts and words which describe rates, algebra, calculus and the like" (Sanders, 2011, p. 321).

It is an honor to work from and with Dave Sanders towards research at the intersection of Indigenous (Lakota) education and undergraduate math education at SBC. After beginning to read his dissertation, I reached out to him and we have had multiple conversations since. My dissertation hopes to build upon his work of a Lakota mathematics to articulate it further and its

implications for undergraduate math education. Further, I hope to do it all through IRMs and a Lakota communication style.

2.2.9. Paper 1 – Circulating Conversations Methodology (CCM)

I am planning for a three-paper dissertation where the first paper is the story of how I got to my research questions through experiencing my IRMs theoretical framework. Within an Indigenous research methodology, the process is the product (Wilson, 2008), so the process of developing the research questions is equally as important as the questions themselves. My attempt of this article is to weave together a story web that shares both my IRMs Circulating Conversations Methodology (CCM) and my personal experiences using this methodology to develop the research questions. Co-researcher Josh Mattes, a SBC pre-engineering instructor, shared vehemently with me his personal frustration towards vacuous conceptual frameworks that have not been tested practically nor useful for instructors (J. Mattes, personal communication, February 22, 2021). Additionally, co-researcher Hollie Mackey shared with me her frustration with methodological laziness that she believes is rampant in so much of academic research including Indigenous Research Methodologies (H. Mackey, personal communication, February 19, 2021). This paper seeks to share the specific methodology that was used in the actual development of my research questions.

2.2.10. Paper 2 – Higher Order Math Concepts (HOMC) Authentic Cultural Connections Model

The current plan for Paper 2 will be the story of how the Higher Order Math Concepts (HOMC) Authentic Cultural Connections model developed. Currently the model aligns with the first three research questions and was developed using CCM. However, as CCM continues and the Lakota Math Connections course is prepared for and actually happens, I am prepared to adapt

the research questions and HOMC Authentic Cultural Connections model throughout the research process. Within CCM and IRMs, I specifically am (and remain) accountable to math instructors at TCUs (i.e. Josh Mattes), Indigenous language speakers and instructors (i.e. Sunshine Carlow), Indigenous scholars (i.e. Hollie Mackey), and myself as I seek a dual PhD in math and STEM education at NDSU.

The Higher Order Math Concepts (HOMC) Authentic Cultural Connections model will be used throughout this research project. The ideas for the model originated within CCM for research question development. As I circulated conversations with Sunshine, Josh, Hollie, Warren, and Bill, the research questions were formed through co-connecting knowledge. The HOMC Authentic Cultural Connections model visualizes the current research questions.

It will adapt as I develop the Lakota Math Connections course with Dave Sanders. It will change as course participants experience the CCM framework and give their feedback and lastly it will change during the CCM data analysis. As more language speakers and math instructors connect to the CCM framework, each of these relationships will connect with and inevitable bring some new way to view the HOMC Authentic Cultural Connections model.

Here is the current state of the Higher Order Math Concepts (HOMC) Authentic Cultural Connections model. The arrows represent the connections between these three different areas. This research is exploratory in nature and seeks to articulate more connections. The 'wall' between Western HOMC and Non-Western HOMC represents the fenced-off or siloed nature of Western mathematics (Bishop, 2012). Sunshine and I laughed over the idea of breaking the wall down with a sledgehammer (S. Carlow, personal communication, March 5, 2021) and Josh wondered why we had to be so violent and instead could simply use a ladder (J. Mattes, personal communication, March 10, 2021). Whatever way you look at it, the overall goal is to connect

these three areas by articulating specific authentic cultural connections that math and language instructors can use in their curriculum.

Figure 8

Current Model for Higher Order Math Concepts (HOMC) Authentic Cultural Connections
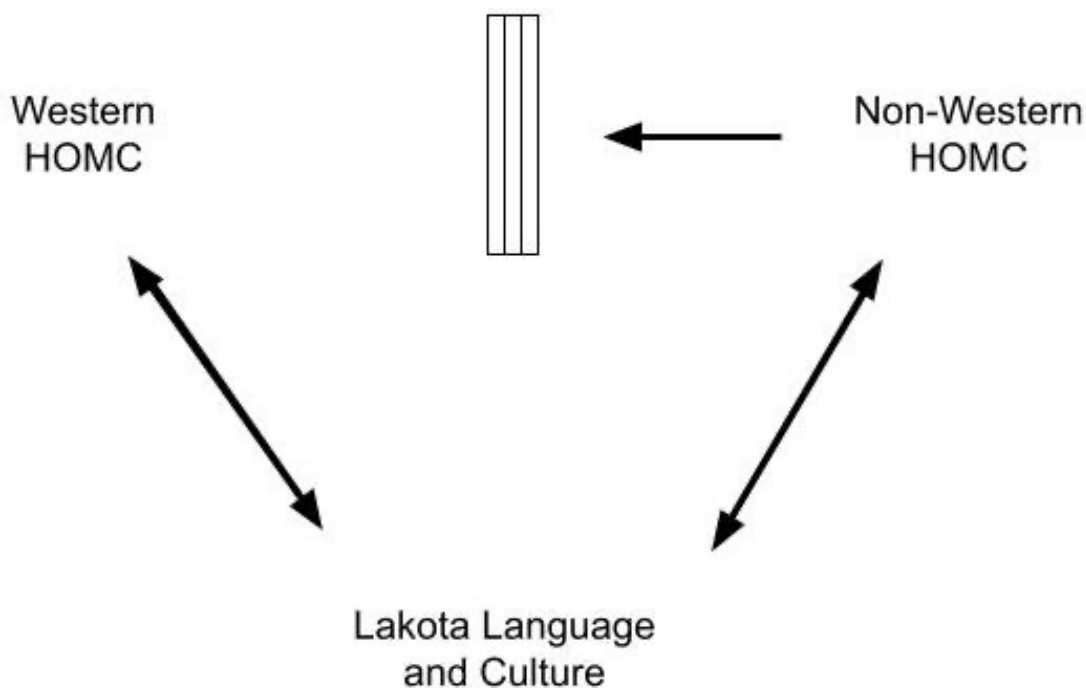
The first three research questions align with the HOMC Authentic Cultural Connections model. The double-sided area on the left-hand side is looking at the first two research questions. In simple terms, how can Lakota language and culture be integrated into the teaching of Western HOMC? Per Josh Mattes, this is a hugely beneficial topic for him as a math instructor at SBC. He recognized that articulating connections between collegiate mathematics and Lakota language and culture will be extremely challenging but even if results are minimal, it is still worth it from his perspective (J. Mattes, personal communication, September 25, 2020). And vice versa, how can Western HOMC be integrated into the teaching of Lakota language and culture? Per Sunshine Carlow, this is a question that Lakota instructors are specifically interested in (S. Carlow, personal communication, January 26, 2021). In the HOMC Authentic Cultural

Connections model, both Lakota culture/language and Western mathematics are highly valuable.

They are kept in balance, giving neither the greater importance (S. Carlow, personal

communication, February 5, 2021). Then, together they can build with each other towards further

Lakota language fluency and math proficiency/fluency (D. Sanders, personal communication,

May 7, 2021).

My original exposure to the ideas within the HOMC Authentic Cultural Connections

model came directly from the literature. Ruef et al. (2020) sought to answer three questions

including these two: "How are mathematical concepts represented in Yakama culture, and how is

Yakama culture reflected in mathematical concepts?" (p. 1). Then I connected with the idea that

these two questions align with CRISP, culturally relevant and culturally sustaining pedagogies

respectively. And after the HOMC Authentic Cultural Connections model was first developed, I

saw the connection to Sanders' dissertation abstract that says, "I also argue that, self-

determination, at the curriculum level, has much potential, not only in integrating Lakota culture

and language into the teaching of mathematics but also integrating mathematics into the teaching

of the Lakota language and culture" (Sanders, 2011, p.iii).

The example that piqued my interested in Lakota language and HOMC is the language

around the number 'one.' I recall like it was yesterday talking with Tyrel Iron Eyes, a graduate

student friend in anthropology at NDSU and Lakota language learner, about the word/number

one. He shared that his is a difficult topic because there are multiple Lakota words for the

number one including the counting 'one', the hypothetical 'one', and the realized 'one' (T. Iron

Eyes, personal communication, October 14, 2020). Although I do not yet know the nuances of

this within the language yet, this could be a distinctively Lakota way of understanding the

multiplicative identity within the language. These three words for 'one' and their interplay could

connect to multiple Western HOMC such as the multiplicative identity or the identity within group theory. When rationalizing the denominator, there is a hypothetical 'one' that needs to be multiplied, that is the conjugate over the conjugate. Within basic algebraic simplification, it is often said that when there is multiplying terms in the numerator and denominator and some terms are the same, then 'they cancel.' Alternatively, this can be understanding not as canceling but become 'one' and no longer being included in our writing of the problem. Lastly, I wonder how multiple words for 'one' in Lakota could influence the teaching of the identity in group theory. I do not yet know if using the Lakota words for 'one' will blossom into new pedagogical content knowledge for teaching collegiate mathematics or teaching the Lakota words for 'one'. That will be part of the results of this study, and I am eager to see them.

So far, I have only discussed the double-sided area on the left-hand side within the HOMC Authentic Cultural Connections model. However, through CCM, both Josh and Sunshine shared with me something I had not connected with up to that point. That is the idea of Lakota mathematics. They both shared that to assume that the current mainstream math curriculum contained all that Lakota mathematics could entail would be presumptuous (J. Mattes and S. Carlow, personal communication, February 5, 2021). Currently there is one main example of Lakota mathematics that will be further examined throughout the Lakota Math Connections course and the follow-up interviews.

The example is that numbers are considered verbs in the Lakota language and not objects or abstract quantities. Instead of viewing three as a quantity, it can be viewed as an action (three-ing) or the state of doing three (S. Carlow, personal communication, February 26, 2021). Again, I certainly do not yet know if implementing the Lakota view of numbers as verbs will blossom

into new pedagogical content knowledge for teaching collegiate mathematics. However, this is certainly outside the current realm of Western HOMC.

For me, this example is like an existence proof for Lakota Mathematics. It shows that Non-Western HOMC exist because of this single example. The third research question is focused on exploring more examples of Non-Western HOMC. This relates to one of the initial guiding articles. Garcia-Olp et al. (2019) prioritize that "Our Indigenous youth need to know that our ancestors have always engaged in high-level critical thinking [pre-contact with the Western world]" (p. 14).

Finally, I share that the HOMC Authentic Cultural Connections model developed with CCM may have benefit to TCU math departments and Indigenous language revitalization efforts beyond Standing Rock. Paper 2 will be the public record of how the HOMC Authentic Cultural Connection model was developed, implemented, and used to articulate CRISP curriculum. In particular, Paper 2 could benefit TCUs that believe the same assumption the co-researchers do in that language fluency and math proficiency/fluency can synergistically grow together.

2.2.11. Dakota/Lakota Summer Institute (DLSI) Lakota Math Connections (LMC) Course

As I shared in the 'Proposal Introduction', the opportunity to co-facilitate a course titled 'Lakota Math Connections' is a major spiritual confirmation to me. The research questions that were formed through CCM (without knowledge of a LMC course) can be best approached through the interactions and connections between Lakota elders, language speakers, and SBC math instructors. That is exactly what this course is! It is a workshop for elders, speakers, and mathematicians to explore and make connections between mainstream (collegiate) mathematics and the Lakota language and culture. Furthermore, Sunshine has shared on multiple occasions that both the DLSI leadership team and the Dean of Academics at SBC are enthusiastic about the

course (S. Carlow, personal communication, April 23 and 30, 2021). Furthermore again, the scholar who wrote the main dissertation that this course and my research will build from, Dave Sanders, has agreed to co-facilitate the course with me! Not only have I read his lengthy dissertation, but we are discussing the nuances and additions to his work together! I am learning insights about Lakota mathematics from him directly through conversation as we plan the Lakota Math Connections course together (D. Sanders, personal communication, May 2021).

The course is June 14-18th, Monday through Friday, 3pm-6pm at Sitting Bull College. We are anticipating about ten or so Lakota language speakers, a couple elders, and a handful of high school and college math instructors. The exact numbers and demographics are not known yet as participants are still signing up for the course. Participants know they are signing up for a research project because the course description and promotional materials say, "This course is also an active research project studying Lakota Math Connections so consent forms, video recording, pre/post surveys and potential follow-up interviews are involved" (LMC course description). Consent forms (approved by SBC IRB and NDSU IRB) will be signed at the beginning of the course with an opportunity to change privacy selections at the end of the course (see Appendix C).

Each day of the course will have the same general outline as follows:

Course/research goals review (Dave and Danny)

Introduce one of Bishop's six universal math activities (Dave)

Guest presenter speaks on Lakota cultural knowledge

Micro-lecture on pertaining mathematics (Danny)

Guided small group discussions (language speakers and math instructors mixed)

Whole class discussion to share out Lakota Math Connections developed in small groups

Recap of day/course/research goals (Dave and Danny)

2.2.12. Data Collection

The entire course will be video recorded including large group and small group discussions. These guided discussions between language speakers and math instructors are the main data source for this research. Secondly, follow up interviews will be conducted with every willing participant. Specifically, topics that connect with collegiate mathematics will be sought after. The interview protocol will follow Margaret Kovach's conversation method (Kovach, 2010). She wrote this a year after her book 'Indigenous Methodologies' (2009) to reflect on examples of IRMs and this method in action. The conversation method is "dialogic, relational, and reflective" (Kovach, 2010, p. 46). With the conversation method, I am thankful that this course and all interviews will be in person. As seen in the consent form and in line with the conversation method, "participants are given the option of waiving confidentiality" (Kovach, 2010, p. 45). The final major data collection source will be pre/post surveys given to each course participant (See Appendix D). The Standing Rock Language and Culture Institute Director as well as the Sitting Bull College library have determined with me that data should be stored indefinitely at the Sitting Bull College library with access dependent on the consent forms.

2.2.13. Paper 3

The current plan for Paper 3 will be the sharing of the actual Lakota Math Connections (LMC) that are developed through co-connecting knowledge during the course. LMC are the authentic cultural connections within the HOMC Authentic Cultural Connections model. To accomplish this, the video recordings will be analyzed through CCM. It is not yet certain who

will be part of the CCM web for analyzing yet. I am not assuming it will be the same people of Sunshine, Josh, and Hollie as it was for CCM during the research question development phase. At this point I desire to have one or two fluent Lakota speakers, one or two SBC math instructors, and hopefully someone who has taken upper-level collegiate math/engineering courses and can partially speak Lakota. If possible, I would like each person in the CCM web for data analysis be a fluent Lakota speaker and have a PhD in mathematics but that simply is not a reality. Having fluent speakers and college math instructors as part of the CCM web for data analysis gives further opportunity for them to experience co-connecting knowledge together. Lastly, I say perhaps two people is better than one in both categories of language speaker and college math instructor, so a single individual does not feel overly pressured to carry too much on their shoulders.

Coming out of the CCM data analysis phase, I am hopeful for specific curricular (or pedagogical) adjustments that can be shared with SBC math instructors, Lakota language instructors, and publicly through publishing Paper 3 and my dissertation. The following table shows LMC by row. The first five rows align with the main theme for the five days of the LMC course. The last three rows will be mentioned within the course but am currently expecting to be discussed more during follow up interviews.

Table 1

Table of Initial Lakota Math Connections

Bishop's Activity	Sanders' Dissertation	Lakota Authentic Cultural Connections	Collegiate Math Topic
Counting	Numbers, negative numbers, fractions	Language development	Set theory, types of numbers
Designing	Shapes and their meanings	Medicine wheel, Lakota designs	Unit circle, Cartesian / polar coordinates
Measuring	Rates with time and distance	Constructing and shooting arrows	Linear/quadratic equation modeling
Locating	Distance and direction	Lakota Star Knowledge	Geometry / trigonometry
Playing	Hand Games	Hand Games	Probability / statistics
Explaining	Spiral number line	Winter counts	
		Language around the words for 'one'	Algebraic simplifying, rationalize the denominator, identity in Group Theory
		Numbers as verbs	

Each of these LMC comes from some relationship within this research whether Sanders'
dissertation, talking with Lakota language speaker and friend Tyrel, or discussing with the
people that are part of CCM for the research question development phase. Within the research
paradigm of IRMs and therefore part of the theoretical framework CCM and key notion co-
connecting knowledge, some knowledge is sacred and should not be shared out of certain
contexts (Wilson, 2008). Further, because the ontology and epistemology are relationality, there
is no owner of knowledge but rather each person connected to the knowledge is responsible for it
and accountable to it (Wilson, 2008). Therefore, it is possible that I will not share (i.e. publish)
some LMC connections. To be accountable to the knowledge and to the community, some
knowledge is only for the community. Right now, it seems to me the only possible topics that
may not be shareable outside the community are the medicine wheel, Lakota designs, and Lakota
Star Knowledge.

2.2.14. Thank you! Yakoke!

Thank you for reading through this proposal and being part of my committee. After experiencing CCM within the research question development, I am only more excited and confident to continue in this way for the data collection and again using CCM for the data analysis phase and publishing phase. The near zero literature (at least that I could find) that precisely looks at undergraduate math education from an Indigenous perspective makes me feel that this will be a difficult journey. Yet, in that same moment, the journey feels/becomes all the more rewarding. This has been personal rewarding so far and I look forward to completing my degree and seeing the results of this research be incorporated at the Lakota Language Immersion Nest and in the Sitting Bull College math department.

Lastly, I will close with a story. Dr. Bob told me in one of our conversations driving across the state to a TCU that 'doing it the right way' to honor the community is important. He encouraged me in saying that you seem to be doing that well Danny. But you also need to ensure that with 'doing it the right way' you are able to 'find the right it' (R. Pieri, personal communication, September 2019). To me, this meant I needed to ensure the topic and research questions that I decided upon were the right questions to honor Standing Rock Nation as well as satisfy the requirements for a PhD in a mainstream institution. At this point, it seems the questions I am answering are 'the right it' for Sitting Bull College and the Lakota Language Immersion Nest. Now you as the committee will decide if this is 'the right it' to meet the requirements for a dual PhD in math and STEM education.

Yakoke!

Danny

2.2.15. Appendix of Literature

*Note: These categories are not definitive, nor exclusive in any way. Rather, most are nested and overlapping in some way. They were originally for personal use only to help me process/organize the literature. Order goes by category and date published.

A.1 - Literature around K-12 Culturally Relevant Pedagogy

A.2 - Literature around Antiracism / Racial Justice (Education) Theories

A.3 - Literature around Ethnomathematics

A.4 - Literature around Native Science

A.5 - Literature honoring Indigenous Communities through Education and Research

A.6 - Literature honoring Indigenous Communities through Culturally Relevant K-12 Math Education

A.7 - Literature connecting RUME and Indigenous Peoples

2.2.15.1. A.1 - Literature around K-12 Culturally Relevant Pedagogy

Ladson-Billings. (1995) Towards a Theory of Culturally Relevant Pedagogy

Paris. (2012) Culturally Sustaining Pedagogy: A Needed Change in Stance, Terminology, and Practice

Paris and Alim. (2014) What Are We Seeking to Sustain Through Culturally Sustaining Pedagogy? A Loving Critique Forward

Ladson-Billings. (2014) Culturally Relevant Pedagogy 2.0: a.k.a. the Remix

Hammond. (2014) Culturally Responsive Teaching and The Brain: Promoting Authentic Engagement and Rigor Among Culturally and Linguistically Diverse Students

McCarty and Lee. (2014) Critical Culturally Sustaining/Revitalizing Pedagogy and Indigenous Education Sovereignty

American Indian Science and Engineering Society. (2020) Literature Review: STEM Education for Native American Students

Abdulrahim and Orosco. (2020) Culturally Responsive Mathematics Teaching: A Research Synthesis

Mackey et al. (2020) Honoring Culturally Sustaining and Affirming Educational/School Leadership Practices for Indigenous Children and Youth

2.2.15.2. A.2 - Literature around Antiracism / Racial Justice (Education) Theories

2.2.15.2.1. Critical Race Theory

Ladson-Billings. (1995) Toward a Critical Race Theory of Education

Delgado and Stefancic. (2001, 2017) Critical Race Theory: An Introduction

Gillborn. (2005) Education policy as an act of white supremacy: whiteness, critical race theory and education reform

Taylor et al. (2009) Foundations of Critical Race Theory in Education

Gutstein. (2016) "Our Issues, Our People—Math as Our Weapon": Critical Mathematics in a Chicago Neighborhood High School

Leyva. (2016) "Mapping the margins [in mathematics]": examining the gendered and racialized intersectionality of mathematics experiences among African American and Latin@ undergraduate students in a large, predominantly white university

2.2.15.2.2. Tribal Critical Race Theory

Brayboy. (2005) Toward a Tribal Critical Race Theory in Education

Castagno and Lee. (2007) Native Mascots and Ethnic Fraud in Higher Education: Using Tribal Critical Race Theory and the Interest Convergence Principle as an Analytic Tool

Writer. (2008) Unmasking, Exposing, and Confronting: Critical Race Theory, Tribal Critical Race Theory and Multicultural Education

Brayboy. (2013) Tribal Critical Race Theory: An Origin Story and Future Directions

Luecke. (2020) RUME Poster Presentation titled "Using Successful Affective Measures Among Native Populations in the U.S."

2.2.15.2.3. *General*

Kozol. (1991, 2012) Savage Inequalities: Children in America's Schools

Tuck. (2009) Suspending Damage: A Letter to Communities

Orange. (2018) There There

Cooper. (2018) Eloquent Rage: A Black Feminist Discovers Her Superpower

Kendi. (2019) How to Be an Antiracist

2.2.15.2.4. *Cornell University Press about Antiracism and Racial Justice*

Douglass. (2013) In the Words of Frederick Douglass: Quotations from Liberty's Champion

Gosin. (2019) The Racial Politics of Division: Interethnic Struggles for Legitimacy in Multicultural Miami

Jones. (2019) From Willard Straight to Wall Street: A Memoir

Keels. (2020) Campus Counterspaces: Black and Latinx Students' Search for Community at Historically White Universities

Johnson. (2020) Undermining Racial Justice: How One University Embraced Inclusion and Inequality

2.2.15.3. A.3 - Literature around Ethnomathematics

D'Ambrosio. (1985) Ethnomathematics and Its Place in the History and Pedagogy of Mathematics

Bishop. (1988) Mathematics education in its cultural context

Stigler and Bishop. (1989) Mathematics Meets Culture

Bishop. (1990) Western mathematics: the secret weapon of cultural imperialism

Bishop. (1991, 2012) Mathematical Enculturation: A Cultural Perspective on Mathematics Education

Lipka. (1991 – 2014) [Literally every article he has written, here is three most cited]

(1991) Toward a culturally based pedagogy: A case study of one Yup'ik Eskimo teacher

(2005) Math in a cultural context: Two case studies of a successful culturally based math project

 (2014) Transforming the Culture of Schools: Yup'ik Eskimo Examples

Barton and Frank. (2001) Mathematical Ideas and Indigenous Languages

Sanders. (2011) Mathematical views within a Lakota community: Towards a mathematics for tribal self-determination

Greene. (2017) Decolonizing Mathematics through Cultural Knowledge: Construction of the Nehiyawak Mîkiwâhp (Cree Tipi)

2.2.15.4. A.4 - Literature around Native Science

Cajete. (1994) Look to the Mountain: An Ecology of Indigenous Education. First Edition

Aikenhead. (1996) Science Education: Border Crossing into the Subculture of Science

Cajete. (2000) Native Science: Natural Laws of Interdependence

Aikenhead. (2006) Science Education for Everyday Life: Evidence-based Practice

Kimmerer. (2013) Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge and the Teachings of Plants

Medin and Bang. (2014) Who's Asking?: Native Science, Western Science, and Science Education

American Indian Science and Engineering Society. (2020) Literature Review: STEM Education for Native American Students

Garcia-Olp et al. (2020) INDIGENOUS EPISTEMOLOGIES: Implementing Indigenous Practices and Perceptions to the Area of STEM

2.2.15.5. A.5 - Literature honoring Indigenous Communities through Education and Research

Deloria and Wildcat. (2001) Power and Place: Indian Education in America

Boyer. (2006) Should Expediency Always Trump Tradition?: AIHEC/NSF Project Develops Indigenous Evaluation Methods

LaFrance and Nichols. (2009) Indigenous Evaluation Framework: Telling Our Story in Our Place and Time : Written for the American Indian Higher Education Consortium (AIHEC)

Tuck and Yang. (2012) Decolonization is not a metaphor

Allaire. (2014) A'ohe pau ka 'ike i ka hālau ho'okāhi : all knowledge is not taught in the same school: a multiple-case study on the navigation of personal, cultural, and professional identities of Native Hawaiian members of Hawaiʻi's science, technology, engineering, and math community

Joseph and Windchief. (2015) Nahongvita: A Conceptual Model to Support Rural American Indian Youth in Pursuit of Higher Education

Shelly. (2016) Identity drum: an indigenous framework exploring identity loss, discovery and recovery through autoethnography

Windchief and Brown. (2017) Conceptualizing a mentoring program for American Indian/Alaska Native students in the STEM fields: a review of the literature

Windchief et al. (2018) Developing an Indigenous Mentoring Program for faculty mentoring American Indian and Alaska Native graduate students in STEM: a qualitative study

Bang. (2018-2021) http://learninginplaces.org/

Pewewardy et al. (2018) The Transformational Indigenous Praxis Model: Stages For Developing Critical Consciousness in Indigenous Education

Cummins. (2019) An Apsaalooke view for educational leadership

American Indian Science and Engineering Society. (2020) Literature Review: STEM Education for Native American Students

John. (2019) What can łįį' teach us about decolonizing education?

Mackey et al. (2020) Honoring Culturally Sustaining and Affirming Educational/School Leadership Practices for Indigenous Children and Youth

2.2.15.5.1. Nation-Building

Brayboy et al. (2012) Postsecondary Education for American Indian and Alaska

Natives: Higher Education for Nation Building and Self-Determination

Brayboy et al. (2014) Looking into the Hearts of Native Peoples: Nation Building as

an Institutional Orientation for Graduate Education

Brayboy et al. (2015) Sovereignty and Education: An Overview of the Unique Nature

of Indigenous Education

Brayboy et al. (2018) Why Don't More Indians Do Better in School? The Battle

between U.S. Schooling & American Indian/Alaska Native Education

Pauin. (2019) Decolonizing Pathways Through Indigenous Education: Native Student

Conceptions of Nation Building

2.2.15.5.2. Indigenous Research Methodologies

Smith. (1999, 2012, 2021) Decolonizing Methodologies: Research and Indigenous

Peoples

Wilson. (2001) What Is an Indigenous Research Methodology?

Mihesuah. (2003) Indigenous American Women: Decolonization, Empowerment,

Activism

Grande. (2004, 2015) Red Pedagogy: Native American Social and Political Thought

Wilson. (2008) Research is ceremony: Indigenous research methods

Archibald. (2008) Indigenous Storywork: Educating the Heart, Mind, Body, and

Spirit

Kovach. (2009) Indigenous Methodologies: Characteristics, Conversations, and

Contexts

M. A. Meyer (2014). Holographic Epistemology: Native Common Sense

Smith, Tuck, and Yang. (2018) Indigenous and Decolonizing Studies in Education: Mapping the Long View

Minthorn and Shotton (2018). Reclaiming Indigenous Research in Higher Education

Windchief et al. (2018) In Reciprocity: Responses to Critiques of Indigenous Methodologies

Windchief and Pedro. (2019) Applying Indigenous Research Methods: Storying with Peoples and Communities

2.2.15.6. A.6 - Literature honoring Indigenous Communities through Culturally Relevant K-12 Math Education

Fox and National Indian School Board Association. (2001) Creating Sacred Places for Students in Grades 9-12

Sgarlotti and National Indian School Board Association. (2006) Creating A Sacred Place for Students in Mathematics Grades Pre-K - 12

Gutiérrez. (2008) A "Gap-Gazing" Fetish in Mathematics Education? Problematizing Research on the Achievement Gap

Gutiérrez and Dixon-Román. (2010) Beyond Gap Gazing: How Can Thinking About Education Comprehensively Help Us (Re)envision Mathematics Education?

Kukahiko. (2014) Quanti-native, ka helu kahiko : Hawaiian culture-based education in mathematics

Trinick et al. (2014) Teachers learning the registers of mathematics and mathematics education in another language: an exploratory study

Technical Review Panel for The National Indian Education Study. (2015) Setting the

Context

North Dakota Native American Essential Understandings. (2017-2019)

https://teachingsofourelders.org/

Gutiérrez. (2017) LIVING MATHEMATX: Towards a Vision for the Future

Hunter et al. (2018) Developing Mathematical Inquiry Communities: Enacting

Culturally Responsive, Culturally Sustaining, Ambitious Mathematics Teaching

Marshall. (2018) To Sustain Tribal Nations: Striving for Indigenous Sovereignty in

Mathematics Education

Nicol et al. (2020) Living Culturally Responsive Mathematics Education with/in

Indigenous Communities

Garcia-Olp et al. (2019) Conceptualizing a Mathematics Curriculum: Indigenous

Knowledge has Always Been Mathematics Education

Washington. (2019) Family-School-Community (Dis)Engagement: An Indigenous

Community's Fight for Educational Equity and Cultural Reclamation in a New

England School District

Doolittle. (2020) Mathematics and Reconciliation

First Nations Education Steering Committee. (2020) Math First Peoples Teacher

Resource Guide: Elementary and Secondary

Ruef et al. (2020) Why indigenous languages matter for mathematics education: a

case study of Ichishkíin

2.2.15.7. *A.7 - Literature connecting RUME and Indigenous Peoples*

Smith, Cech et al. (2014) Giving back or giving up: Native American student experiences in science and engineering.

Downing. (2019) Leveraging Culturally Relevant Pedagogy in a College Algebra Course: A Mixed Methods Study

2.2.15.7.1. *Identity*

Martin. (2000) Mathematics Success and Failure Among African-American Youth: The Roles of Sociohistorical Context, Community Forces, School Influence, and Individual Agency

Cobb et al. (2009) An Interpretive Scheme for Analyzing the Identities That Students Develop in Mathematics Classrooms

Tsinnajinnie. (2018) Indigenous and Latinx Students' Developing Mathematical Identities

Tsinnajinnie. (2019) Using Identity to Frame Mathematics Educational Learning Experiences of Historically Marginalized Students

Windchief. (2019) Rationale for Cocreating a Community for Underrepresented Minorities in Science, Technology, Engineering, and Math: An Indigenous Paradigm

Ruef. (2020) Embracing Students' Complex Mathematical Identities

2.3. Literature Published/Found During the Dissertation Process

The main data collection happened in June 2021 during the week-long course part of the Dakota/Lakota Summer Institute. The literature review before the data collection phase is seen in the initial literature review and proposal section. During the data synthesis portion of this project more literature was published and/or found that directly related to the D/Lakota Math

Connections project and influenced the data synthesis process. These examples will be described below. Specifically, this literature can be divided into four categories including…

Confirmatory of the framework and process

Examples of Indigenous Math

Dictionaries for Math Neologisms in other Indigenous languages

Impact on School Mathematics and Professional Development for Teachers

2.3.1. Confirmatory of the Framework and Process

"Beyond being seen as a legitimate participant (a "doer" of mathematics), a student should be able to feel whole as a person—to draw upon all of their cultural and linguistic resources—while participating in school mathematics. That is, every student should be provided with windows and mirrors (Style 1996) onto the world through mathematics (Gutiérrez 2007); they should see aspects of themselves reflected back (mirror) as well as obtain views of new worlds outside of their own (windows). Unfortunately, for many [Indigenous, Latinx, and Black] students, mathematics classrooms are experienced almost exclusively as windows. We are in need of research-based illustrations of teachers' and researchers' initiatives that promote forms of what I refer to as rehumanizing mathematics" (Gutiérrez, 2018, p.1).

Rochelle Gutiérrez's framework on rehumanizing mathematics is confirmatory literature to the D/Lakota Math Connections research project. The above quote is her introduction to rehumanizing mathematics but continues on to describe many aspects that support the D/Lakota Math Connections development process and framework. First, Gutiérrez highlights teaching and learning as culture-specific activities. Then she elaborates on the link between knowledge and power specifically relating to what knowledge is valued and how knowledge is developed. She

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posits that math education cannot truly improve until the strengths and intersectionality of the students the system has failed [Black, Indigenous, Latinx] are centered, not to do well by Whitestream standards, but by their specific community standards. Gutiérrez continues in identifying all humans as doers of math and mathematics as a living practice full of culture, history, power dynamics, and divergent answers that can connect to a students' identity and emotions. Gutiérrez's seminal work in rehumanizing mathematics and call for more research-based exemplars supports the framework and process of the D/Lakota Math Connections project.

Further, the Show Me Your Math project, event, and research (found during the research process) strongly corroborates the D/Lakota Math Connections research process and results. The Show Me Your Math project is based in the Mi'kmaw and Maliseet nations throughout eastern Canada. Students in grades K-12 participate where "in their ethnomathematical investigations they identified mathematics at work in current and traditional community practices" (Borden & Wagner; 2011, p.10). Students present their projects to the community online and through the annual Show Me Your Math event.

The process has similarities to and corroborates with the D/Lakota Math Connections project. A group of committed math teachers and elders from Mi'kmaw communies initiated the effort and organize it annually starting in 2006. They introduce the project to students through the six math activities of counting, measuring, locating, designing, explaining, and playing from Bishop (2012) and also used by Sanders (2011) and now the D/Lakota Math Connections project. The projects are presented to the community and highlights "To whom are students reporting their mathematics? Whose problems/needs are students addressing when they do the tasks assigned to them? How are people and communities represented in applications of mathematics introduced in school?" (Wagner & Borden, 2012, p.69). Further the approach to

learning from the fluent elders about the Mi'kmaw language and how it gives insight to how Mi'kmaw children think about mathematical concepts. Teaching and learning the language provides valuable insight for First Nations students/learners of math. (Borden, 2013). Even further the process/connection of the Indigenous language with the math activities of counting, locating, measuring, designing, playing, and explaining is a strong similarity between Show Me Your Math and the D/Lakota Math Connections project.

Further, verb-oriented mathematics, spiritually-connected mathematics, and equity in math classrooms are all corroborating results. Borden describes "the concept of verbification as a linguistic process that stands in contrast to the predominance of nominalization in the teaching and learning of mathematics… verbification holds promise as a means of supporting Aboriginal students in mathematics learning" (Borden, 2011, p.8). Similar within the initial D/Lakota Math Connections proposal and results, the idea of numbers as verbs was explored in the D/Lakota language. Additionally, both Show Me Your Math and the D/Lakota Math Connections project both acknowledge the spiritual connection of mathematics as math is embedded in designing, explaining, language, elders' stories, nature, etc. (Borden & Wagner; 2011). Lastly, all these aspects together increase equity in the math classroom. Borden shares that "Show Me Your Math is contributing to greater sense of equity [in math classrooms] by addressing critical questions of identity and power and enabling community voices to be seen as a source of authority." (Borden et al., 2019, p.91)

2.3.2. Examples of Indigenous Math

Three examples of Indigenous math published or encountered after the main data collection phase will be highlighted here. None of the three cite each other but all are seminal examples of Indigenous math in each place.

Apache mathematics as described by Philip Stevens (San Carlos Apache) contrasts Eurocentric approaches to math that follow a decontextualized epistemology. Apache mathematics is rather "the mathematics used by Apache people in context of their daily lives beyond schools" (Stevens, 2021, p.3) and its connections with and distinctions from Western mathematics. Stevens found that "'mathematics' as identified in English [and school settings] conjures up a very limited form of mathematics relegated to budgetary and arithmetic formats. Participants did not often connect mathematical reasoning in Apache daily life" (Stevens, 2021, p.10). His title example discussed two-dimensional Euclidean tessellation done in school in contrast with three-dimensional non-Euclidean tessellation of mesquite wood stacking. An activity most kids experience as a child to stack wood in the back of the truck in the time frame of chainsaw gas tank running empty with the only instructions from the adult as 'Do it good.' Stevens gives further examples of Apache mathematics embodied and experienced in daily activities as shooting an arrow or gun, making tulipai and water drums, and Apache spirituality.

The "Dakota/Lakota Star Map Constellation Guidebook: An Introduction to D(L)akota Star Knowledge" (A. S. Lee et al., 2014) focuses on the D/Lakota constellations intertwined with astronomical understandings of the stars. Names and stories of the D/Lakota constellations are organized by the four seasons and the north circumpolar stars. Although this resource was not used during the June 2021 data collection, the book "Lakota Star Knowledge: Studies in Lakota Stellar Theology" (Goodman & Seeger, 1992) was a significant source for the constellation guidebook. The "Lakota Star Knowledge" book was used in the June 2021 course and shares Lakota observational star knowledge and its connections to Lakota spirituality.

Lastly, the book "Indigenous Statistics" (Walter & Anderson, 2013) is a seminal example of Indigenous math applied to government statistics in the Australian and Canadian contexts.

Walter and Anderson describe Indigenous to mean both modern and place specific as its defining characteristics. Further, they give examples of how federal, settler-colonial, governments uses of statistics to describe Indigenous peoples as deficit. Their development and application of nayri kati ("Good Numbers") is a seminal example of Indigenous quantitative methodology in practice (Walter & Anderson, 2013).

2.3.3. Dictionaries for Math Neologisms in Other Indigenous Languages

Multiple Indigenous language math dictionaries have published in the last decade. There are likely more but the following three are accessible to the public and are influencing the neologism (new word for modern times) development process for math vocabulary in the D/Lakota language. Everything from the content, math words prioritized to be in the dictionary, structure of the dictionary, and the process to developing the dictionary is influencing the D/Lakota math neologisms process. Summer 2022 was the first math neologisms course at Sitting Bull College to begin the process to work towards a D/Lakota math dictionary. The three examples are a Maori math dictionary, Cree math dictionary, and the Ojibwe vocabulary project.

The Te Reo Pangarau (Maori math dictionary) is available freely online courtesy of He Kupenga Hao i te Reo (A Fishing Net of the Language) which compiled multiple Maori language resources altogether in math as well as multiple more school subjects. The dictionary website is fully displayed in Maori but thanks to Google Translate it can be translated to English. The dictionary allows for both English-Maori and Maori-English (He Kupenga Hao i te Reo, 2023).

The "Cree Dictionary of Mathematical Terms with Visual Examples" (Sardarli & Swan, 2022) was first published in print in 2017 and then developed an electronic version afterword. The Cree math dictionary is strictly English-Cree and discusses that elders from three distinct

Cree dialects came together to make the singular math words across the dialects. It has many visual examples that fit the Cree cultural context.

The Aaniin Ekidong: Ojibwe Vocabulary Project (Moose et el., 2010) brought together fluent elders from multiple Ojibwe communities in the United States and Canada. In a three-day gathering, fluent speakers, editors, and project team members brainstormed and discussed math vocabulary as well as other subjects. The project differentiated between words with universal acceptance among the fluent elders with different dialects and words that were unique to each dialect or elder. "There was no attempt to standardize the language" (Moose et al., 2010, p. 9).

There are many similarities between all three dictionaries. First, they all specifically name the contributors (fluent speakers, other workers) and the communities in which they are from. Further, they are all fully accessible, not for profit, want to give credit to the elders, and thank the funders and hosting institutions. Even though each language is in a different place as in its immersion school journey, the challenges to teach state-mandated curriculum in mathematics prompted these efforts. The introduction of Aaniin Ekidong shares that "many fluent speakers complain that when speaking about the language or certain subjects that the conversation slips into English because of vocabulary challenges. A language lives when it can be used for everything in life, not just certain parts of life" (Moose et al., 2010, p.5). These math dictionaries are one small part of allowing the language to be used in every aspect of life and school.

2.3.4. Impact on School Mathematics and Professional Development for Teachers

Indigenous math and pedagogy can have a large influence on school mathematics and professional development for teachers. This section highlights a couple articles and projects that focus on Indigenous pedagogy for learning math and professional development for teachers.

Although the article titled "Let's Do it First and Talk About it Later" (Hogue, 2014) focuses on secondary science education, Hogue (Metis) begins by describing science from an Aboriginal paradigm, in contrast to a Western paradigm. An Aboriginal paradigm for science is inclusive, connected and interconnected, and has a spiritual dimension. The inclusivity breaks down the siloes of biology, chemistry, physics, as well as math. However, especially in the science, technology, and math, lack of relevant curriculum and the appropriate teaching methodologies that attend to Indigenous ways of knowing and learning has led to pushing Native students out of the STEM fields. Hogue argues one of the main barriers is how science/math is taught from the Western perspective of theoretical first and then maybe practical much later. She argues "this is counterintuitive to the *learning by doing first* pedagogy of Aboriginal ways of knowing and learning… [where] successful learning achievement is not measured through written examination, but through the ability to apply learning and knowledge in the practical live of life" (Hogue, 2014, p.139). She argues that relevant, hands-on curriculum is essential for all First Nations/Metis/Inuit learners, but even more so in math and science. Hogue re-developed a post-secondary introduction to chemistry course with very positive results for Aboriginal students learning from a do-it-first pedagogy (Hogue, 2014).

Further in 2021, a pair of articles described a professional development project for non-Indigenous math teachers (Grades 5-12) to strengthen their curriculum and pedagogy through the Indigenous mathematizing (S. Meyer & Aikenhead, 2021a,b). Indigenous mathematizing is exemplified by the mathematical activities of counting, measuring, locating, designing, playing, and explaining (Bishop, 1988) in alignment with and respect for Indigenous languages being verb-based in contrast to English being noun-based. Through immersive cultural experiences and cultural mentors, the teachers went through a four-phase process for lesson plan development

including planning, teaching the lesson, reflecting on the lesson, and listening to outsider's observations. The results, that is support/needs for teachers, came in two categories: learning and unlearning ways of perceiving math and the world. Teachers using Indigenous mathematizing in their classroom need to learn:

"The plurality of mathematical systems,

The perspective of Western mathematics as a human endeavor along with its values, ideologies, and definitions,

The mere inclusion of Indigenous mathematizing in a lesson is not enough,

And the goal of two-eyed seeing" (S. Meyer & Aikenhead, 2021b, p.119).

Further, teachers using Indigenous mathematizing in their classroom need to unlearn:

"Pure mathematics' claim to be value-free,

All students have a predilection to excel in mathematics,

And subtle appropriation committed by many mathematics educators as if it were common sense to do it" (S. Meyer & Aikenhead, 2021b, p. 119).

2.4. Relationships Inform Every Step of the Research Process

This last section of the literature review is not actually about literature at all. Rather, this section seeks to follow the Indigenous research paradigm literature the way I understand it. This last section attempts to describe the human relationships developed through the research process and describe how I began and will continue to remain accountable to these relationships.

Wilson's description of an Indigenous research paradigm laid out that "the shared aspect of an Indigenous ontology [what is real?] and epistemology [how do I know what is real and what is not?] is relationality. The shared aspect of an Indigenous axiology [what moral beliefs will guide the search for reality?] and methodology [how do I find out more and explore this

reality?] that research must maintain accountability to all the relationships that it forms" (Wilson, 2008, p. 137).

As shared in my written proposal above, Wilson describes an Indigenous research paradigm to have an ontology and epistemology of relationality and a methodology and axiology of relational accountability. Further, he lays out that no matter the ontology, epistemology, axiology, and methodology, the academic/scientific rigor is demonstrated through the alignment of these four aspects of research (Wilson, 2001, 2008). To align the ontology that relationships form reality, epistemology of a living web of knowledge amongst all human and non-human persons, and a methodology and axiology that focuses on relational accountability, this section emphasizes how relationships informed every aspect of the research process, and these relationships were not just for research. Rather, deep and long-term friendships will continue.

This section attempts to describe my relationships and accountability to those relationships throughout the PhD journey. Relationships are not set in stone, not easily measurable, and always in motion/changing. Not just the literature, but rather the relationships I had before and during this research were the largest influence in how I filtered (implicitly or explicitly) what I was reading in the literature and what I was experiencing in the research process. These relationships are invaluable. Even though Western forms of communication and citation emphasize the written word, not so within an Indigenous research paradigm.

This section is not identical to but in conjunction with the templates to cite Indigenous Elders and knowledge keepers beyond the minimal 'personal communication' in-text citation. Solely 'personal communication' citation practices devalue Indigenous oral communication by equating knowledge passed down generationally through story to a quick phone conversation (MacLeod, 2021). Similarly, not describing my relationships and accountability to the project

contributors devalues relationality and relational accountability elevating the written word above oral communication, that is elevating Western values above Indigenous values. Additionally, attempting to write down all the project contributors and relationships may also be seen as elevating the written word over above my oral communication with them.

Wilson describes the written word as fixed and to easily taken out of context and dissected. He says the written word minimizes the mutual responsibility that is inherent in oral communication (Wilson, 2008). Further, Long Feather in her dissertation on D/Lakota communication states "Communication for Native people then, as asserted here, is not the mere exchange of facts or messages. For Native people, communication involved primarily relationship building" (Long Feather, 2007, p. 51). This section is my best attempt to being forthright about the relationships that influenced me as part of this research. If the communication of my dissertation is primarily about relationship building and not merely transmission of information, then the human relationships part of this research process cannot remain hidden.

I concede that the dissertation will be in written form, and without naming names, this section is my best attempt to relationship build and maintain accountability within the written word. However, the real accountability will happen off the page and throughout our lives.

This section (along with the Acknowledgements section) hopefully allows readers not part of this dissertation process to get a glimpse of the relational web that was formed and see the relational web that holds our relational understanding of the D/Lakota Math Connections project.

All the relationships that began before any research took place, the experiences we shared together, and the stories they shared with me became the literature to learn from, connect with, and depend on. The literature was second to relationships and experience, however the literature

also taught and influenced me as well. Whatever literature I was reading got filtered implicitly or explicitly through these relationships, including the experience of the engineering/math educators at their respective TCU and the students who experienced firsthand math education on the reservation. These relationships became invaluable to me and in the PhD research process. All these friendships I anticipate lasting long beyond any research project and hopefully many of them becoming lifelong.

It has been amazing to meet many people through the PhD process and I will not disappear after my PhD is completed. The results of this research do not belong to me nor should be under my name, but rather all who contributed. The knowledge, a web of connections itself, is held amongst the web of relationships that experienced it together. In closing, I have full confidence in saying that the relationships that begin through this research are not solely about research and will continue into the future.

3. PAPER 1 – CIRCULATING CONVERSATIONS METHODOLOGY[2]

The first paper of this four-paper dissertation is published in the peer-reviewed, open-source journal titled "Philosophy of Mathematics Education Journal" in September 2022. I am thankful to the reviewers for their comments, critiques, and questions that strengthened my work.

3.1. Cover Page and Abstract

CIRCULATING CONVERSATIONS METHODOLOGY: CO-CONNECTING KNOWLEDGE TO DEVELOP RESEARCH QUESTIONS AT SITTING BULL COLLEGE

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Abstract:

How does one determine a research direction and research questions for research in undergraduate math education? Shawn Wilson (Opaskawayak Cree) articulates that "research is all about unanswered questions, but it also reveals our unquestioned answers" (2008, p.6). Circulating Conversations Methodology is one approach within an Indigenous research paradigm to determine the research direction and research questions. This methodological paper shares both the process of developing Circulating Conversations Methodology as an Indigenous Research Methodology and how the Circulating Conversations Methodology was specifically enacted at Sitting Bull College to develop research questions for undergraduate math education.

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[2] The material in this chapter was co-authored by Danny Luecke, Sunshine Carlow, Josh Mattes, Warren Christensen, and Hollie Mackey. Danny Luecke had primary responsibility for the discussions/informal interviews. Danny Luecke was the primary developer of the conclusions that are advanced here. Danny Luecke also drafted and revised all versions of this chapter. Sunshine Carlow, Josh Mattes, Warren Christensen, and Hollie Mackey served as contributors, proofreaders, and editors for Danny Luecke.

Through collaborative connecting via conversation and story, relationships were strengthened and formed as we co-connected knowledge. This paper is a story intertwining the process of developing the research questions, the resulting research questions, and the relationships formed through the process. Circulating Conversations Methodology and this paper seek to follow an Indigenous principle, "the process is the product." (Wilson, 2008, p.103)

3.2. Introduction and Discussion

The purpose of this paper is to share how we applied a specific Indigenous research methodology within the community context at Sitting Bull College. Indigenous Research Methodologies literature lays the foundational principles for the process and outcomes of research with Indigenous Peoples while leaving room to uniquely reflect place and community (Archibald, 2008; Kovach, 2009; Wilson, 2008). Sitting Bull College is a tribal college/university chartered by Standing Rock Nation and guided by Dakota/Lakota culture, values, and language (Sitting Bull College, 2023). This methodological paper articulates how we experienced conceptual ideas related to Indigenous research and methodologies such as relationality, responsibility, and reciprocity within specific place-based math education research. The methodology is titled Circulating Conversations Methodology and implements what we came to describe as co-connecting knowledge. As far as we are aware, Indigenous research methodologies have not yet been applied to research in undergraduate math education. Circulating Conversations Methodology demonstrates both the possibilities and value for using Indigenous research methodologies to strengthen undergraduate math education.

3.2.1. Formal Introductions

In following a Lakota/Nakota/Dakota model of communication, we will start with a formal introduction to begin establishing context and relationship (Long Feather, 2007).

Hau mitakuyepi. Ċhaṇte waṡteya nape ċhiyuzapi. Danny Luecke emaċiyapi. Fargo, North Dakota el wathi na Fargo emataṇḣaṇ. Ina Kathy Jo Dahlgren eċiyapi. Ate Lenny Luecke eċiyapi. In Lakhol'iyapi (the Lakota language) I said, hello my relatives. With a good heart I shake your hand. My name is Danny Luecke, and I am from and currently live in Fargo, North Dakota. I shared my parent's names as part of common protocol and in part to fulfill my desire to honor all my ancestors. My mother also grew up in Fargo and is of Danish, Norwegian, and Swedish ancestry. My father grew up on a farm in South Dakota and is of Irish, German, and Choctaw ancestry. I am enrolled in Choctaw Nation of Oklahoma and often reflect on the tension of embracing or neglecting my Choctaw heritage because of my predominantly white background and experiences. In hopes to neither romanticize nor demonize any of my/our/your ancestors, I am reminded that nobody chose their birth family, but Creator determined this for each one of us. Even though I am Choctaw, I introduced myself in Lakhol'iyapi to honor the Nation, people, and land that this research is from. My understanding of Indigenous Research Methodologies has come from books and not experience, which is an obvious limitation to my work. In response, I have sought to whole-heartedly live the teachings I have learned from the Indigenous research methodologies literature. Currently I live with my wife and two daughters in Fargo. This collaborative paper and research is part of my PhD in math and math education at NDSU.

Throughout this paper, the pronouns 'I' and 'we' are intentionally used. 'I' will specifically reflect Danny's individual experiences and beliefs as the lead author. When another author writes in first person instead of Danny, it will be explicitly stated. 'We' will reflect

collaboration and having a mutual experience or belief. The positionality of the co-authors will be shared throughout our paper as part of the story of Circulating Conversations Methodology.

3.2.2. Acknowledgements to Land, People, and Readers

The story begins with acknowledging Land and the place we are. We acknowledge that Land is alive, dynamic, and relational. Land was here long before we were and will be here far beyond all of us. We honor the Land and the Tribal Nations that have been in reciprocal, sustainable relationship with her for generations. We acknowledge the Oceti Sakowin, Anishinaabe, and any other Indigenous Peoples continuing their relationship with the Land despite settler colonialism seeking to divide them from one another.

Further, I specifically acknowledge and say thank you to the faculty and community at Sitting Bull College and Standing Rock Nation. Apart from you, this research would not exist, and I would not be the person I am today. Yakoke (thank you in Choctaw). I pray that everything I do can lead to strengthening our relationships with one another, the Land, our ancestors, and Creator.

Similarly, I pray for you, the reader/listener to this story. I pray that your connection with us could grow. I pray that you would also seek to honor all your relations. We, as co-authors, only share from our context/relations and cannot say how it will apply to your relations. Further, we desire your reading experience to be cyclical in nature. We purposefully communicate through story using a web of seven strands. Thank you for joining with us to unravel the journey of Circulating Conversations Methodology at Sitting Bull College to develop math education research questions.

3.2.3. Overview

Seven strands make up the web structure of this paper.

(1) Writing Style and Structure

(2) Indigenous Research Methodologies as Conceptual Framework

(3) Context of Colonialism in Research and Education

(4) The Story of Circulating Conversations Methodology

(5) The Research Questions

(6) Co-Connecting Knowledge

(7) Reflections on Circulating Conversations Methodology

This paper weaves together a story web that shares both the theory of Circulating Conversations Methodology (CCM) as well as shares my personal experience using this methodology to develop math education research questions.

I am continually learning from Shawn Wilson that "the process is the product" (2008, p. 103). Within my understanding of an Indigenous research paradigm, the process to arrive at our research questions is equally as significant as the answer to the research questions (Medin & Bang, 2014; Wilson, 2008). Similarly, the relationships developed through the process are equally as significant as the results. Or more in line with Shawn Wilson's phrasing, the relationships are the results. Note that this is inclusive of not only human to human relationships, but also human to nature and human to knowledge relationships. In this way of being and thinking, we seek to write this paper in such a way that honors the process as product. How you read this paper (the process) will certainly impact how you learn from it (the product). In our attempt to strengthen relationship and process-oriented thinking, we will share Circulating

Conversations Methodology and the four research questions stemming from it later in this paper after more context can be developed.

When entering graduate school interested in Indigenous math education, I intuitively knew from my previous life experiences in cross-cultural communication that I would need to build relationships through listening well. During the literature review phase of graduate school, I read Jo-ann Archibald's (Stó:lō and St'at'imc) work titled "Indigenous Storywork: Educating the Heart, Mind, Body, and Soul" (2008). She shares a powerful story leading to piercing questions that I have reflected upon since,

> Was I doing anything different from earlier 'outsider' academics who created a legacy of mistrust among First Nations concerning academic research? How was my research going to benefit the education and wellbeing of Indigenous peoples and their communities? How would I address ethical issues related to respect and ownership of Indigenous intellectual property? (Archibald, 2008, p. 36)

As I seek to do math education research with Indigenous Peoples, listening to potential answers to these reflection questions from Indigenous community leaders and friends guides me.

Confronted with these reflection questions, and others like it from Indigenous scholars, I attempt to move forward in a good way in both doing the research and sharing it with others. The purpose of this paper is to respectfully share the methodology we used in developing the research questions in undergraduate math education. We specifically applied one form of an Indigenous research methodology to one specific context at Sitting Bull College. Through our example, we seek to demonstrate the value and affordances of using Indigenous research methodologies within math education research.

3.3. Strand 1: Writing Style and Structure

The first strand is writing style and structure. In seeking to follow Indigenous ways of knowing and being throughout every aspect of this research, it is important to understand that how knowledge is transferred is equally significant with the knowledge itself (Kovach, 2009; Wilson, 2008). Lewis Cardinal (Cree) in 'Research is Ceremony' tells a story circling around the principle "the process is the product" (Wilson, 2008, p.103). This principle has become central to our work as well. Further, it connects with why we desire for the writing style (process) to align, or be in balance with, the content being shared (product). Specifically, for us, the research questions and the naming of Circulating Conversations Methodology were the product that came through our process. So, we will not share the research questions at this stage in the paper but will wait until more context is developed. Similarly, in a calculus course, or any math course for that matter, if all a student shows is '7' for their answer, this is vacuous without seeing the process. In contrast to 'the end justifies the means,' we see that the means is the end.

With this idea in mind, we join with other Indigenous authors and researchers in grappling with how to best honor Indigenous knowledges in a university/academic setting and in printed literature (Kovach, 2009). Archibald clarifies that applying Western communication (literary and oratory) theory and thought onto the work and stories of Indigenous elders and scholars is a modern form of conquest and colonization (2008). Therefore, we chose to write this article in story. As Wilson says, this is "not just a matter of preference but a result of our relationality" (Wilson, 2008, p. 133). Wilson elaborates in sharing:

> As we Indigenous scholars have begun to assert our power, we are no longer
> allowing others to speak in our stead. We are beginning to articulate our own research

paradigms and to demand that research conducted in our communities follows our codes of conduct and honors our systems of knowledge and worldviews. (Wilson, 2008, p. 8)

We are attempting to follow this demand in every possible way, which certainly includes writing style and structure.

Cheryl Long Feather (Lakota/Dakota) shares her perspective of an Indigenous theory of communication. She prefaces her "Native American Theory of Communication Conceptual Model" in saying that although it may generally represent an Indigenous perspective, it is her responsibility and obligation to acknowledge this is her perspective based on her understanding and she cannot claim it extend to all Tribal Nations or Indigenous Peoples (Long Feather, 2007). Long Feather (2007) states the following:

"This illustration (see Figure 1) represents the 'world' of communication. A profound and quintessentially Native American adage states *what is above is also below*. In other words, everything in our human world consists of ever-expanding and ever-contracting circles that mimic the structure of the entire universe. This conception underscores the reason most uniquely Native American models – whether they be related to communication, social structure, mental health, mathematics, or any other subject – are circular." (p. 46-47)

Figure 9

Paper 1 Figure 1: Long Feather's "Native American Theory of Communication Conceptual Model"

Note. Found at Long Feather, 2007, p.46

This paper is structured in a similar fashion. The abstract is a first and smallest circle. Then the Introduction and Discussion is the second pass at the same themes from the abstract but with more depth and connections. The rest of the paper focuses on seven themes/strands.

The writing style is specifically non-linear but rather circular. This paper attempts to follow the unique characteristics Long Feather noted including being centered, fluid, evolutionary, and relational (2007). Margaret Kovach (Plains Cree/Saulteaux) shares her understanding that "Tribal knowledge systems are holistic. They move beyond the cognitive to the kinetic, affective, and spiritual. They are fluid" (Kovach, 2009, p. 176). This paper seeks to follow this holistic way of knowing through every aspect, including the writing style. The organizational structure for this paper is a web (see Figure 2).

Figure 10

Paper 1 Figure 2: A Web Organizational Structure for this Paper.

"For traditional Lakota/Nakota/Dakota people, as well as many other Tribes, a fundamental understanding of the universe is based on the concept of balance and perpetual movement. This is perhaps why so many of our symbols are predicated on circles." (Long Feather, 2007, p. 26). A circular writing structure and contextualized story give space to make as many connections as possible within the work itself and with you as the reader. Each strand and circle is a story within itself and is also interdependent and interrelated with every other strand and circle (Hampton, 1995; Kovach, 2009; Long Feather, 2007; Smith, 2021; Wilson, 2008). For me, it was a spiritual moment of connection as I read Long Feather's dissertation. When I saw her "Native American Theory of Communication Conceptual Model" (see Figure 1) and the examples she gave of circular communication structures (see Figure 3), the connection came to me for both the weblike structure of this paper as well as the weblike structure I experienced in developing Circulating Conversations Methodology (CCM). The paper's structure is *not like* a web, it *is a* web. Similarly, CCM is *not like* a web, it *is a* web. Both CCM and this paper's

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structure attempt to exemplify the process is the product. How you connect with these ideas in process is equally the product as much as what we have written (Wilson, 2008).

Figure 11

Paper 1 Figure 3: Long Feather's "Circular Speech Structure"

Note. Found at Long Feather, 2007, p.100

To complete the circle, you could consider reading the Introduction and Discussion again after reading the body as you might read the Discussion section in another Western research paper. However, the thought of me telling you how to read is "personally and culturally repulsive" (Wilson, 2008, p. 134). There is no way that we can know all your relations and how you are accountable to them. The choice is yours on how to read and how you will connect with this article. We share this reading pattern only as an option. This pattern (Abstract, Introduction and Discussion, the Seven Strands, Introduction and Discussion, Abstract) also aligns with our writing pattern. I wrote the Abstract and the Introduction and Discussion first. Then we collaboratively discussed that portion. Then I wrote the Seven Strands, re-wrote the Introduction and Discussion, and finally re-wrote the abstract. We met again to edit the paper in its entirety. To me this writing process demonstrates the non-linear process that Cheryl Long Feather describes of increasing and decreasing circles. Further, the writing process was fluid and non-static like how a spider web moves and blows with the wind.

The person at the center of Long Feather's "Native American Theory of Communication Conceptual Model" (see Figure 1) can remind us that each person has their own set of relationships and connections. Indigenous knowledge systems view knowledge as relational and

therefore without an individual owner (Grande, 2015; Kovach, 2009; Wilson, 2008). Instead, there is a joint responsibility with knowledge. You as the reader and we as the co-authors are all accountable to how we learn, embody, use, and share knowledge (Kovach, 2009; Wilson, 2008). As co-authors/storytellers, we are responsible for how we present Circulating Conversations Methodology (CMM), co-connecting knowledge, and the research questions. You as the reader are responsible for listening, learning, and being accountable to all your relations. Thus, we assume that each listener/reader will process and receive what their relationships have prepared them for (Archibald, 2008; Kovach, 2009; Wilson, 2008). Wilson describes the position of author/storyteller by saying,

> My role is not to draw conclusions for another or to make an argument. My role, based upon the guidelines of relationality and relational accountability… is to make as many connections or relationships available as possible and to respect the reader's ability to take in what they are ready to receive. (Wilson, 2008, p. 133)

There is no final or concluding point as relations continue to evolve, form, and flow. The web of this paper, Circulating Conversations Methodology, and our learning continue to be in motion just as a spider moves up, down, and around their web. Wilson expands in saying, "Carrying this one step further, it becomes unethical to reiterate or restate previous messages… [to do so] is to tell them what lessons they were supposed to pick up and this would be inappropriate." (Wilson, 2008, p. 133). Long Feather shares a similar idea in her conception of Lakota/Nakota/Dakota oratory that "by directly responding to another point of view, an orator impedes another's ability to come to his or her own conclusions" (Long Feather, 2007, p. 138). Our role is not to tell you what an Indigenous research methodology is. Rather we will present

some of the connections we have made with the Indigenous research methodology literature and share our experience of enacting Circulating Conversations Methodology.

Another writing style decision for this research paper is being written in first person. Since knowledge is relational and we each have our own set of relationships, then using first person point of view can easily follow. Further, since Wilson, Archibald, Kovach (key scholars in my understanding of Indigenous Research Methodologies) use first person point of view in their written work to some degree, then I seek to respect them as my academic 'elders' by following their pathway. Using a first-person point of view does not diminish academic rigor. Rather, the academic rigor is demonstrated in the alignment of ontology (what is real?) epistemology (how do I know what is real?), methodology (how do I find out more and explore this reality?), and axiology (what moral beliefs will guide this search for reality?) (Wilson, 2001, 2008). Beyond simply writing in first person, Wilson, in "Research is Ceremony" (2008), shared his knowledge in such a way that allowed me to simmer in them, relate to him and the content, and then gave me the opportunity to strengthen relationships with myself, my spirituality, my research, and Indigenous communities. I desire to write in a similar way and have much to keep learning.

Further, I want to strongly dismiss any notions of being an 'expert' (Kovach, 2009; Wilson, 2008; Fast & Kovach, 2019). Since each of us are accountable to our own set of relations, we emphasize that this paper is my/our understanding of these ideas. In a relational way of knowing, any notion of 'expert' breaks down, because nobody can possibly know all of another's relations (Wilson, 2008). For me, when it comes to Indigenous knowledges and Indigenous research methodologies, I feel like a very young child! Through this process, I have come to believe that I may always feel this way. Despite over the past year greatly strengthening

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my relationship with Indigenous research methodologies, it has only continued to confirm how little I know about the methodology and Indigenous knowledges in general. However, I trust in the process. I am a learner to Indigenous ways of knowing and being. I did not grow up participating in ceremony but rather much of my learning has come from reading and connecting with Indigenous scholars. I have and continue to experience a central notion to Wilson and his co-researchers. They share that "If research doesn't change you as a person, then you haven't done it right" (Wilson, 2008, p. 135). At the start of this research project, I did not realize the change to me and my writing style that would unfold. This paper is both a personal story as well as a collaborative process simultaneously.

3.4. Strand 2: Indigenous Research Methodologies as Conceptual Framework

As Indigenous communities and nations are asserting their sovereignty, there is a growing demand for research by, for, and with the community towards an indigenizing or decolonizing outcome (Kovach, 2009; Smith, 2021; Tuck, 2009; Wilson, 2008; Windchief & Pedro, 2019). This is clear in the literature and fit my personal experiences as well. Linda Tuhiwai Smith (Ngāti Awa, Ngāti Porou) shared in her catalytic book, Decolonizing Methodologies (1999, 2012, 2021) that "it is surely difficult to discuss 'research methodology' and 'Indigenous peoples' together, in the same breath, without have an analysis of imperialism" (Smith, 2021, p. 1). The next strand of this paper will focus on just that, the "Context of Colonialism in Research and Education." However, this paper will first focus on Indigenous Research Methodologies to further emphasize an asset-based approach and to help demonstrate that Indigenous ways of research have been happening on this land for millennia, long before Western Imperialism came here. An Indigenous way of research is circling back to the forefront.

My journey with Indigenous Research Methodologies has been highly shaped by the book "Research is Ceremony: Indigenous Research Methods" by Shawn Wilson (2008). Many Indigenous scholars use the term 'Indigenous Research Methodologies', but Wilson uses the term 'Indigenous Research Paradigm'. I understand them to mean something similar and at times use them interchangeably. Paradigm can be helpful as well since it can help make a clear category for Indigenous Research Methodologies amongst other research paradigms such as positivist, critical/feminist, constructivist, etc. We will share more on that and forms of validity in the Co-Connecting Knowledge strand.

Indigenous research methodologies are as diverse as Western research methodologies. We believe that until we can articulate the vast array of Indigenous methodologies they may be inaccurately viewed as vague or fuzzy. Dr. Hollie Mackey (Northern Cheyenne) taught us this. Further, until Indigenous research methodologies can simply be described as research methodologies (as Western research methodologies are privileged), Indigenous research methodologies will continue to be seen as 'other' (Hollie Mackey, personal communication, February 2021).

Dr. Hollie Mackey and I met at NDSU in her first semester as a professor there in 2018. I often have joked with other people who know Hollie that she is a fount of wisdom and passion as it relates to navigating academia, Indigenous education, and Tribal Nation building. Hollie has continually helped guide me in using Indigenous research methodologies throughout the whole process. Further, she gave me great encouragement to not discount my Indigenous ancestry but take on and learn about my Choctaw ancestors through my dad, grandmother, and aunties.

Our attempt with this strand is to share what we have learned about Indigenous research methodologies in a way that will honor our academic elders (that is, Indigenous scholars and

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community leaders that we have learned from). We hope this will bring further clarity about an Indigenous research paradigm to you as the reader. My greatest fear (that almost brought me to stop this work completely) is misrepresenting and/or disrespecting the Indigenous knowledges and Indigenous Peoples that I am connecting with and learning from.

While reading "Research is Ceremony" (2008) the first time, I wrote down in my notebook "Relationality is the sum of the whole Indigenous research paradigm." Going through the book for a third time months later, the actual quote reads, "Relationality *seems to* sum up the whole Indigenous research paradigm *to me*" (Wilson, 2008, p. 70, emphasis added). This epiphany moment struck my heart and mind. In my first reading, I had removed 'seems to' and 'to me.' I had removed the subjectivity and personal connection, opting for a more definitive way of knowing. It was not until the third reading, and after a discussion with my mentor, Dr. Hollie Mackey, about my absolutist writing style at that time, did the revelation come that my reading and writing patterns were not matching the subjectivity inherent within relationality (H. Mackey, personal communication, September 21, 2020). I was reading the seminal pieces with an eye for the single precise definition for an Indigenous research paradigm so I could extract that out of context into my work (Smith et al., 2018). The single definition for an Indigenous research paradigm is *not* written in any of the seminal works, which fully aligns with the paradigm itself. There is no one way to apply an Indigenous research paradigm! There *cannot* be one way because it is dependent on all relations. This may include spirituality, a specific place, a specific language and culture, and certainly a dependence on the researcher, co-researchers, and participants themselves (Archibald, 2008; Kovach, 2009; Wilson, 2008).

Wilson shares that to him relationality is the idea that everything is in relationship (Wilson, 2008), that everything including knowledge is alive and connected (M. A. Meyer,

2014). Wilson taught me that it goes beyond the idea that I *have* a web of relationships to I *am* a web of relationships. "Rather than viewing ourselves as being *in* relationship with other people or things, we *are* the relationships that we hold and are part of" (Wilson, 2008, p. 80, emphasis in original). This is not for human relationships only. Knowledge as a living entity does not have relationships, but knowledge *is* relationships. Wilson says relationality to him is that "relationships form reality" (Wilson, 2008, p. 137). To help me remember I often think of the word relationality as an informal contraction of the two words relationship and reality. Mathematically, it may be seen as emphasizing the study of the edges instead of the vertices. This reality of nature and knowledge is distinct from constructivism, and other Western research paradigms, that center individual human knowing, and not a web of all relations (Hatch, 2002; Kovach, 2009).

Language has an impact on reality (Smith et al., 2018). Lakota, as well as most Indigenous languages, have more verbs compared to nouns whereas English contains more nouns than verbs. The emphasis on nouns puts objects as the single reality. However, the emphasis on verbs centers dynamic relationships (Wilson, 2008). One example of relational knowledge is found in a short story. An English-only speaker asks a bilingual Cree-English speaker "How do you say grandma in Cree?" The Cree speaker responds, "You can't." Noticing a head tilt and perplexed facial expression, the Cree speaker continues. "You cannot be a grandmother without being attached to someone. You can either be 'my grandmother' or 'your grandmother'" (Wilson, 2008). Language influences how we understand reality. This short story demonstrates the inherent bias of using English to learn about Indigenous knowledges.

This assumption about the nature of reality, that is ontology, impacts not only research but perspectives about science and math as living entities themselves (Kimmerer, 2013). Greg

Cajete (Santa Clara Pueblo), a well-known Native scientist, is quoted by Manulani Aluli Meyer ('Ōiwi Hawai'i) by saying "The perspective of Native science goes beyond objective measurement honoring the primacy of direct experience, interconnectedness, relationship, holism, quality and values, and they are specific to tribe, context, and cultural tradition" (M. A. Meyer, 2014, p. 98). Thus, both the views of science/math and how research is done is specific to place, nation, and local tradition.

Wilson (2008) brought me to tears as he shared a metaphor describing relationality applied to knowledge, that knowledge has a time and space to be shared as well as not to be shared depending on one's relationships. His analogy leads directly into the responsibility and relational accountability with knowledge that we all have as we learn and grow.

> So the way I see it, gaining knowledge is more like being married to someone – you don't own your spouse or children but you do share a special relationship. It is a relationship that you are accountable to. And therefore it becomes cultural appropriation when someone comes and uses that knowledge out of its context, out of the special relationships that went into forming it... You know that sexual exploitation and total denigration of our humanity was a big part of colonialism. Now that is taking place with our ideas and knowledge. Our knowledge is being stripped of its relationships and being used without accountability. (Wilson, 2008, p. 114)

Through this metaphor I can feel the weight of knowledge and perhaps you may too. The metaphor not only helped me crystallize knowledge as relational (and therefore personal, subjective, experiential, and holistic) but also demonstrated the obligation of responsibility and accountability we have towards the Indigenous Knowledges and Indigenous Peoples we learn from. Through Circulating Conversations Methodology, we as co-authors have built and

strengthened relationships that we are now accountable to. Further, as I read the Indigenous Research Methodologies literature, now I am accountable and responsible to the Indigenous scholars who I learned from. Figure 4 shows the pathway that led towards applying an Indigenous Research Methodology into education research. I am following this path to apply an Indigenous Research Methodology into undergraduate math education research.

Figure 12

Paper 1 Figure 4: Indigenous Research Methodologies Literature Pathway

"Decolonizing Methodologies: Research and Indigenous Peoples" (1999, 2012, 2021) by Linda Tuhiwai Smith became a catalyst book for many Indigenous scholars (2021). Smith not only challenges the status quo of dehumanizing research by identifying research as a significant site of struggle between Western and Indigenous interests, but she also illuminates 25 current research projects as a vision for the future of research with Indigenous Peoples across the globe.

In 2004 and 2005, a book and an article came out respectively that also had a large impact on the development of Indigenous research methodologies through decolonizing efforts. "Red Pedagogy: Native American Social and Political Thought" (2015) by Sandy Grande (Quechua) and "Towards a Tribal Critical Race Theory in Education" (2005) by Bryan Brayboy (Lumbee) both emphasized decolonization through connecting with Western research frameworks. Red Pedagogy brilliantly intersects dominant modes of critical theory and feminist theory with decolonizing thought and gives a vision towards political, land, intellectual, and spiritual sovereignty (Grande, 2015). Tribal Critical Race Theory, as the name suggests, intersects the well-known Critical Race Theory with Native identity and beliefs (Brayboy, 2005).

Then in 2008 and 2009, three books came out with no reference to or connection amongst one another but all describing their understanding of Indigenous Research Methodologies (Archibald, 2008; Kovach, 2009; Wilson, 2008). This three-some of books seems to crystalize Indigenous Research Methodologies. Each share their own perspective, a place and relation specific understanding of Indigenous Research Methodologies. "Research is Ceremony" has had an immeasurable impact on this research. His stories drew us in. His humility drew us in. His strength to say that our Indigenous approach to research does not need to be compared to Western approaches changed me. He shared gently and firmly with laughter throughout. An Indigenous research paradigm based in relationality can stand on its own. It needs no outside validation from Western research or researchers (Wilson, 2008). I am forever grateful for what Wilson allowed me to learn from him.

"Indigenous Methodologies: Characteristics, Conversations, and Contexts" (2009) by Margaret Kovach highly influenced this research project as well. Kovach emphasizes that Indigenous research methodologies flow from tribal-specific knowledge, language, cultures, and

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communities. She helped me learn that not all research in Indigenous contexts requires an Indigenous methodology. The methodology is dependent on the context, researcher, and the research questions and therefore a Western research paradigm may be the best fit for a particular situation. To remind myself of the core of Indigenous research methodologies and what it can be, I often go back to Kovach's work. She shares that "the sacredness of Indigenous research is bound in ceremony, spirit, land, place, nature, relationships, language, dreams, humor, purpose, and stories in an inexplicable, holistic, non-fragmented way, and it is this sacredness that defies the conventional" (Kovach, 2009, p140).

"Indigenous Storywork: Educating the Heart, Mind, Body, and Spirit" (2008) by Jo-ann Archibald Q'um Q'um Xiiem rounds out this powerful three-some on Indigenous Research Methodologies. Archibald shares a story, that we won't repeat here, that spiritually and intellectually confirmed the use of an Indigenous research paradigm over a Western research paradigm for this project. The Elders taught Archibald about seven principles which she termed storywork. They are respect, responsibility, reciprocity, reverence, holism, interrelatedness, synergy. Writing this paper and looking back at all my conversation notes reminds me once again that respect is the foundation for all relationships (Archibald, 2008). I pray that my writing of this story and your reading may lead us towards growing respect for one another, Indigenous Knowledges, Indigenous Peoples, and Land.

Each of books in this three-some share their story of an Indigenous Research Methodology. Then in 2018 and 2019, three more books come out articulating how they applied an Indigenous research methodology into their unique context and set of relations. "Indigenous and Decolonizing Studies in Education: Mapping the Long View" (Smith et al., 2018), Applying Indigenous Research Methods: Storying with Peoples and Communities" (Windchief & Pedro,

2019), and "Reclaiming Indigenous Research in Higher Education" (Minthorn & Shotton, 2018) all emphasized their context of education. Before we share our story of applying an Indigenous Research Methodology in the context of undergraduate math education in Strand 4 and 5, we will further set the context of colonialism in research and education.

3.5. Strand 3: Context of Colonialism in Research and Education

This section begins by expanding on the most quoted line in "Decolonizing Methodologies" (1999, 2012, 2021). Linda Tuhiwai Smith shares about the dirtiness of research to Indigenous Peoples. The following is the first words of her book:

> From the vantage point of the colonized, a position which I write, and choose to privilege, the term 'research' is inextricably linked to European imperialism and colonialism. The word itself, 'research', is probably one of the dirtiest words in the Indigenous world's vocabulary. When mentioned in many Indigenous contexts, it stirs up silence, it conjures up bad memories, it raises a smile that is knowing and distrustful… At a commonsense level research was talked about both in terms of its absolute worthlessness to us, the indigenous world, and its absolute usefulness to those who wielded it as an instrument. It told us things already known, suggested things that would not work, and made careers for people who already had jobs. (Smith, 2021, p.1-2)

When I first read the quote above, it brought an experience I had a couple months before reading back to the forefront. I was visiting a tribal college in North Dakota and a tribal college administrator strongly warned me of parasite research. With an adamant tone, the administrator declared 'We are stopping it here!' Not fully understanding what was meant by the declaration I sheepishly asked what was meant by parasite research. The administrator continued that parasite research and researchers take, take, take, and give nothing back. They show up for a short period

of time to extract data solely for their own benefit and then disappear, giving nothing back to us or the community.

This conversation with a tribal college administrator pushed me again toward the piercing reflection questions shared by Archibald (2008). I share the questions again to fit the many times I have gone back to them myself. "Was I doing anything different from earlier 'outsider' academics who created a legacy of mistrust among First Nations concerning academic research? How was my research going to benefit the education and wellbeing of Indigenous peoples and their communities? How would I address ethical issues related to respect and ownership of Indigenous intellectual property?" (Archibald, 2008, p. 36). Reflecting on these questions alongside past and present colonialism within research and education nearly stopped me altogether. I see myself succumbing to valuing intent over impact. I see my personally biases inevitably having an impact on our collective work (Kovach, 2009; Wilson, 2008).

Particularly, my personal biases show up in one of the definitions for colonialism that brought me to even further prayer and self-reflection. Grande in "Red Pedagogy" describes colonialism as "a multidimensional force underwritten by Christianity, defined by racism, and fueled by global capitalism" (Grande, 2015, p. 8, 124). Personally, as a follower of Jesus, I was struck by the direct implication of Christianity. However, time after time I continue to learn more about how the Doctrine of Discovery, Manifest Destiny, and the whitewashing of Jesus undergirds colonialism. I lament and repent with and for my spiritual ancestors and current brothers and sisters in faith. Amy Parent (Nisga'a) gave my heart words when she said "I did not work with Jo-ann's principle of reverence [in Indigenous Storywork] for my master's or doctoral studies because I was uncomfortable writing about it due to the effects of Christianity, colonialism, and my exposure to a dominant modernist worldview (that values secularism,

segmentation, polarization, fragmentation, and abstraction) … I can see now the contradictory ways that I was engaging Indigenous knowledge through my engagement with Indigenous storywork. At the time, I was in my infancy of understanding Indigenous knowledge" (Archibald & Parent, 2019, p. 11).

This is exactly how I often feel. I am genuinely concerned that my Western training, spiritual subjectivity of faith in Jesus Christ, and infancy to Indigenous knowledges will continually lead me into contradictory places that put Indigenous knowledges in danger of appropriation. It has slowed me down and led me to think about the possibility of stopping multiple times. Yet, through the mentorship of Dr. Hollie Mackey and the encouragement of community members and friends I am gaining confidence in Creator leading me to this work, in my own Choctaw identity, and in storying with Indigenous Research Methodologies. For you, how does the connecting of Christianity, racism, and capitalism with colonialism impact your heart, mind, body, and spirit?

Brayboy in Tribal Critical Race Theory has a complimentary view of colonialism and emphasizes its current impact. "By colonization, I mean that European American thought, knowledge, and power structures dominate present-day society in the United States" (Brayboy, 2005, p. 430). Grande agrees and elaborates on how past efforts to civilize and Christianize the Indians easily seen in the boarding school era are now replaced with efforts to 'make equal' seen through deficit approaches to research and education and the achievement gap dialogue. She states that Indian Education in the U.S. sets out to continually "reinvent Native American people in the likeness of white people" (Grande, 2015, p. vii). Deloria and Wildcat (2001) agree and share that "the thing that has always been missing from Indian education, and is still missing today, is Indians" (p. 152). In response, Indigenous researchers and educators have recently

begun using the term "Indigenous Education" which centers Indigenous Peoples, Land, and Indigenous visions for the future (Mackey, 2020).

Colonialism sets the context for all research and education with Indigenous Peoples (Archibald, 2008; Brayboy, 2005; Grande, 2015; Kovach, 2009; Minthorn & Shotton, 2018; Smith, 2021; Smith et al., 2018; Tuck, 2009; Wilson, 2008; Windchief & Pedro, 2019). Famous activist and scholar, Vine Deloria Jr. (Lakota) wrote the seminal piece responding to colonialism in the United States of America long before the term Indigenous Research Methodologies was seen in the literature. His provocative book title is "Custer Died For Your Sins: An Indian Manifesto" (Deloria, 1988).

Then and now, each educator and researcher enter their work with their own assumptions, biases, and beliefs (Archibald, 2008; Brayboy, 2005; Grande, 2015; Kovach, 2009; Minthorn & Shotton, 2018; Smith, 2021; Smith et al., 2018; Tuck, 2009; Wilson, 2008; Windchief & Pedro, 2019). Wilson shares one quote two times from Eber Hampton (Chickasaw) emphasizing the individual's influence on research. We believe it can be extended to education as well. "We do what we do for reasons, emotional reasons… Feeling is connected to our intellect and we ignore, hide from, disguise, and suppress that feeling at our peril and at the peril of those around us. Emotionless, passionless, abstract, intellectual research is a goddam lie, it does not exist. It is a lie to ourselves and a lie to other people. Humans – feeling, living, breathing, thinking humans – do research" (Hampton, 1995, p. 52 found twice in Wilson, 2008).

In all this, we hope we have set the context well for the story of Circulating Conversations Methodology that we used for this research project. The context of colonialism in research and education, the literature on Indigenous Research Methodologies, the writing style

and structure, and our personal positionalities are all intertwined with each decision, conversation, and revelation within the Circulating Conversations Methodology.

3.6. Strand 4: The Story of Circulating Conversations Methodology

I began the research for my PhD with Sitting Bull College (SBC) with an understanding about the historical context of disrespectful research with Indigenous Peoples and the goal of advancing the core of an Indigenous research paradigm centered around relationality, respect, and accountability. Before the research began, I had a couple friendships with people from Standing Rock and a few strong professional connections through a pre-engineering educational collaborative that connected multiple tribal colleges in North Dakota together. I was confident that I could not come in with my research questions, framework, or agenda. I was confident that I wanted to do research that was beneficial and actionable for the SBC math instructors and that outside of directly talking with them I had no aspiration of thinking I could determine that on my own.

Dr. Joshua Mattes is the SBC faculty part of the pre-engineering educational collaborative in North Dakota. I got involved at NDSU and met Josh through this collaboration. Josh has been at SBC for almost a decade and is passionate for authenticity and will do whatever it takes to give the students he works with the absolute best learning opportunities. In our discussions, Josh shared both the desire to have authentic cultural connections within the math and engineering courses he taught at SBC and the scarcity of respectful, non-stereotyping resources available to him. Josh is someone I look up to as a self-reflective non-Native STEM faculty at a tribal college. He demonstrates the practice of "interrogating Western entitlement to knowledge" and trusted me to do similar in our work together (J. Mattes, co-authors meeting, October 20, 2021).

Within my literature review, I found precisely one article about collegiate math and Indigenous culture/languages. It was exciting to me showing a potential path forward but also warned of difficulties within the delicate relationship between math education research and fluent elders (Ruef et al., 2020). Due to the implications of the COVID-19 pandemic, my norm became a time of waiting, struggle, research roadblocks, prayer, and strengthening my Choctaw identity. I saw no clear path forward. Then in late January 2021, a spiritual moment of connection brought Sunshine and I together for our first meeting.

My name is Sunshine Woman Archambault Carlow. I am a Hunkpapa and Oglala Lakota and Northern Cheyenne woman. I first encountered Danny Luecke via an email introduction from a colleague, former teacher, friend, and mentor, Dr. Kathy Froelich (whose son I also went to elementary and high school with). Danny was a mathematician looking to do Math research with an Indigenous focus. Maybe a Lakota focus. Lakota Math. Math in Lakota. Lakota in Math. I admit, it keeps me up at night. I am a Lakota Immersion school teacher at "The Nest" – the Lakholiyapi Wahohpi and Wichakini Owayawa Lakota Immersion School at SBC. I am trained as an AMI Primary Montessori guide as well as in Project Based Learnings and prior to my time at the nest developed adult Lakota language curriculum for my tribe. I work with elders, Lakota Language 2nd Language Learners and am creating an education space that is healing and learning and reviving our Lakota language, history, and culture. Together we work to create a space that pilots a relevant education for all Lakota people, Indigenous people. And in creating that relevant space we have to constantly combat and push back on the imbalance colonization has created in overvaluing Western Math and devaluing Lakota Math.

Before going into the Circulating Conversations Methodology that we as the co-authors enacted together, let me (Danny) finish the introductions. Warren Christensen is currently a

physics faculty at NDSU with dual appointment to the STEM Education PhD program. Warren and I first met when my freshman year taking his calculus-based physics course over a decade ago. His course prompted me towards a physics and physics education minor. Now Warren is my co-advisor in the STEM Education PhD program, and I am so thankful for his guidance in the PhD process. He has supported me in applying an Indigenous research paradigm in undergraduate math education from the start. He has continually used his privileges to fight for this inclusion and I am thankful to him for that.

Hollie, Sunshine, Josh, and Warren all agreed to be involved in my PhD process in varying ways. Relationships that begin with appropriate professional formality became more informal and friendly as trust grew through each conversation and interaction together. Most recently they each have agreed to be a co-author and editor for this paper. The trust that we have built amongst ourselves is paramount and I have sought to keep that trust through self-reflecting often on my experiences, dispositions, and attitudes using a reflective journal. Since this work is for my PhD, I have been the main author for this paper. However, the ideas, connections, and entire process of Circulating Conversations Methodology was experienced altogether.

After initial introductions and first interviews with Hollie, Sunshine, Josh, and Warren, more focused conversations happened within the next week and a half about potential research directions at the intersection of undergraduate math and Dakota/Lakota language and culture. I took notes and recorded each conversation. With the notes from all four conversations in front of me and drawing upon what I remembered hearing, I sought to holistically (heart, mind, body, spirit) connect all the ideas together. This time of synthesis formed an initial one-pager with four first draft research topics including cultural math content, methodology of math education research at a tribal college, the affective domain for student learning in math, and faculty

experiences. I circulated amongst Hollie, Sunshine, Josh, and Warren again to connect with each of them and listen to their feedback on the initial four topics. Through these four conversations and the time of synthesis after the four conversations, two topics revealed themselves as the place of connection amongst us all, that is cultural math content and the methodological approach we were using. I circulated again amongst Hollie, Sunshine, Josh, and Warren again to connect with each of them, listening to their feedback on the two topics. Those conversations and time of synthesis afterwards led to the initial four research questions with accompanying diagram. In this case, all these conversations happened through Zoom because of the COVID-19 pandemic.

In a spiritual moment of epiphany as we were finalizing the research questions, I came to realize the pattern of relationships we were enacting was a web. My experiential journey of conversations with each key person was my theoretical framework! I named it Circulating Conversations Methodology (CCM). Another round of circulating conversations took place to discuss the CCM web and prepare to write this methodological paper. Although time moved forward as CCM happened, the connecting of themes and ideas was anything but linear as shown in Figure 5. Each circle represents a stage in the process and each line represents a key person I connected with. Each intersection point on the web is a particular conversation. Upon reflection afterwards, each conversation followed Margaret Kovach's conversational interview protocol, where sharing through both giving and receiving are essential to the conversation (Kovach, 2010). The research questions are the central component and end goal of this CCM that brought together multiple people, ideas, value systems, and institutions.

Figure 13

Paper 1 Figure 5: A Diagram Showing Circulating Conversations Methodology as a Web
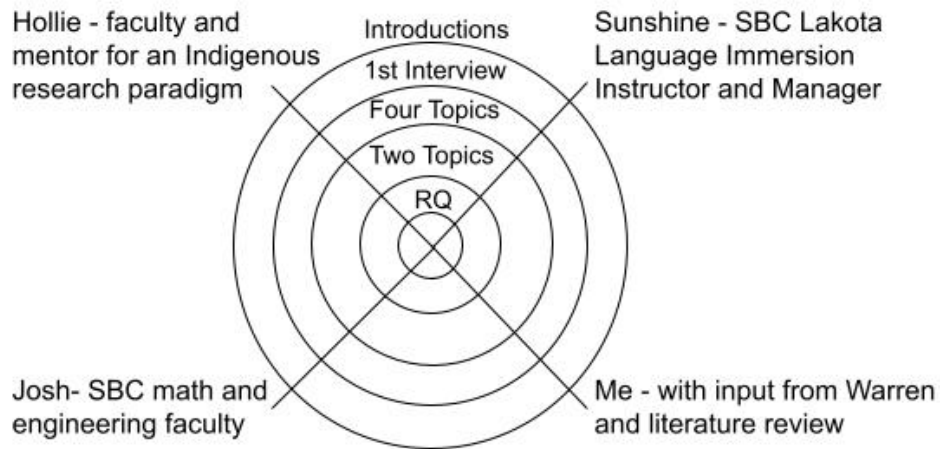
Like a spider web that waves with the wind, the circulating conversations web is non-static. Each conversation connects to another in a unique way. Like a spider web that glistens as the sun hits it, each intersection point between circles and strands is unique, that is each conversation is unique. The following Research Questions (RQ) strand will share the research questions and specific conversations that brought about specific wording and emphasis of each research question. Each person brings in an essential component to the CCM web. Hollie, Warren, and I represent the North Dakota State University line, where I am earning my PhD. Sunshine and Josh represent the Sitting Bull College line. Hollie connected her knowledge of an Indigenous research paradigm and Indigenous Knowledges. Sunshine connected her knowledge of Dakota/Lakota language and culture. Josh connected his knowledge of teaching math and pre-engineering courses at Sitting Bull College (SBC). Warren and I connected with an impetus for my PhD research in STEM education and my PhD level understanding of mathematics. Through CCM, the research questions developed through an iterative, circular, and collaborative process.

3.7. Strand 4: The Research Questions

I did not come up with these research questions myself. I did not choose a topic or gap in the literature. Rather I chose a set of values and a process, that is an Indigenous research paradigm, and it guided me throughout. Through conversation, connections, and strengthening relationships, the questions iteratively became known to us. I did not come into Sitting Bull College with my agenda for research to be done on an Indigenous community. Instead, every word of the research questions has a specific moment of co-connecting knowledge through Circulating Conversations Methodology that brought that idea and specific wording to bear.

The research questions developed through Circulating Conversations Methodology (CCM) are:

A: In what ways can Western higher order math concepts be identified within Dakota/Lakota space, place, and language, to inform possible Sitting Bull College math curricular/pedagogical adjustments [for Josh]?

B: In what ways can Dakota/Lakota culture and language be identified within Western higher order math concepts, to inform possible Lakota Language Immersion Nest curricular adjustments [for Sunshine]?

C: In what ways can Dakota/Lakota space, place, and language represent non-Western higher order math concepts?

D: In what ways can Indigenous Research Methodologies lead an individual researcher towards more ethical and impactful (beneficial and actionable) research in undergraduate math education at tribal colleges and universities?

The following definitions and stories share only part of what we experienced together. These examples illustrate the iterative process of development through relationships. First,

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'higher order math concepts' as a term has a multi-faceted definition. Through the circulating conversations I noticed that multiple people were using the term differently. One of my co-advisors, Dr. Bill Martin, saw it as specifically relating to higher order thinking as previously written about in undergraduate math education research literature. Sunshine, who teaches pre-kindergarten students viewed higher order math concepts to mean simply not elementary math, but math that was at the collegiate level. The wording originally came from the desire to build from David W. Sanders' dissertation titled "Mathematical Views within a Lakota Community: Towards a Mathematics for Tribal Self-Determination" (Sanders, 2011). Sanders looks at Bishop's framework of six universal mathematical activities, counting, measuring, locating, designing, playing, and explaining, in the Oglala Lakota context (Bishop, 2012). My desire to build on Sanders' work, to go beyond vocab lists and direct translation of math concepts, and to do research in math education at the tribal college were combined to form the initial phrasing 'higher order math concepts'.

None of these views on higher order math concepts are wrong. At this stage in the research, to be accountable to all my relations, we are not ready to claim or declare a single definition. Further, we are not convinced the term needs a single, precise definition within an Indigenous research methodology. In one conversation, technically outside of the Circulating Conversations Methodology formally but not in spirit, Dr. Hollie Mackey and my PhD committee were discussing the definition for higher order math concepts. She shared that it could be possible to not define the term at this point, or at least not have it defined by outside literature to the Standing Rock Nation and Sitting Bull College community. She offered the possibility of waiting to see how the community may come to understand the term 'higher order math concept'

through the process of answering the research questions, and that is what we decided upon (Mackey, PhD Committee Meeting, March 2021).

The term 'space and place' in the research questions has a story that begin with Sunshine and again finished with Hollie. In my first and second conversations with Sunshine, she shared her interest in specifically articulating the mathematical connections to Lakota star knowledge and its mirrored patterns in the Land. Sunshine had often heard people in her community say "there's math in that, math is connected to everything" but then when probed for any specifics only a dumbfounded look is given in return. So, within the initial four research questions it seemed fully fitting to ask about mathematical connections to 'culture, land, and language' through question A and B. However, discussing the 'culture, land, and language' phrasing with Hollie, it came up that within academia using the terminology 'space and place' has more specific clarity and might be better understood within Academe while using the terms culture, land, and language might be more appropriate when communicating outside an academic audience. This story is an example of how multiple conversations in the Circulating Conversation Methodology web went into forming the specific ideas and phrasing found within each research question.

We are choosing not to share every story about every word in the research questions in hopes to not lose your attention if we haven't already. However, we will share about non-Western higher order math concepts. Non-Western math concepts are something I certainly would have missed on my own, that is apart from engaging in Circulating Conversations Methodology (CCM). As the focus of four topics was set on cultural math content and the connections between collegiate level mathematics and Dakota/Lakota language and culture, both Josh and Sunshine brought up the same idea in separate conversations. Both Josh and Sunshine

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exclaimed that there is more than Western (universal) math, or at least we must not assume that Western math already covers all higher order math concepts that could be embedded within Lakota language and culture. An existence proof for a non-Western higher order math concept was discussed with Sunshine. In Lakota language and thought, numbers can be considered as verbs, depending on context. That is numbers are not objects or abstract quantities but rather can be seen as the action of being three for example. I have been pondering the implications of this view of numbers since I learned it myself. Still today I am not sure what implications this may have in the field of math and/or the teaching mathematics but it certainly is an example of a non-Western higher order math concept that became known to us all through Sunshine as part of CCM.

The following diagram (see Figure 6) was used in the final phases of CCM as we moved from two research topics to four research questions. I called it the Higher Order Math Concepts Authentic Cultural Connections Model Version One. But since everyone kind of laughed at me and my long title during CCM, now we call it the "Research Questions Diagram". Note research questions A, B, C rotate around three ideas to inform Sitting Bull College math curriculum and Immersion Nest math curriculum. Those three ideas are Western Higher Order Math Concepts, Lakota Language and Culture, and Non- Western Higher Order Math Concepts. Notice research question A and B are paired together on the bi-directional arrow on the left side of the diagram. This was intentional to keep balance and maintain relational accountability with both Josh and Sunshine. As Sunshine shared her knowledge and relational connections with us about Lakota language and culture to teach Western higher order math concepts, to stay clear from parasite research, a balance of reciprocal giving needed to be kept. To maintain balance the giving and receiving had to go both ways, that is, be reciprocal. Reciprocity is one of Archibald's seven

principles for Indigenous Storywork. Thus, research question A and B are partners, balancing

one another, and going both directions between Western higher order math concepts and Lakota

language and culture.

Figure 14

Paper 1 Figure 6: Research Questions Diagram
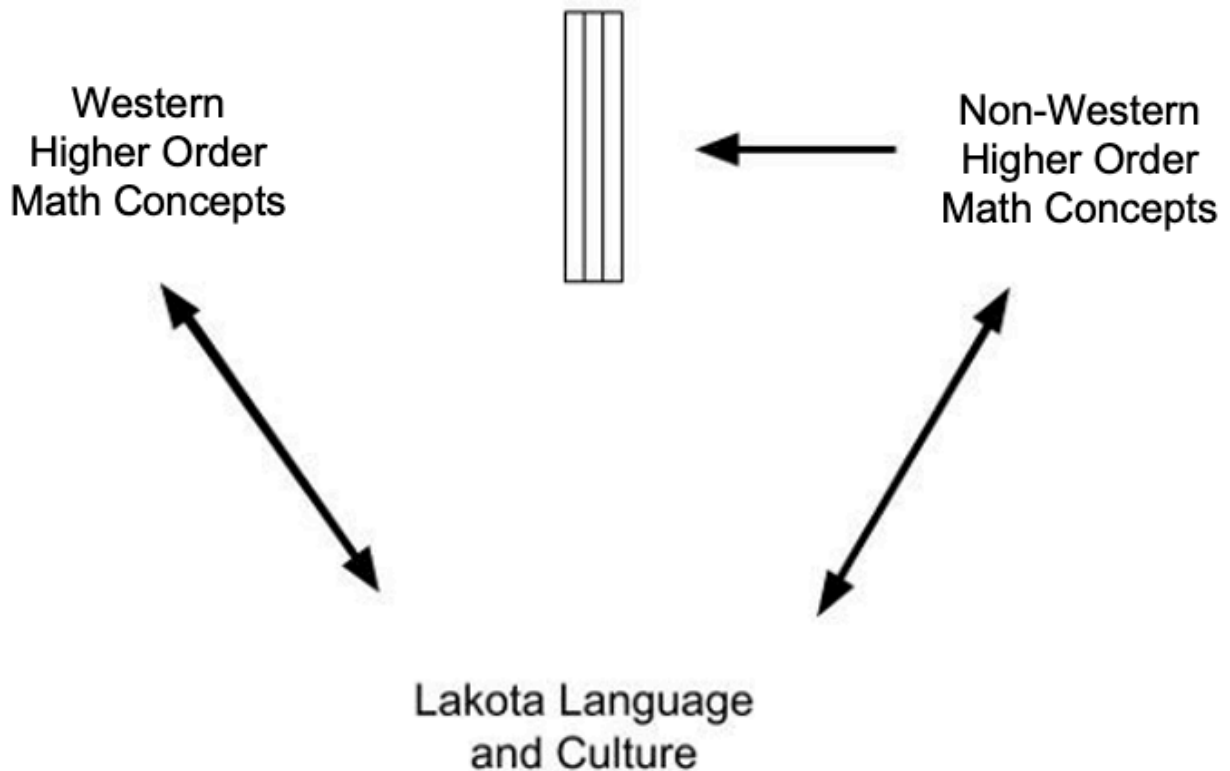
Research question C specifically relates to the bi-directional arrow on the right. This

arrow and research question attempts a balance with Western higher order math concepts on the

left. However, the three vertical lines and stunted arrow on the top of the diagram represent a

wall between Western and Non-Western higher order math concepts. In final conversations

about the research questions and this diagram, we laughed at the many analogies we came up

with to break down, go around, go through, or go over this wall. The wall represents two

different ideas. First, we had a consensus that we were not sure if Non-Western higher order

math concepts would be allowed 'into' Western math. We suspected that Western math might put up a wall to keep anything that does not abide by its Western beliefs out. Secondly, in the example of numbers as verbs as an existence proof for Non-Western higher order math concepts, we were unsure what implications would entail when translated into Western math.

Lastly, research question D looks at the intersection of Indigenous Research Methodologies, research in undergraduate math education, and tribal colleges and universities. In part it stems from Wilson's powerful phrase "the process is the product." The question includes the words 'beneficial and actionable' because these were the two words that I began this journey with when asking the engineering instructors part of the tribal college pre-engineering educational collaborative about potential research directions to go. This paper and the next paper on data collection and data synthesis are the answer to research question D.

In closing, we explicitly share that these four research questions are inseparable from our enactment of Circulating Conversations Methodology (CCM). The process of developing the research questions and the connections formed in the process are just as significant as the questions (and answers) themselves. The process is the product. This contrasts with me searching the literature for a gap in undergraduate math education research and individually developing research questions from the literature. CCM is a web of relationships and seeks to be accountable to all of them all the time. The research questions as the product of CCM are inter-connected to the process and cannot be taken out of context from the specific place, people, and Nation that co- developed them. As an outsider academic researcher, I am reminded that I now have ethical, moral, spiritual, and legal responsibilities to the Sitting Bull College (SBC) and Standing Rock community because of the relationships built through this process.

3.8. Strand 6: Co-Connecting Knowledge

One key aspect of Circulating Conversations Methodology is the use of co-connecting knowledge. Co-connecting knowledge was certainly not the term we used at the start of the process. This term, along with the term Circulating Conversations Methodology and higher order math concepts, came about *through* the process. The terminology 'co- connecting knowledge' began in conversation with Hollie about the four research topics. Within our conversation, Hollie recognized that our word choice of 'co-constructing knowledge' was a Western term that was distinct from the activity we were doing. We found ourselves stuck in Western terminology "to describe something that's far more nuanced" and desired to "come up with something that actually catches what it is" (H. Mackey, personal communication, February 19, 2021). Later that week, in a time of prayer, the revelation was given to me to name it 'co-connecting knowledge'. Please note that my role is only writing/sharing the terminology given to me. The experiential practice of knowledge making itself known through collaborative connecting and strengthening relationships has been happening within Indigenous ceremony, lifeways, and research methodologies for millennia.

During the conversation with Hollie and in multiple other conversations, both Hollie and I have referenced, learned from, and connected with Manulani Aluli Meyer. Her work titled "Holographic Epistemology: Native Common Sense" (2014) shares her understanding of an Indigenous worldview from Elder Willis Harman that "everything in the universe is alive... [and] we are relatives" (M. A. Meyer, 2014, p. 99). This includes knowledge. Knowledge is alive and is our relative, just like Wilson's metaphor of knowledge as a marriage. Thus, as Hollie easily noted, knowledge is not something we construct. None of the conversations within Circulating Conversations Methodology constructed, created, found, or discovered new knowledge. Rather it

was the collaborative connecting via conversation and story that new relationships were formed and knowledge became known to us. Wilson said, "knowledge is shared with all creation... [and] the idea belongs to the cosmos, to all of the relations that it has formed, not to the individual who happens to be the first to write about it." (Wilson, 2008, p. 56, 113-114).

Circulating Conversations Methodology is not haphazardly talking to a few different people. It is specifically based in the ontology (nature of reality) and epistemology (nature of thinking and knowing) of relationality. Similarly, co-connecting knowledge is specifically based in relationality. It cannot be separated from the belief that knowledge is alive and reveals itself to us in emotional, spiritual, physical, and intellectual ways. An Indigenous research methodology is distinct from Western methodologies in its decolonizing aim, tribal-specific knowledges, and knowledge being bound to place through ancestors, language, and land (Grande, 2015; Kovach, 2009; Windchief & Pedro, 2019). Similarly, co-connecting knowledge is not constructing meaning with other humans but is based in the core beliefs of an Indigenous research methodology that everything is alive and we are all related.

Additionally, we understand co-connecting knowledge to describe the space where theory from the literature connects with personal experiential knowledge in practice. It describes the space where intellectual knowledge connects with spiritual knowledge (M. A. Meyer, 2014). Before my work with Indigenous research methodologies, a spiritual mentor of mine told me that "life on earth following Jesus is all about relationship, relationship, relationship" (personal communication, Pastor James Brooks, June 2017). This is my spirituality, and it certainly influences my understanding of co-connecting knowledge and Indigenous research methodologies in general. My spirituality influences how I experience Indigenous scholars describing a relational, spiritual, and verb/movement-oriented worldview. My spirituality is part

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of how I experience and enact co-connecting knowledge in every conversation, prayer, and epiphany moment. Each person's spirituality will influence their work, their relationships, and who they are. It is part of co-connecting knowledge.

Further, we see co-connecting knowledge as a clear link to neuroscience that claims "Instead [of making new brain cells], learning appears to occur primarily because of changes in the strength and number of connections between existing neurons" (Owens & Tanner, 2017, p. 16). Although neuroscience is at the microscopic level, it mirrors an Indigenous research paradigm, that instead of new knowledge coming from research, knowledge becomes known to us through making connections and strengthening existing relationships.

Co-connecting knowledge also connects with Meyer's description about an Indigenous worldview. Meyer's shares that "An Indigenous worldview thus begins with the idea that relationships are not nouns, *they are verbs*" (M. A. Meyer, 2014, p. 98, emphasis in original). Knowledge is not a static object but made up of fluid relationships. Relationships are dynamic and a lived experience, not an intellectual idea. Cora Weber-Pillwax (Cree) warns of intellectualizing Indigenous research methodologies and shares that "until we live them [Indigenous knowledges]... it's like writing 'bread' on a piece of paper and eating the paper instead of having the bread" (Wilson, 2008, p. 103). Co-connecting knowledge gives the space for holistically connecting neuroscience, spirituality, lived experiences, and an Indigenous worldview that everything is alive and related altogether.

Co-connecting knowledge instead of co-constructing knowledge is one example of how an ontology (nature of reality) and epistemology (nature of thinking and knowing) based in relationality is distinct from Western research paradigms (Grande, 2015; Kovach, 2009; Wilson, 2008; Windchief & Pedro, 2019). Some Western frameworks/methods are popular in Indigenous

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communities such as participatory action research, critical/feminist paradigms, and a constructivist paradigm because the expansive intersection in seeing knowledge as personal, subjective, and political (Grande, 2015; Gutiérrez, 2012; Kovach, 2009; Sfard, 1998). By no means does research with Indigenous Peoples require an Indigenous research methodology. Each community and research should make their own decision based on their relationships. Co-constructing meaning within a research framework can be the right fit for a particular place and context. However, these Western frameworks are distinct from an Indigenous research methodology since they are still based in Western constructs such as human-centrism and progressivism (Grande, 2015; Kovach, 2009). For example, Gutiérrez's work (2012) in equity recognizes math education as going well beyond individual intellectual capacity to include the critical dimensions of student identity and power dynamics at multiple levels. However, math is still viewed through a human-centric lens. Similar can be said for Sfard's work on using an acquisition metaphor or participation metaphor for learning (1998), that learning and knowledge are still human-centric. The ontology and epistemology of these frameworks are not based in relationality and Indigenous knowledges. They can work well in many Indigenous contexts but are not specifically based in Indigenous knowledges. Co-connecting knowledge is in no way an improvement to the term co-constructing knowledge. It is simply based in a different view of reality, a different set of relationships. Co-connecting knowledge describes how the cosmos reveals itself through strengthening relationships.

Co-connecting knowledge is about strengthening relationships between people, land, knowledge, and the cosmos. Some of Wilson's final words in "Research Is Ceremony" will close the Co-Connecting Knowledge strand.

Many things in our modern world try to force us to be separated, isolated individuals. We separate the secular from the spiritual, research and academia from everyday life. It is my dream that we may turn away from this isolation to rebuild the connections and relationships that are us, our world, our existence. We need to recognize the inherent spirituality, as well as the everyday applicability, in our research. Indigenous research needs to reconnect these relationships.

Research is ceremony. It bears repeating, as I think this statement ties up and holds together all of the relationships that have gone into the formation of this book. The purpose of any ceremony is to build stronger relationships or bridge the distance between our cosmos and us. The research that we do as Indigenous people is a ceremony that allows us a raised level of consciousness and insight into our world. Through going forward together with open minds and good hearts we have uncovered the nature of this ceremony (Wilson, 2008, p. 137).

3.9. Strand 7: Reflections on Circulating Conversations Methodology

During the writing phase, we had much time to reflect on the process of enacting Circulating Conversations Methodology before the term existed, on the spiritual moment of epiphany that revealed the web and the name, and on the process of sharing the term and experience with others. A handful of additional connections have emerged in this time of reflection and writing. They are shared in no particular order.

Knowledge is power. We believe this adage and see its impact in many ways. Graduating from high school or college gives students greater opportunities in our current society. Further, we believe Indigenous Peoples have been educating the next generation for millennia without accepting the Western beliefs and implications for schooling that Grande articulated (Grande,

2015, p. 69-71). This gives us even greater power to fight back against colonialism. Knowing the strategies and impacts of colonization gives us greater power to resist. If knowledge is power, then we also believe that the process of gaining knowledge (research methodologies) is powerful also. Our experience in applying Indigenous Research Methodologies has taught us that how we go about gaining knowledge, what questions are asked, how those questions are determined are all related to power, and therefore political. Who has the authority to determine what is an appropriate methodology for a particular context? Who has the authority to determine which questions get asked? Who has the authority to determine if the work is done well?

There are many socio-political answers to these questions. Wilson emphasizes axiology in "Research is Ceremony" and his previous journal article in 2001. Axiology is about the worth of knowledge, what types of knowledge and products will be privileged, and what moral beliefs will guide the research (Wilson 2001, 2008). From his perspective, the core Indigenous research paradigm and its axiology is relationality and relational accountability, respectively. Wilson further explains his stance of relational accountability through the lens of research validity.

> So even though we don't need externally imposed measures or tests of whether or not something is 'true,' we have our own ways of ensuring this. We have our own ways or questions to ask, so that we know that what we are saying is strong enough to say, 'Yes, we can go ahead and design a program for our children, or our community, based on what we have learned from this research." And we have trust or faith enough so that we are willing to use this in our communities, for our own people. (p. 102)

If Sunshine Carlow, financial manager and instructor at the Lakota Language Immersion Nest, uses the results of this research, that is our strongest validation. If Josh Mattes, Sitting Bull

College math instructor, and other tribal college math instructors, use the results of this research in their undergraduate math courses, that is our strongest validation.

Further, through Circulating Conversations Methodology, we came to see research validity and rigor in a more generalizable way. Our journey has helped us see our working definition for academic/scientific/research rigor. In 2002, Hatch published the well-known "Doing Qualitative Research in Education Settings". He shared five research paradigms, each with their own ontology, epistemology, methodology, and expected products. Building from that, our understanding of scientific/academic rigor is the *alignment* of all four of these categories. It is the agreement of ontology, epistemology, methodology, and products. For example, lack of rigor would be mixing positivist ontology, feminist epistemology, and constructivist methodology.

An Indigenous Research Paradigm has its own form of validity, distinct from any other paradigm based on its distinct ontology. Research validity for an Indigenous Research Methodology/Paradigm does not come from a high 'n' value or statistical significance. It comes from the community's test of you personally and the work you are doing. Will the community use it for their children at the pre-K to tribal college level? Even if a research project meets the Western standards of rigor but does not show respect to the relationships between researcher, participants, topic, Land, and community it would be considered inauthentic or non-credible within Indigenous Research Methodologies (Archibald, 2008; Kovach, 2009; Wilson, 2008).

I have been conditioned and trained into Western beliefs throughout my Western education. Although this research journey has certainly changed me, I apologize to the reader and those I am working with for where my embodiments of Western thinking have certainly influenced my relationship with Indigenous Knowledges. Specifically, I apologize for when my

impact has been negative, even when my intent was positive. I am a common man full of mistakes. I pray continually that my work will be beneficial and actionable to Sitting Bull College and Standing Rock Nation. For anyone considering research with Indigenous Peoples, I pray that our story/article may urge self-reflection and a willingness to slow the pace, or stop altogether, if that is what the Nation and/or community leaders are suggesting.

   Circulating Conversations Methodology and co-connecting knowledge as an Indigenous research methodology are not secluded to only research in undergraduate math education as we have applied them. For anyone seeking to show deep respect to the community and knowledge through research, center an Indigenous worldview of relationality, and be changed through the process of research, then Circulating Conversations Methodology and co-connecting knowledge may be beneficial for you. You have the responsibility to all your relations and can make the decision if Circulating Conversations Methodology and/or co-connecting knowledge is valuable to you and any research you do. We attempted to follow a spiritual, holistic, respectful, reciprocal, relationship-oriented approach in every aspect of this process from developing the research questions to writing this article. Thank you for joining us in unraveling this journey. I pray that you were able to connect holistically with some of this writing and it can be beneficial to you and your work. In Choctaw, Yakoke. In Lakota, Pilamayapilo. In English, Thank you.

4. PAPER 2 – THE STORY OF CIRCULATING CONVERSATIONS METHDOLOGY TOWARDS RUME RESEARCH QUESTIONS

The second paper of this four-paper dissertation covers the same content as Paper 1 synthesized down to a much smaller word count and written to a different audience. I am the sole author on this paper. It was peer-reviewed (double-blind) and accepted into the "SIGMAA (Special Interest Group of the Mathematical Association of American) on RUME (Research in Undergraduate Math Education) Conference 2022" in Boston, Massachusetts. I am very thankful to the reviewers. Their comments, critiques, and questions helped strengthen the final draft you read here.

4.1. Cover Page and Abstract

The Story of Circulating Conversations Methodology towards RUME Research Questions

Danny Luecke

North Dakota State University

Abstract

The goal of this paper is to convey an Indigenous research paradigm to the RUME (Research in Undergraduate Math Education) community in a way as authentic as possible. This paper stories my PhD research journey of applying an Indigenous research paradigm to research in undergraduate math education at Sitting Bull College (SBC). For this study, Circulating Conversations Methodology (CCM) was named as the theoretical framework with one of its key features as co-connecting knowledge. This paper shares the process of developing Circulating Conversations Methodology (CCM) within an Indigenous research paradigm and shares its

results of four research questions. Within an Indigenous research paradigm, the process is the product of my research (Wilson, 2008).

Keywords: Indigenous research paradigm, relationality, co-connecting knowledge, tribal college, math curriculum and pedagogy

4.2. Paper 2 Manuscript

In seeking to follow Indigenous ways of knowing and being throughout every aspect of this research, how knowledge is transferred is equally significant with the knowledge itself (Kimmerer, 2013; Kovach, 2009; Wilson, 2008). The goal of this paper is to discuss my process of applying an Indigenous research paradigm which in turn led to the development of research questions. Through this experiential process, I am continually learning from Shawn Wilson (Opaskwayak Cree) that "the process is the product" (Wilson, 2008, p. 103). Within my understanding of an Indigenous research paradigm, the process to arrive at the research questions is equally as significant as the answer to the research questions. This process-centric and relational way of writing and view of knowledge will likely feel striking to a Western trained reader. In this paper, the research questions are part of the product, that is developed in process through CCM, and so will be shared near the end. I will begin this paper with the cultural protocol of introductions.

4.3. Introductions

Hau mitakuyepi. Ċhaŋte waṡteya nape ċhiyuzapi. Danny Luecke emaċiyapi. Fargo, North Dakota el wathi na Fargo emataŋḣaŋ. Ina Kathy Jo Dahlgren eċiyapi. Ate Lenny Luecke eċiyapi.

In Lakhol'iyapi (the Lakota language) I said, hello my relatives. With a good heart I shake your hand. My name is Danny Luecke, and I am from and currently live in Fargo, North Dakota. I shared my parent's names in my desire to honor all my ancestors. I am from multiple

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European nations as well as Choctaw Nation and reflect upon the bind of embracing or neglecting my Choctaw heritage because of my predominantly white background, privileges, and experiences. I am honored by your interest in reading my work and learning with me. I pray that this proposal would strengthen the relationship between us and strengthen your relationships with Indigenous knowledges and Indigenous Peoples. There are so many connections I do not know. I strongly dismiss any notions of being an 'expert' (Fast & Kovach, 2019; Kovach, 2009; Wilson, 2008). All I share with you are some of the connections I have made. I acknowledge the land I am from as the land of Oceti Sakowin, Anishinaabe, and multiple more Nations. I honor and thank them for their millennia of sustainably partnering with the Land as a living relative. In humility, I introduce Land as one who has been here long before any of us and will be here long after any of us (Styres, 2018).

While Western research demands the notion of objectivity, an Indigenous research paradigm embraces the clear articulation of subjectivity (Archibald, 2008; Grande, 2015; Kovach, 2009; M. A. Meyer, 2014; Wilson, 2008; Windchief & Pedro, 2019). A first-person introduction like this and a story writing style may seem unusual to you. It certainly was to me when I began learning about Indigenous research paradigms. Shawn Wilson wrote a seminal work that likely has the most influence on me and this research titled "Research Is Ceremony: Indigenous Research Methods" (2008). Wilson and his co-researchers developed a saying that I have embraced also. "If research doesn't change you as a person, then you haven't done it right" (Wilson, 2008, p. 135). I know I have changed dramatically through this process, personally as well as my professional views towards research and writing. I did not grow up participating in spiritual ceremony. I am learner to Indigenous ways of knowing and being. My continual greatest fear is not respecting the Indigenous knowledges and Indigenous Peoples that I am

connecting with and learning from. Today, I am trusting Creator, my academic elders, and the relationships being developed through the research process to guide me.

Another seminal work towards an Indigenous research paradigm written by Jo-Ann Archibald, also known as Q'um Q'um Xiiem, (Stó:lo Nation) is titled "Indigenous Storywork: Educating the Heart, Mind, Body, and Spirit" (2008). In doing any research with Indigenous communities, she shares pivotal self-reflection questions addressing issues from past and ongoing colonialism within research. "Was I doing anything different from earlier 'outsider' academics who created a legacy of mistrust among First Nations concerning academic research? How was my research going to benefit the education and wellbeing of Indigenous peoples and their communities? How would I address ethical issues related to respect and ownership of Indigenous intellectual property?" (Archibald, 2008, p. 36). As I seek to do RUME at a tribal college, these questions help guide my work by guiding my heart, mind, body, and spirit.

Wilson elaborates in sharing that "As we Indigenous scholars have begun to assert our power, we are no longer allowing others to speak in our stead. We are beginning to articulate our own research paradigms and to demand that research conducted in our communities follows our codes of conduct and honors our systems of knowledge and worldviews" (Wilson, 2008, p. 8). Circulating Conversations Methodology (CCM) seeks to follow this demand in every possible way. Thank you for joining in unraveling this CCM journey towards RUME research questions.

4.4. Indigenous Research Paradigm

While reading "Research is Ceremony" (2008) the first time, I wrote down in my notebook "Relationality is the sum of the whole Indigenous research paradigm." Going through the book for a third time months later, the actual quote reads, "Relationality *seems to* sum up the whole Indigenous research paradigm *to me*"{emphasis added} (Wilson, 2008, p. 70). This

epiphany moment struck my heart and mind. In my first reading, I had removed the subjectivity

and opted for a more definitive way of knowing. It was not until the third reading, and after a

discussion with my mentor, professor of education, Dr. Hollie Mackey (Northern Cheyenne)

about my absolutist writing style at that time, did the revelation come that my reading and

writing patterns were not matching the subjectivity inherent within relationality (H. Mackey,

personal communication, September 21, 2020). I was reading the seminal pieces with an eye for

the single precise definition for an Indigenous research paradigm so I could extract that out of

context into my work (Smith et al., 2018). The single definition for an Indigenous research

paradigm is **not** written in any of the seminal works, which fully aligns with the paradigm itself.

There is no one way to apply an Indigenous research paradigm! There **cannot** be one way

because it is dependent on all relations. This may include spirituality, a specific place, a specific

language and culture, and certainly a dependence on the researcher and participants themselves

(Archibald, 2008; Kovach, 2009; Wilson, 2008).

Relationality to me is the idea that everything is in relationship (Wilson, 2008), that

everything [including knowledge] is alive and connected (M. A. Meyer, 2014). Wilson taught me

that it goes beyond the idea that I have a web of relationships to I **am** the web of relationships.

This is not for humans only, knowledge as a living entity does not have relationships, but

knowledge **is** relationships. This reality of nature and knowledge is distinct from constructivism

that centers human knowing (Hatch, 2002; Kovach, 2009). Wilson says relationality to him is

that "relationships form reality" (Wilson, 2008, p. 137). I laughingly remember the essence of

relationality via seeing relationality as a contraction of the two words relationship and reality.

Mathematically, it may be seen as emphasizing the study of the edges instead of the vertices.

This assumption about the nature of reality, that is ontology, impacts not only research but

perspectives about science and math as living entities themselves (Kimmerer, 2013). Greg Cajete (Santa Clara Pueblo), a well-known Native scientist, is quoted by Manulani Aluli Meyer ('Ōiwi Hawai'i) by saying "The perspective of Native science goes beyond objective measurement honoring the primacy of direct experience, interconnectedness, relationship, holism, quality and values, and they are specific to tribe, context, and cultural tradition" (M. A. Meyer, 2014, p. 98). Wilson (2008) brought me to tears as he shared a metaphor describing relationality applied to knowledge, and therefore my responsibility to the knowledge in its relational context.

> So the way I see it, gaining knowledge is more like being married to someone – you don't own your spouse or children but you do share a special relationship. It is a relationship that you are accountable to. And therefore it becomes cultural appropriation when someone comes and uses that knowledge out of its context, out of the special relationships that went into forming it. You have to build a relationship with an idea or with knowledge, just like you have to with anything or anyone else… For someone else to come along and use this knowledge in an inappropriate manner is [abuse]. You know that sexual exploitation and total denigration of our humanity was a big part of colonialism. Now that is taking place with our ideas and knowledge. Our knowledge is being stripped of its relationships and being used without accountability. (p. 114)

This metaphor hits the heart, body, and spirit. I can feel the knowledge and perhaps you may too. This metaphor not only helped me crystallize knowledge as relational (and therefore personal, subjective, experiential and holistic) but also demonstrated the obligation of responsibility and accountability I have towards the Indigenous knowledges and Indigenous Peoples I learn from. Linda Tuhiwai Smith (Ngāti Awa, Ngāti Porou) addresses the specific

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connection between research and Indigenous Peoples in her high impact book "Decolonizing Methodologies" (1999, 2012, 2021). Here are the first words of her introduction.

> From the vantage point of the colonized, a position which I write, and choose to privilege, the term 'research' is inextricably linked to European imperialism and colonialism. The word itself, 'research', is probably one of the dirtiest words in the Indigenous world's vocabulary. When mentioned in many Indigenous contexts, it stirs up silence, it conjures up bad memories, it raises a smile that is knowing and distrustful… At a commonsense level research was talked about both in terms of its absolute worthlessness to us, the indigenous world, and its absolute usefulness to those who wielded it as an instrument. It told us things already known, suggested things that would not work, and made careers for people who already had jobs. (p. 1-2)

As Indigenous communities/nations are asserting their sovereignty, there is a growing demand for research by, for, and with the community towards an indigenizing or decolonizing outcome (Kovach, 2009; Smith, 2021; Tuck, 2009; Wilson, 2008; Windchief & Pedro, 2019). This demand fit with my experiences. When I first read the quote above, I recalled an experience I had a couple months previous with a tribal college administrator who strongly warned me of parasite research. With an adamant tone, the administrator declared 'We are stopping it here!' Not fully understanding what was meant by the declaration I sheepishly asked what was meant by parasite research. The administrator continued that parasite research(ers) take, take, take, and give nothing back. They show up for a short period of time to extract data solely for their own benefit and then disappear, giving nothing back to us or the community.

An Indigenous research paradigm, grounded in Indigenous knowledges, moreover a tribal-specific knowledge and language, emphasis giving back to the community and

strengthening all relationships in the process (Archibald, 2008; Kovach, 2009; Wilson, 2008). From my viewpoint, themes of relationality, subjective knowledge, holism, and story seem to circulate with values of responsibility, respect, and reciprocity to form the dynamic and place-based research paradigm (Archibald, 2008; Kovach, 2009; Smith et al., 2018; Wilson, 2008; Windchief & Pedro, 2019). However, my understanding of an Indigenous research paradigm is only my understanding. Each person, including you, will connect with it in their own way and join in the joint responsibility of being in relationship with an Indigenous research paradigm (Archibald, 2008; Kovach, 2009; Wilson, 2008).

4.5. Circulating Conversations Methodology (CCM)

With a context of hurtful research with Indigenous Peoples and with the core of an Indigenous research paradigm centered around relationality and relational accountability, I began the research for my PhD with Sitting Bull College (SBC), where multiple personal and professional friendships had already been established. SBC is a tribal college chartered by Standing Rock Nation guided by Dakota/Lakota culture, values, and language. I was confident that I could not come in with my research questions, framework, or agenda. I was confident that I wanted to do research that was beneficial and actionable for the SBC math instructors and that outside of directly talking with them I had no aspiration of thinking I could determine that on my own. Two statements rang in my ears after a discussion with Dr. Josh Mattes, engineering/math instructor at SBC. From his perspective, looking at the intersection of math and Dakota/Lakota language and culture was an "excellent idea" and that "even minimal results here would be beneficial [for SBC math instructors]" (J. Mattes, personal communication, September 25, 2020).

Within my literature review, I found precisely one article about collegiate math and Indigenous languages. It excited me showing a potential path but also warned of difficulties with

the delicate relationship between math education research and fluent elders (Ruef et al., 2020).

Due to the implications of the COVID-19 pandemic, a time of waiting, struggle, research

roadblocks, prayer, and Choctaw identity development became the norm. I saw no clear path

forward. Then at the end of January 2021, a spiritual moment of connection brought Sunshine

and I together for our first meeting. Sunshine Carlow (Lakota) is an instructor and the financial

manager for Lakȟól'iyapi Wahóȟpi Wičhákini Owáyawa (Lakota Language Immersion Nest)

located at SBC. This new relationship made a way to learn about the intersection of

undergraduate math education and Dakota/Lakota language and culture.

 After initial introductions and first interviews with Hollie, Sunshine, Josh, and my

advisors, more focused conversations happened within the next week and a half about potential

research directions at the intersection of undergraduate math and Dakota/Lakota language and

culture. With all the conversation notes in front of me, drawing upon what I remembered

hearing, I sought to holistically (heart, mind, body, spirit) connect all the ideas together. This

time of synthesis formed an initial one-pager with four first draft research topics looking at

content, development methodology, student affect, and faculty experiences. I circulated amongst

Josh, Sunshine, Hollie, and my advisors to connect with each of them and listen to their feedback

on the initial four topics. Again, seeking to holistically connect each of their responses altogether

illuminated two topics. Content and development methodology becoming research question 2-4

and 1, respectively, through a final round of conversations with each key person.

 In a spiritual moment of epiphany midway through, I came to realize the pattern of

relationships I was enacting **was** literally a web. My experiential journey of conversations with

each key person was my theoretical framework! I named it **Circulating Conversations**

Methodology (CCM). Although time moved forward as CCM happened, the connecting of

themes and ideas was anything but linear as shown in Figure 1 below.

Figure 15

Paper 2 Figure 1: A Diagram Showing that Circulating Conversations Methodology as a Circular Web.
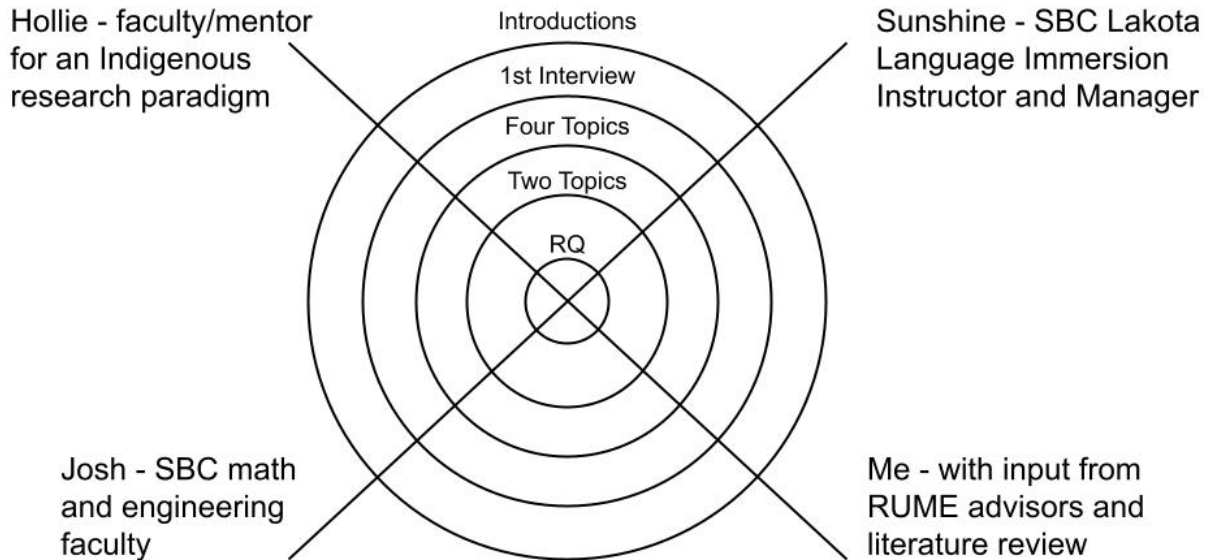
Like a spider web that glistens and waves with the wind, each intersection point between

circles and strands is unique. The circles represent different stages, moving from one to the next

through moments of synthesis. The strands represent central people in the development of the

research questions. Each intersection point is an essential conversation in the web. Conversations

followed Kovach's conversational interview protocol (2010). The RUME research questions

were the end goal of this particular CCM that brought together multiple people, ideas, value

systems, and institutions. Hollie connected her knowledge of an Indigenous research paradigm

and Indigenous Knowledges. Sunshine connected her knowledge of Dakota/Lakota language and

culture. Josh connected his knowledge of teaching math and pre-engineering courses at Sitting

Bull College. I and my advisors connected with an impetus for my PhD research and our PhD

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level understanding of mathematics. Through circulating conversations, the research questions developed through an iterative, circular, and collaborative process.

4.6. Co-Connecting Knowledge: Relationships Form Reality

Circulating Conversations Methodology (CCM) is based in an Indigenous research paradigm. Within this paradigm, theoretical frameworks and/or methodologies are as diverse as in Western research paradigms. Until we can articulate the vast array of these theoretical frameworks, they may be seen as vague or fuzzy (H. Mackey, personal communication, February 19, 2021). To attempt further clarity for CCM, one critical component is co-connecting knowledge, a term like CCM that was developed through the process. CCM is not haphazardly talking to a few different people. It is specifically based in the ontology (nature of reality) and epistemology (nature of thinking and knowing) of relationality. As Hollie and I discussed the initial four research topics, we recognized our word choice of "co-constructing knowledge" was a Western term that was distinct from the activity we were doing. We found ourselves stuck in Western terminology "to describe something that's far more nuanced" and desired to "come up with something that actually catches what it is" (H. Mackey, personal communication, February 19, 2021). Co-connecting knowledge became that term. None of our conversations constructed, created, found or discovered new knowledge. Rather it was the collaborative connecting via conversation and story that new relationships/knowledge developed.

Co-connecting knowledge describes the space where theory from the literature can connect with personal experiential knowledge in practice. It describes the space where intellectual knowledge can connect with spiritual knowledge (M. A. Meyer, 2014). It allows a relational worldview to connect with the neuroscience that says learning is new connections in the brain. Plus, co-connecting knowledge gives the space to connect all of these connections

together holistically. Co-connecting knowledge aligns with an ontology and epistemology of relationality where knowledge is not owned, discovered, created or constructed but rather "knowledge is shared with all creation… the idea belongs to the cosmos, to all of the relations that it has formed, not to the individual who happens to be the first to write about it" (Wilson, 2008, p.56, 114).

Co-connecting knowledge instead of co-constructing knowledge is one example of how an ontology (nature of reality) and epistemology (nature of thinking and knowing) based in relationality is distinct from Western research paradigms (Grande, 2015; Kovach, 2009; Wilson, 2008; Windchief & Pedro, 2019). Some Western frameworks/methods are popular in Indigenous communities such as participatory action research, critical/feminist paradigms, and constructivist paradigm because the expansive intersection in seeing knowledge as personal, subjective, and political, recognizing a larger meaning to the mantra 'knowledge is power' (Grande, 2015; Gutiérrez, 2012; Kovach, 2009; Sfard, 1998). However, these Western frameworks are still based in Western constructs such as human-centrism and progressivism (Grande, 2015; Kovach, 2009). For example, Gutiérrez's work (2012) in equity recognizes math education as going well beyond individual intellectual capacity. However, math is still viewed through a human-centric lens. Similar can be said for Sfard's work on using multiple metaphors for learning (1998). The ontology and epistemology of these frameworks are not based in relationality and Indigenous knowledges. An Indigenous research paradigm is distinct in its decolonizing aim, tribal-specific knowledges, and knowledge being bound to place through ancestors, language, and land. Further, an Indigenous research paradigm can certainly include quantitative methods as well (Grande, 2015; Kovach, 2009; Windchief & Pedro, 2019).

4.7. Scientific/Academic Rigor

A distinct ontology and epistemology of relationality and a distinct set of values of being accountable to all these relationships through respect, responsibility, and reciprocity leads to distinct validity measures. Scientific/academic rigor in my understanding is the alignment of ontology (what is real?), epistemology (how do I know what is real?), methodology (how do I find out more and explore this reality?), and axiology (what moral beliefs will guide this search for reality?) (Wilson, 2001, 2008). Even if a research project meets the Western standards of judgement, like validity and reliability, but does not show respect to the relationships between researcher, participants, topic, Land, and community it would be considered inauthentic or non-credible within Indigenous research paradigms. Wilson (2008) explains,

> We don't need externally imposed measures or tests of whether or not something is 'true,' we have our own ways of ensuring this. We have our own ways or questions to ask, so that we know that what we are saying is strong enough to say, 'Yes, we can go ahead and design a program for our children or our community based on what we have learned from this research." And we have trust or faith enough so that we are willing to use this in our communities, for our own people. (p. 102)

I have been conditioned and trained into a specific ontology through my Western education. In contrast, to remind myself of the heart and core of an Indigenous research paradigm I often look back to the words of Margaret Kovach (Plains Cree/Saulteaux). In part she shares, "The sacredness of Indigenous research [and knowledge] is bound in ceremony, spirit, land, place, nature, relationships, language, dreams, humor, purpose, and stories in an explicable, holistic, non-fragmented way" (Kovach, 2009, p. 140).

I attempted to follow this holistic way through Circulating Conversations Methodology (CCM). In that attempt I learned that the process of determining the research questions is equivalent in significance as the research questions and results themselves. Without this CCM process, the four research questions for the next phase of this research would not exist in this way whatsoever. Looking back in my reflective journal I see how much I and my attitudes towards my PhD research have changed. I am indeed continually experiencing and learning that "the process is the product" (Wilson, 2008, p. 103).

4.8. Research Questions

The four research questions that were co-connected via CCM are:

1: In In what ways can an Indigenous research paradigm lead an individual researcher towards more ethical and impactful (beneficial and actionable) RUME at TCUs?

2: In what ways can Western higher order math concepts (HOMC) be *identified within* Dakota/Lakota space, place, and language, to inform possible SBC math curricular/pedagogical adjustments for TCU math courses?

3: In what ways can Dakota/Lakota culture and language be *identified within* Western HOMC, to inform possible Lakota Language Immersion Nest curricular adjustments?

4: In what ways can Dakota/Lakota space, place, and language *represent* non-Western HOMC?

I did not come up with these research questions myself. I did not choose a topic or gap in the literature. Rather I chose some values and a process, that is an Indigenous research paradigm, and it guided me throughout. I did not come into SBC with my agenda for research to be done on Indigenous communities. Instead, every word of the research questions has a specific moment of co-connecting knowledge through CCM that brought that wording or idea about.

The goal of this paper was to introduce an Indigenous research paradigm through my journey of CCM. Future RUME at tribal colleges could potentially use this research paradigm and theoretical framework. My work at SBC has built from these research questions and will hopefully be presented in the future. Thank you for joining me in unraveling this journey. I pray that you were able to connect holistically with some of this writing and it can be beneficial to you and your work. In Choctaw, Yakoke. In Lakota, Pilamayayelo. In English, Thank you.

5. PAPER 3 – D/LAKOTA MATH CONNECTIONS COURSE AND FRAMEWORK[3]

The third paper of this four-paper dissertation is published in 2023 in the peer-reviewed (open), high impact, open-source journal titled "Frontiers in Education: Centering Humanism in STEM Education Volume 8." I am very thankful to the reviewers. Their comments, critiques, and questions helped strengthen the final draft that you read here.

5.1. Cover Page and Abstract

Dakota/Lakota Math Connections: an epistemological framework for teaching and learning mathematics with Indigenous communities and students

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[3] The material in this chapter was co-authored by Danny Luecke and David Sanders. Danny Luecke had primary responsibility for collecting and analyzing data as well as initiating and organizing the manuscript. David Sanders co-facilitated data collection, analyzed some of the data, and served as proofreader and editor for the manuscript.

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Abstract:

Tribal colleges/universities have and continue to seek out connections between the local heritage and culture and the mainstream education content. In math, calls for culture to be more integrated into the classroom have been met with epistemological challenges as well as a dearth

of math and local culture resources. The Dakota/Lakota Math Connections research project addresses both of these challenges. This article will specifically share the collaborative development, pilot, evaluation, and confirmation of an epistemological framework for curriculum development in both the math and language classrooms at Sitting Bull College. Following an Indigenous research paradigm focusing on relationality and relational accountability, the co-authors gathered a group of tribal college math instructors, Lakota language immersion teachers, and fluent elders. Altogether they experienced, evaluated, and confirmed the Dakota/Lakota Math Connections framework as a path for teaching and learning mathematics with Indigenous communities and students. Using an Indigenous research paradigm led to circular, reciprocal research questions for this article: In what ways, if any, did the framework impact the participants? In what ways, if any, did the participants influence the framework? The framework includes four major components (Western Math, Dakota/Lakota Math, the English language, and the Dakota/Lakota language) and the intersections among each component. The framework builds from the assumptions that language is intimately tied with culture and identity and that higher order mathematical thinking is embedded within Dakota/Lakota language and culture. This is based on the assumption that all cultures "do" math. The framework asserts that math fluency and Dakota/Lakota language fluency can grow together. The Dakota/Lakota Math Connections framework lays an epistemological pathway for Dakota/Lakota students to see their culture, identity, and language in the math curriculum as well as for math instructors to honor the call to connect the math classroom with the local heritage and culture.

Keywords: Indigenous research methods, math education, Dakota/Lakota, language, math, self- determination, curriculum, tribal college and university

5.2. Introduction

Tribally controlled colleges and universities (TCUs) have and continue to seek out connections between the local heritage and culture and the mainstream education content (American Indian Higher Education Consortium, 2023). At Sitting Bull College in Standing Rock Nation, a portion of the mission statement reads "Guided by Lakota/Dakota culture, values, and language, Sitting Bull College is committed to building intellectual capacity through academics." (Sitting Bull College, 2023). At Sitting Bull College, as well as many other TCUs, every course is required to connect to the culture as demonstrated by the college's syllabus template that specifically has a section on cultural relevance.

"Guided by Dakota/Lakota culture, values, and language" (Sitting Bull College, 2023) also specifically applies to science, technology, engineering, and math (STEM) courses at Sitting Bull College. Across all TCUs, there are efforts to connect STEM with place-based, community-specific culture, language, and knowledge (Boyer, 2011; American Indian Science Engineering Society, 2020). Calls for culture to be more integrated into the classroom continue at the TCU-level as well as the K-12 level (Lipka et al., 2005; American Indian Science Engineering Society, 2020; S. Meyer & Aikenhead, 2021a,b; Stevens, 2021). At the K-8 level, the Yup'ik in Alaska have taken major strides in developing their curriculum called "Math in a Cultural Context" (Lipka et al., 2005). The decades of work within this project both answered the call for math and local culture integration and were able to demonstrate its many benefits from increased cultural identity for students to increased math exam scores (Kisker et al., 2012; Lipka & Adams, 2004; Lipka et al., 2007).

At the college level, calls for culture to be more integrated into the math classroom have been met with epistemological challenges as well as a dearth of math and local culture resources

(Webb et al., 2017; Ruef et al., 2020; S. Meyer & Aikenhead, 2021a,b; Stevens, 2021). If Western mathematics is assumed to transcend culture, as it often is in mainstream Western education, then how can the TCU math classrooms connect with Indigenous culture (Bishop, 1990; Aikenhead, 2017; Ernest, 2021; Stevens, 2021)? More specifically, in what ways could Sitting Bull College math classrooms connect with Lakota/Dakota culture, values, and language? The Dakota/Lakota Math Connections research project addresses both challenges of epistemological misalignment and the scarcity of college math and Dakota/Lakota culture resources.

This article will specifically focus on the first challenge of epistemological misalignment between Sitting Bull College's mission (2023) of academics guided by D/Lakota culture, value, and language with the Western assumption of mathematics as universal and objective, meaning that math is the same for everyone with no influence from local culture but rather transcends local culture (Bishop, 1990; Aikenhead, 2017; Ernest, 2021; Stevens, 2021). As the Sitting Bull College mission mandates, D/Lakota culture, values, and language are place-based [not universal]; holistically include mind, heart, body, and spirit; and have a strong emphasis on relationship/context. In this tension of epistemological misalignment, the D/Lakota Math Connections project emerged. This article will specifically share the collaborative development, evaluation, and confirmation of an epistemological framework for teaching and learning mathematics in both the math and language classrooms at Sitting Bull College.

Building on the considerable body of STEM education literature for Native students at the K-12 level, the American Indian Science and Engineering Society conducted a literature review with the goal "to provide an understanding of the most effective educational strategies for (primary and secondary). Native learners in the areas of STEM" (American Indian Science and

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Engineering Society, 2020, p. 4). Their concluding statement for K-12 STEM education for Native students follows.

Indigenous people, cultures, and communities have rich histories, traditions, and ways of knowing, being, and connecting with the world around them. For too long mainstream education systems have undervalued and disregarded Indigenous Knowledge and Indigenous Science. Research now suggests these Indigenous assets are not only important for the success of Indigenous people themselves but for the healing and health of our world. Stemming from this foundation of immense wealth, researchers posit improved educational outcomes for Native and non-Native students result when STEM instruction is culturally relevant, rooted in Indigenous ways of knowing, linked to place, and embedded in community (p. 12).

Specific to math education, Garcia-Olp et al. (2019) posit that "Indigenous Knowledge has Always Been Mathematics Education." They state that Indigenous mathematical knowledge has been passed down from one generation to the next in Indigenous communities through "experiential relationships in the natural world" (p. 11). Furthermore, the D/Lakota Math Connections project builds upon Sanders' (2011) dissertation work that brought together both the idea of a Lakota view of mathematics and the action of a math curriculum designed to follow the community's desire for self-determination in (math) education.

In this context of math education with Indigenous communities, Luecke and initial collaborators (a Sitting Bull College math instructor, a language instructor, and an Indigenous research methodology specialist) applied an Indigenous research paradigm to research in undergraduate math education. Their collaboration laid the groundwork for the Dakota/Lakota Math Connections course and framework (Luecke et al., 2022).

The foundation for the course content was previous research in Lakota math by Sanders (2011). Luecke invited him to co-facilitate the 1-week summer course together. They gathered a group of tribal college math instructors, Lakota language instructors, and fluent elders to further understand D/Lakota math. During the course, participants/contributors collaboratively discussed connections between mathematics and D/Lakota culture, values, and language. Altogether, they experienced and evaluated the "Dakota/Lakota Math Connections Framework." The course collaboratively confirmed the use and further implementation of the framework while simultaneously further describing D/Lakota math and refining the framework's nuances.

The D/Lakota Math Connections framework (see Figure 1) includes four major components (Western Math, Dakota/Lakota Math, the English language, and the Dakota/Lakota language) and the interactions among each component. The framework builds from the assumptions that language is intimately tied with culture and identity (Wilson, 2008; Ruef et al., 2020; Sitting Bull College, 2023) and that higher order mathematical thinking is embedded within Dakota/Lakota language and culture (Bishop, 2012; Sanders, 2011; Garcia-Olp et al., 2019; Ruef et al., 2020). This assumes that all cultures "do" math (Bishop, 2012; Sanders, 2011). The framework asserts that math fluency and Dakota/Lakota language fluency can grow together. The Dakota/Lakota Math Connections framework, sometimes called the "Four Circles Framework" lays an epistemological pathway for Dakota/Lakota students to see their culture, identity, and language in the math curriculum as well as for math instructors to honor the call to connect the math classroom with the local heritage, culture, values, and language. The college is part of the D/Lakota communities' effort to revitalize the language, and the Four Circles framework shows a path for mathematics teaching and learning to also join that effort.

Figure 16

Paper 3 Figure 1: Dakota/Lakota Math Connections Framework.
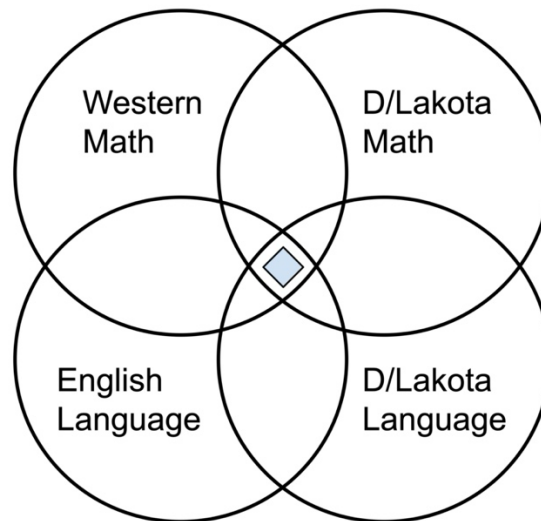
Note. The D/Lakota Math Connections framework is a four-circle Venn diagram, and thus sometimes referred to as the "Four Circles framework." Content in the intersection of all four circles, pictured as a blue diamond, is sometimes called a "D/Lakota math connection."

The course piloted the D/Lakota Math Connections framework. This article describes the course and framework implementation as well as the research methods, analysis/synthesis, and results from this pilot course. The two research questions guiding this study are as follows:

In what ways did the framework impact the participants?

In what ways did the participants influence the framework?

Following an Indigenous research paradigm that centers on relationality and relational accountability (Wilson, 2008), these two questions highlight "the process is the product" (Wilson, 2008, p. 103) and the Indigenous value of reciprocity. First, reciprocity is evident in the reciprocal questions reflecting upon each other. In contrast to a more linear process where the framework would be static and pre-determined during data collection, analysis, and synthesis, Question 2 probes how the participants change our understanding of the framework. Fuller comprehension of the framework came through the participants' experience of the

course/framework. Additionally, the two guiding questions of this article highlight an Indigenous research paradigm that is circular and iterative. In contrast to a linear research paradigm, these two questions guiding the quantitative analysis were developed after the initial synthesis of relationships throughout the course by the co-authors. "The process is the product" (Wilson, 2008, p. 103). The framework and participants co-inform with one another. Similarly, the data collection and data synthesis/analysis/results co-inform one another (Wilson, 2008). Again, instead of the linear logic for writing/reading an article (introduction to methods to results to discussion), the framework of four interconnected circles also describes the four main sections of this article (introduction, methods, results, and discussion). This research project attempts to follow an Indigenous research paradigm within academia. However, "Indigenous epistemologies challenge the very core of knowledge production and purpose. While this is not a matter of one worldview over another, how we make room to privilege both, while also bridging the epistemic differences, is not going to be easy" (Kovach, 2009, p. 29).

Answering the two reciprocal research questions confirms the D/Lakota Math Connections framework and expands upon the nuances for curriculum development at Sitting Bull College and more generally teaching and learning mathematics with Indigenous communities and students. This article honors the call on TCU math instructors, and more broadly STEM instructors, at all levels, teaching Indigenous students, to bring balance and epistemological alignment between their math curricula and the community/nation's expectation of math education being guided by local culture, values, and language.

5.3. Methods

5.3.1. Indigenous Research Paradigm Viewpoint on Data Collection and Synthesis

This subsection is not defending the validity of an Indigenous research paradigm compared with Western research approaches, but rather "a conceptual framework gives researchers a tool to show how their methods are being aligned with a particular way of knowing" (Kovach, 2009, p. 43). As far as the authors are aware, an Indigenous research paradigm collectively described by Archibald (2008), Wilson (2008), and Kovach (2009) has not been applied to research in undergraduate math education to date. Wilson (2008) asserts that an Indigenous research paradigm is built on relationality and relational accountability. Relationality, meaning relationships form reality, is the ontology (what is real?) and epistemology (how do I know what is real?). With relationality as the ontology and epistemology, one does not *have* relationships but *is* relationships. Thus, increased understanding does not come from triangulating an object's location/definition, but rather encircling/strengthening the relationships with the central idea/activity. Therefore, knowledge is not contained in this written article, but rather in all the relationships of the participants/co-researchers who have participated in the D/Lakota Math Connections project as well as all who will think about D/Lakota math connections and/or read this article. Relational accountability is the methodology (how do I find out more about this reality?) and axiology (what moral beliefs will guide this search for reality?). Strengthening and being accountable to all relations is the value system and process in which to align all methods and research decisions. Specifically, in this research project and study, the use of story, intuitive synthesis, and non-linear data collection and analysis are all implemented to follow a research paradigm based on relationality and relational accountability.

First, "story as method elevates the research from an extractive exercise serving the fragmentation of knowledge to a holistic endeavor that situates research firmly within the nest of relationships" (Kovach, 2009, p. 99). In this research project and study, story was used for data collection, data synthesis, and in writing/reading this article. Wilson expands to describe non-fragmented, non-linear research as "the methods of data collection and the data analysis blended into one… The analysis was collaborative and ongoing. It shaped the direction of the research" (Wilson, 2008, p. 131). Note how he does not describe research with fixed linear phases of data collection, analysis, results, and discussion.

How one gathers information, interprets information, and verifies knowledge must follow relationality (ontology and epistemology) and relational accountability (methodology and axiology). Wilson further describes analysis in his understanding of an Indigenous research paradigm.

> "it [analysis/synthesis] just can't be thought of in a linear one-step-leads-to-another-way. All of the pieces go in, until eventually the new ideas come out… [The Indigenous style is to] look at all those relations as a whole instead of breaking it down, because it just won't work. It has to use a more of an intuitive logic, rather than a linear logic… that is the spiritual [ceremonial] part of it… when those ideas all come together, those connections are made [stronger]. (Wilson, 2008, p. 116, 119, 122)

Finally, a non-linear, spiritual research process reveals itself in writing as well. "It [a tribal epistemology of relationality] demanded that I 'write knowledge differently' than I had been instructed to do within previous Western research training… Once this tribal epistemology was visible, then all the research choices were considered against it." All the research decisions in the D/Lakota Math Connections project and this study are made through the lens of an

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Indigenous research paradigm and sometimes summarized as "the process is the product" (Wilson, 2008, p. 103).

5.3.2. The Dakota/Lakota Math Connections Framework

The D/Lakota Math Connections (Four Circles) framework was developed by the co-authors in preparation for the "D/Lakota Math Connections" course. The course they developed brought together math instructors (middle school through TCU), language instructors (immersion through high school), and fluent elders to discuss math topics.

Course participants were introduced to the framework and worked with it throughout the week. At the end of the week, two exercises were completed so participants could reflect on the framework and give feedback to further define and understand the D/Lakota Math Connections framework. Both of these exercises along with participants' quotes and stories are described in the Results section.

The framework was a way to declare the assumptions and goals of the course (as shared below in the Methods section) and the course was a way to collaboratively envision and define the framework (as shared in the Results and Discussion sections). The course was the avenue to experience the framework and the framework was the avenue to evaluate the course.

The framework set the stage/environment for respectful, asset-based conversation among the three distinct groups of people participating in the course (math instructors, language instructors, and fluent elders). Western math expertise (as held by math instructors) and D/Lakota language expertise (as held by fluent elders) are two distinct areas of expertise, but both are highly valuable. Fluent elders are central to the entire process and essential in every community effort toward language revitalization/reclamation. Their participation, comments, and

feedback are pivotal in understanding the framework, the D/Lakota language circle, and the D/Lakota math circle.

Furthermore, language learning and Western math learning can be intimidating. The initial setup of the framework sought to ease these tensions by consistently emphasizing that math fluency and language fluency are both valid and valuable in this course and framework. With English as the medium for communication, the course goals were to further understand and strengthen the D/Lakota Math circle as well as articulate the center intersection, the connections among all four circles, so that TCU math instructors and language instructors can use these connections in their classroom. There are multiple layers of reciprocity and balance between math instructors and language instructors, mathematical knowing and linguistic knowing, and Western ways and D/Lakota ways of knowing.

The process of using the framework determined the product of the framework. Learning how math teachers, language teachers, and fluent elders viewed and responded to the framework brought definition to the framework. Even after this article is published, the D/Lakota Math Connections framework will still be in the process of being defined and understood. Furthermore, each circle, especially D/Lakota math, and the intersections among the circles will continue to be shaped in future by math teachers, language teachers, fluent elders, and whoever else participates in the D/Lakota Math Connections project.

Despite the continual re-understanding and defining of the framework, there were seven initial assumptions/beliefs that were used to describe the framework to participants in the summer 2021 "D/Lakota Math Connections" course. They are as follows.

5.3.2.1. Each Circle Is Distinct

This assumption describes that Western Math does not contain all mathematical knowledge. Due to the distinct ways of the Western worldview compared to Indigenous ways of knowing, being, and doing, there was no assumption that Western Math contains all mathematical thinking. Similarly, the D/Lakota language is distinct from English not just in vocabulary but also in worldview. Each circle is distinct.

5.3.2.2. Each Circle Stands on Its Own

This assumption describes that D/Lakota math existed before colonization. It passed down from one generation to the next and needed no justification from colonial powers or reinforcement with colonial knowledge. Just like the D/Lakota language does not need the English language to justify its credibility, use, or power, D/Lakota math does not need Western math to justify its credibility, use, or power. Each circle can stand on its own.

5.3.2.3. Each Circle (Equally Sized) Is Equally Valuable

This assumption describes that despite colonization creating an imbalance of overvaluing Western knowledge and devaluing D/Lakota knowledge, the framework asserts an equal value to both ways of mathematical knowing. This assumption specifically pushes back against the typical training/education that most people receive in the United States, which values the Western way of knowing over an Indigenous way of knowing. Each circle is equally valuable.

5.3.2.4. Each Circle Is Connected to All the Other Circles

This assumption describes that every circle is connected to every circle (despite the diagram (Figure 1) missing the visual representation of Western Math connected to the D/Lakota Language and English connected to D/Lakota Math). Furthermore, we assume that the center intersection of all four circles exists. The specific examples within that center spot of connection

are called "D/Lakota Math Connections." Articulating these "D/Lakota Math Connections" for use in math classrooms and language classrooms was and continues to be one of the central goals of this project. Each circle is connected to all the others.

5.3.2.5. *No Pre-determined Definition Is Needed*

No precise definition was given to what each label meant, nor the intersection between such circles. No precise definition was given for Western or Western Math. It was informally introduced to the course participants as what the U.S. education system typically teaches in math classrooms, math that happens on desks, with paper and pencil, etc. The balance among the four circles demonstrates no negativity or diminishing of the power of Western math, but rather seeks to bring Western math into balance with other ways of knowing. No precise definition was given for D/Lakota Math either. Course participants (more appropriately named co-researchers) collectively defined the circles, in particular the D/Lakota Math circle. A language instructor in preparation for the course explained that in the D/Lakota language, numbers can be the verbs of a sentence instead of just adjectives or nouns depending on the context. This initial understanding of the distinctiveness of how numbers can be viewed was the proof of concept to help confirm that the D/Lakota language instructors and fluent elders were the most appropriate people to define/describe D/Lakota Math, not an outside researcher. Finally, the D/Lakota Math Connections framework was not even named at the start of the week, but rather was simply called the "course and research framework."

5.3.2.6. *Higher Order Mathematical Concepts Are Embedded within the Language and Culture*

The decision to have the D/Lakota community define D/Lakota math also comes from the belief that "higher order mathematical concepts are embedded within the language and culture"

(Garcia-Olp et al., 2019; Luecke et al., 2022). This builds on the assumption that all cultures "do" math. Bishop (2012) describes six universal math activities [counting, designing, locating, measuring, playing, and explaining] as a framework to articulate the mathematical thinking embedded within every culture. Sanders' dissertation (2011) used Bishop's framework (2012) in another Lakota community and became the basis for the summer 2021 pilot course. Again, what defines a "higher order mathematical concept" was left to the research process and co-researchers (participants and D/Lakota community). The higher order mathematical concepts embedded within the language and culture that were part of the summer 2021 pilot course would become the mathematical examples to define/describe the four circles and intersections. These results are shared in the follow-up study addressing the scarcity of resources connecting college math and Dakota/Lakota culture.

5.3.2.7. *Math Fluency and Language Fluency Can Grow Together*

Sanders shared a story with Luecke and then again with the summer 2021 pilot course of his math teaching experiences. He shared that the class physically next door to his classroom was the Lakota language classroom, but the physical wall felt like an impermeable wall between the two subjects. He lamented the separation between the subjects (typical in Western ways of education) and that feeling helped inspire the topic of his dissertation.

The Four Circles framework not only asserts balance between Western math and D/Lakota math but also a balance between mathematics and language. Similar to the asset-based approach of developing the framework for math teachers, language teachers, and fluent elders, two distinct expertise genres are assumed by the framework to be in balance by the framework. The co-facilitators for the course (and co-authors) fluent in Western math seek to encourage D/Lakota language fluency through this framework and research. Across the D/Lakota nation,

language revitalization efforts are being encouraged and endorsed and the D/Lakota Math Connections framework and the project seek to do the same. The results and discussion of this study will focus on the epistemological stance that math fluency and language fluency grow together.

5.3.3. The Pilot Course

The course took place in June 2021 at Sitting Bull College. It was part of a larger language revitalization effort called "D/Lakota Summer Institute" which is co-sponsored by Sitting Bull College and the Standing Rock Iyapi, a branch of the Standing Rock Department of Education. The class was 3 hours long for 5 days. It was framed as a workshop to course participants who signed up through the "D/Lakota Summer Institute" processes. It was viewed as a pilot course and originally named "Lakota Math Connections." During the course itself, the framework had yet to be named and was simply called "the course and research framework." The goal at that moment was to be honest about the assumptions the co-facilitators (now co-authors) were bringing to the 1-week summer course and to set a safe place of discussion among the TCU math instructors, Lakota language teachers, and fluent elders.

5.3.3.1. Participants

A total of 28 people took part in the course. Not every person participated in each of the 5 days and not every person participated in each data collection approach. In non-exclusive groupings, this included seven math teachers, 14 language teachers, nine elders, six elders who speak the D/Lakota language fluently, six miscellaneous people (science teachers, elementary teachers, and non-teachers), two lead facilitators (co-authors Luecke and Sanders), and five small group facilitators. The seven math teachers included four current math instructors (three at TCUs and one at a middle school in Standing Rock) and three past math instructors (one at the middle

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school and one at the high school level in different reservation communities and one at a mainstream public university). Three of the math instructors were enrolled in D/Lakota Nations and one in another Indigenous Nation. The 14 language teachers included nine second-language learners and five fluent elders. Nine of the language teachers worked in an immersion setting and four worked in a middle school or high school. Twelve of the language teachers were enrolled in D/Lakota Nations and one in another Indigenous Nation. Five of the six fluent elders lived and worked in Standing Rock. The median attendance per day was 21. The median attendance of math teachers, language teachers, elders, and other community members was 7, 10, 5, and 6, respectively.

5.3.3.2. Course Overview

Each day of the course emphasized a specific mathematical activity expressed by Bishop (2012). Sanders used Bishop's framework to establish the Lakota language specific to each activity, thereby showing connections at a basic level between mathematical terms and Lakota words (2011). The course facilitator and lead researcher, Luecke, began each day by introducing an overview of the day's activities. This was followed by a presentation by Sanders who presented a specific universal math activity utilizing content and examples from his dissertation. Luecke then presented the Western mathematical concepts that would be utilized for the subsequent small group discussions leading into a large group discussion. This general rhythm was repeated each day. A summary of the week is given in Figure 2.

Figure 17

Paper 3 Figure 2: Schedule Overview

Day	Universal Math Activity (Bishop 1991)	Language and Culture Topic (Sanders 2011)
Mon	Explaining / Counting	Lakota number system, fractions
Tues	Designing	The Significance of a Circle within Lakota Culture and within Math
Wed	Locating	Lakota Star Knowledge (guest presenter)
Thurs	Measuring	Archery (guest presenter)
Fri	Playing	Hand Game (guest presenter)

Note: This table shows the schedule of the week-long pilot course following the Universal Math Activity framework implemented by Sanders in a Lakota community.

5.3.3.3. Small Group Discussions

After the presentations by Sanders and Luecke, smaller groups were gathered with the selection of idealized group members based on specific criteria. Each group contained a facilitator and at least one Lakota speaker, one Lakota language teacher, one math teacher, and one elder. The small group discussions consisted of answering the small group discussion questions. Often the discussion included a deeper explanation in English of the mathematical concept introduced by Luecke and Sanders. This was followed by a conversation about the concept/activity itself and an engagement with Lakota language speaker(s) to determine if they could recreate the mathematical concept utilizing the Lakota language with additional questions and support offered by the Lakota language instructors. From the framework perspective, the process looked something like this:

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(*) Western Math → English Language → Lakota word or phrase → Lakota context(s) for word or phrase → Discussion and agreement

At the beginning of the week, all participants were gathered together for the first time, most not knowing the participants from a different group (language teachers and math teachers). Relationships were built during the daily exercises and discussions. Much of the work in Indigenous research methodologies has a heavy dependence on strong trusting relationships. Facilitators ultimately had to gain the trust of all participants in their respective groups while implementing the tasks.

5.3.4. Methods of Data Collection and Analysis

Following an Indigenous research paradigm as described by Wilson (2008), the data collection and analysis/synthesis for this project are non-linear and instead flow from a reality based on relationship and relational accountability. Specifically, this means that the two reciprocal research questions guiding this article were not clearly articulated until after the data were collected.

During the course, multiple data sources were collected. Non-quantifiable relational outcomes (among the participants and with the content/framework) were experienced, noted by the co-facilitators (now co-authors), and intuitively synthesized to provide initial confirmation of the D/Lakota Math Connections framework (Wilson, 2008). Later, as a process of circling back (Windchief & Pedro, 2019), the initial confirmation was encircled (that is, brought into greater relationship and a strengthening of the relationships that made up the initial confirmation) by the two reciprocal research (Wilson, 2008).

In the future, circling forward will occur in the continual development of the framework. As math and language teachers implement D/Lakota math connections in their classrooms and

fluent elders continue to share their wisdom and expertise, the Four Circles framework will be re-defined. Data collection and data synthesis will continue reciprocally and cyclically. As new relationships are formed through experiencing the framework, the understanding of the framework will grow beyond this written article. The research process used for the D/Lakota Math Connections project emphasizes a relationship-oriented over object-oriented approach, an action-oriented over definition-oriented approach, a cyclical intuitive over a linear disconnected approach (Wilson, 2008; Kovach, 2009; Smith et al., 2018; Windchief & Pedro, 2019).

The initial confirmation of the Four Circles framework was brought into the greater relationship, that is encircled, by the two research questions. To address how the framework impacted the participants, a quantitative analysis was conducted on participants' self-assessment framework drawings of their change of knowledge from Monday to Friday. To address how the participants influence the framework, two additional methods were employed. First, a quantitative analysis was conducted on the participants' emphasis scale ratings via the framework of the course. Second, and arguably the most important, the knowledge keepers of the community (that is fluent elders) shared their perspectives on the course, framework, and project overall.

5.4. Results

The results section is divided into three subsections:

Connections amongst people as an initial confirmation.

Framework impacts participants.

Participants influence framework.

5.4.1. Connections among People as an Initial Confirmation

Priority is given to relational accountability in an Indigenous research paradigm. It is the crucial concept for both the methodology and axiology (determining what research is valid/credible and what research is valuable, respectively). Generally, non-quantified connections among people may seem insignificant or less credible within some Western research paradigms, but within an Indigenous research paradigm, these relational details are invaluable.

During the summer 2021 "D/Lakota Math Connections" course, multiple relationships began or were strengthened throughout the week. Math teachers, language teachers, and elders all expressed (in off-hand comments and some in their post-surveys and post-interviews) the value of simply being together in the same room with dedicated time to discuss and learn from one another. Even though food was provided each day for the course, during the last 3 days of the week, local language instructors felt invested in the success of the project as evidenced by bringing in additional food to share with the class. The sharing of food created a positive, inclusive environment for all. Furthermore, upon completion of the week, Wahóȟpi Kiŋ (the Lakota Language Immersion Nest) at Sitting Bull College asked Luecke to continue working with the school as a math consultant. They also suggested applying for and co-writing a grant with Luecke to continue the work started during the course. Finally, during the Friday Talking Circle, each person present was able to publicly share their thoughts on the course, the framework, and the future of the project. Elders, along with many participants, shared their public support for the project, framework, and its continuance. Not one person suggested the project be discontinued, but rather every participant encouraged its continuation.

One Wahóȟpi Kiŋ instructor shared publicly during the Friday Talking Circle the following quote:

"I really appreciate everybody that was here because often when something like this happens, and having worked for my tribe, 'the Lakota thing is always the Lakota teachers.' So you being a Lakota teacher, [you are told] 'they will do it.' So I'm really grateful to have the math teachers come in and working and asking, how do you get cultural knowledge into content? [In the past] The math people are always like 'oh you can't do it. Sorry, they are just numbers. It's just not happening.' And then [they] don't come to these things because [they] think it's not possible. So to be open and say yes you can, I think it's important that we have everybody that is working in math move forward with it… We need the cultural knowledge but we also need someone that can clearly articulate and knows the math concept that we are trying to articulate, and like where do we find it. I just think we need all those parts, and it's slower moving to bring everybody. Or you might not think you know a lot about math, but being able to make the connection, 'oh, I know where I see that in our community, in our lifeways, in things that my grandparents taught me.' Making those connections is important. And just making math relevant for our students, for our Lakota kids, is the most important thing. Because a lot of the time there is not a quick connection [with math] to who we are as Lakota people, but we are learning and it [the framework] makes it [math] more open and that connection is made. This connects to your modern day life and the past as well, about keeping those [traditional and modern] connections strong. I deal with it in our school down the hall, and I'm sorry you guys couldn't come down and see the school, but that's what we do, try to make our education as relevant as possible, maintaining who we are as Lakota people, is the core of what we offer as we teach. I think it [this course] was amazing and I'm really grateful to be here."

This quote has many key ideas, from connecting with math teachers, the process/framework of making connections across expertise areas, and how Wahóȟpi Kiŋ values D/Lakota identity. The aspect we will draw out from this public statement is the multiple references to the value of making connections among math instructors, language instructors, and fluent elders. The quote began with an appreciation, and even enthusiasm, for math instructors being present for culture and language efforts contrasted with the past math instructors. The language instructor even apologized for not being able to invite the whole class to visit Wahóȟpi Kiŋ. Furthermore, this language instructor emphasized the expertise needed in both mathematics and the culture and the value of people coming together even if it would take more time and effort. Overall, the strengthening relationships among the math instructors, language instructors, and elders and their collective response to the course and framework was an initial confirmation of the research and framework.

5.4.2. Framework Impacts Participants

The initial framework confirmation was encircled by the two reciprocal research questions for this article. To answer the question "In what ways, if any, did the framework impact the participants?" a quantitative analysis was conducted on participants' Monday–Friday Drawings (MFDs). MFDs are a self-assessment of personal knowledge via free-hand drawings. On Friday, participants described the amount of their knowledge on both Monday and Friday. Participants were asked to reason with/through the D/Lakota Math Connections framework and self-assess the amount of their knowledge in each of the Four Circles as well as their connection among the Four Circles for both Monday when they entered the course and in that present moment on Friday as they were finishing the course. Since perceptions of D/Lakota Math were anticipated to change, fitting with best practice to manage 'response-shift bias' (Howard, 1980),

both the self-assessment drawing for Monday (reflecting back to the start of the week) and for Friday were completed on Friday.

There are limitations in these pre-post self-assessment MFDs. We realize that this form of self-assessment is subjective and wholly dependent on an individual's perceived understanding of a specific circle at a given moment (Howard, 1980). Despite that, we assumed that growth in a circle meant an increase in knowledge. We also assumed that an intersection meant a connection/relationship between the circles. Some participants provided an additional narrative to the diagrams which helped the researchers with their interpretations. The MFDs were analyzed by the two co-authors separately to compare, contrast, and synthesize their findings and discuss implications for teaching and learning mathematics with Indigenous communities and students.

Using the lens of math fluency and language fluency growing together, the MFDs were analyzed by individual circle growth and by intersection with other circles, all by category of people (math instructor, language instructor, and elder). The first subsection analyzes the data showing how the course/framework impacted the individual math fluency and individual language fluency of the participants. The second subsection focuses on the connections between the Four Circles to describe if/how math and language fluency grow together. For both subsections, a middle school math instructor's MFD will be an exemplar leading to a summary of all MFDs.

5.4.2.1. *Math Fluency Increases, Language Fluency Increases*

This subsection focuses on the size of the circles (through size ordering and circle growth tallies) to describe individual math fluency changes and individual language fluency changes. Figure 3 shows the MFD exemplar.

Figure 18

Paper 3 Figure 3: Exemplar of a Monday-Friday Drawing by a Middle School Math Teacher in Standing Rock.
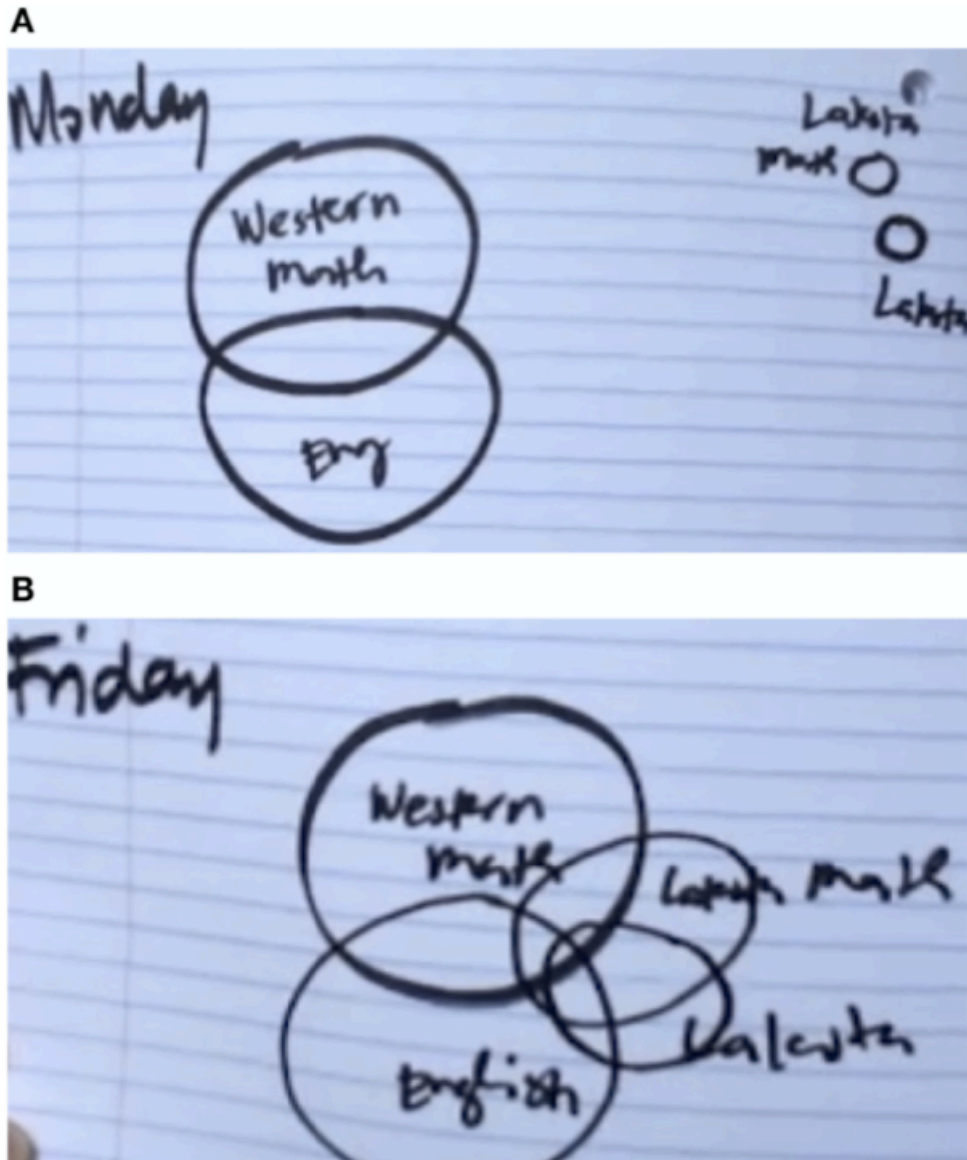
Note. (A) The Monday drawing of self-assessed knowledge of and connection among the four circles. (B) The Friday drawing of self-assessed knowledge of and connection among the four circles.

To initially describe the MFD, on Monday's pre-self-assessment, this participant only had English and Western Math intersecting, showing a relationship between the two. Lakota Math does not intersect with anything nor does Lakota. They are depicted as far away from Western

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Math and English as possible in the study. The participant's Friday diagram shows all the areas

coming together. All four circles intersect with each other on Friday showing connections and

relationships among the four. The circle sizes for Lakota Math and Lakota also substantially

increase showing knowledge growth in both areas. Note that not all participants placed their

circles similar to the standard depiction of the framework.

First, we will analyze circle size ordering. The exemplar on Monday has order largest to

smallest as WM = E and LM = L, meaning the Western Math and English circle tie for largest

(most self-assessed knowledge) and the Lakota Math and Lakota circle tie for third largest (least

self-assessed knowledge). The exemplar on Friday has order largest to smallest as WM = E, LM,

and L. The only change in order is Lakota decreased from third to fourth largest. The circle size

ordering for all MFDs is shown in Figure 4.

Figure 19

Paper 3 Figure 4: Summary of Circle Size Ordering for All MFDs

A

MONDAY (pre-self-assessment)	Largest	2nd Largest	3rd Largest	Smallest
English	18	0	0	0
Western Math	3	7	7	1
Lakota	1	4	12	1
Lakota Math	1	0	8	9

B

FRIDAY (post-self-assessment)	Largest	2nd Largest	3rd Largest	Smallest
English	17	1	0	0
Western Math	3	7	7	1
Lakota	3	2	10	1
Lakota Math	1	0	10	7

C

CHANGES	# Moved	# Increase	# Decrease
Lakota	4	3	1
Lakota Math	4	3	1
English	1	0	1
Western Math	1	1	0

Note. (A) Shows circle size ordering on Monday for all MFDs disaggregated by each circle. (B) Shows similarly for Friday. (C) Shows the movement of circle size ordering from Monday to Friday.

Observe that English was identified as the largest circle by all participants signifying their level of comfort regarding their knowledge of English in relation to the other three areas.

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Lakota Math was an area that was identified by participants as their least knowledgeable area. This demonstrates that most participants do not view themselves as balanced in these four areas of the framework. English and Western Math in general are dramatically over-emphasized in self-assessed knowledge.

Second, we will analyze the growth of each circle compared to itself from Monday to Friday, assumed by the researchers to mean a self-assessed growth in knowledge of that individual circle. Figure 3 exemplar demonstrates growth in Lakota Math and Lakota and no change in Western Math and English. The individual circle growth for all MFDs is shown in Figure 5.

Figure 20

Paper 3 Figure 5: Tallies and Percentages of Self-Assessed Knowledge Growth.

	English Language	Western Math	D/Lakota Math	D/Lakota Language	Group Total (tally - mean)
Language Teachers (n=5)	0 - 0%	2 - 40%	4 - 80%	3 - 60%	9 - 1.8
Math Teachers (n=7)	0 - 0%	2 - 29%	7 - 100%	5 - 71%	14 - 2.0
Random/Misc. (n=5)	0 - 0%	2 - 40%	2 - 40%	2 - 40%	6 - 1.2
Circle Total	0 - 0%	6 - 35%	13 - 76%	10 - 59%	29 - 1.7

Note. The tallies and percentages are disaggregated by individual circles (columns) and categories of people (rows). The bottom row is the circle total across all MFDs. The far-right column is the total tally and means per category of people across all four circles.

There are multiple trends and notable singularities but only two will be highlighted for brevity. First, observe that the D/Lakota Math Circle had the most people self-assess knowledge growth with 13 out of 17. Second, observe that the Western Math Circle had some people from each category share growth in their knowledge. This is especially interesting for two out of seven math teachers who self-assessed growth in their knowledge of Western Math. Overall, the highest tallies and percentages of the table are for math and language teachers for the D/Lakota

Math and D/Lakota Language Circles. This data is the first evidence that math fluency and language fluency can grow together.

To close this subsection, a TCU math instructor's brief explanation of their MFD is unpacked. The TCU math instructor wrote next to their MFD, "English [stayed the] same. Lakota improved. [I] learned more, corrected pronunciations of words I've been saying incorrectly. Western Math [I] learned ways to help students visualize better things I was teaching. Lakota math, I have more ideas on how to integrate culture into the content I teach." In order of the quote, first note that English as a content area did not see any change. The Lakota did improve, especially in the pronunciation of words. It should not be understated how important this is. Pronunciation of Lakota words is key to the communication between speakers. Lakota language has specific guttural sounds, for instance, that if missed damages the word itself. Pronunciation is the first step to communicating in Lakota. The third comment about Western Math is in relation to teaching. The week-long course allowed this participant a fresh look at how to teach mathematics. It increased Western math understanding, making the participant a better math teacher. The final comment is instructive as well, if this individual teaches Lakota/Dakota students, then the participant is more equipped to make the content more culturally responsive. The participant can now draw on the Dakota/Lakota language to make connections between mathematics and the lives of the students.

5.4.2.2. Connections between Math Fluency and Language Fluency Increase

This subsection focuses on the connections between the Four Circles to describe if/how math and language fluency grow together. Once again, the middle school math instructor's MFD is used as an exemplar leading into a summary of all MFDs. Each MFD is redrawn into a standardized diagram as a way to visually see the relationships (and changes in relationships)

between the four circles. Only the intersection between two individual circles is depicted. The six intersections among the four circles are ranked in four tiers from no touching to an increase in connection from Monday to Friday. Recall that the amount of intersection of two circles in the MFD is assumed to mean the amount of connection between the two knowledge areas.

The Figure 3 exemplar is redrawn as the standardized four-tier intersection diagram in Figure 6.

Figure 21

Paper 3 Figure 6: Exemplar of Four-Tier Intersection Diagram from the Monday-Friday Drawing by a Middle School Math Teacher in Standing Rock (Figure 3).

A

Monday Four-Tier Diagram

Friday Four-Tier Diagram

Score = 2

Score = 12
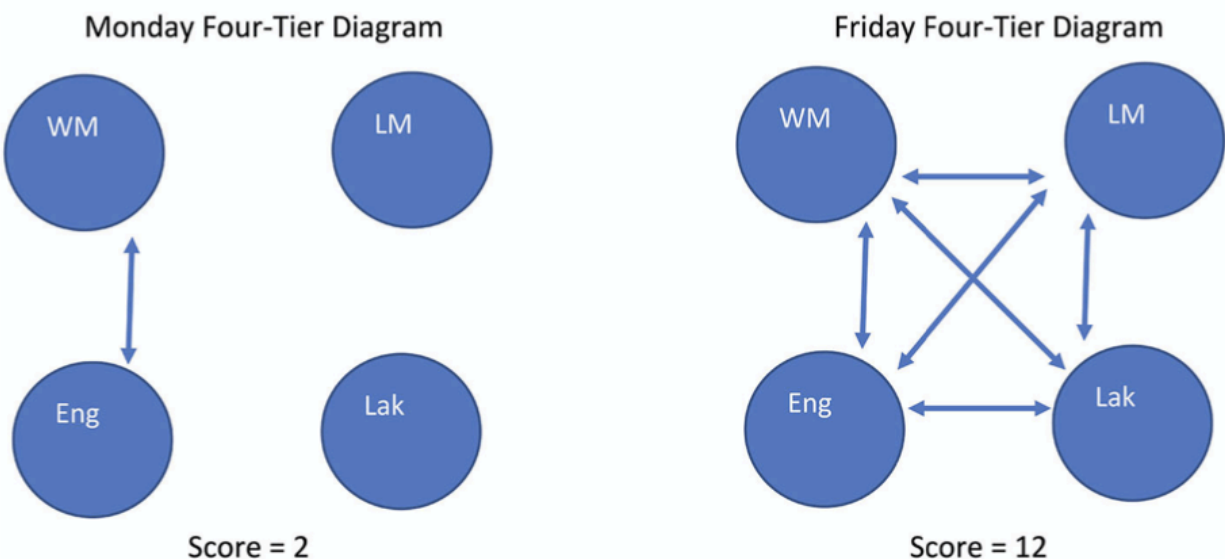
B

Four-Tier Monday and Friday Diagram Key

Tier	Freehand Circles	Arrow Representation	Score
0	No touching of two circles	No arrow	0
1	Two circles tangential with no intersection	Dotted line arrow	1
2	Two circles are intersecting	Standard arrow	2
3	Two circles intersection has increased	Bold arrow	3

Note. (A) The Monday Four-Tier Intersection Diagram and Friday Four-Tier Intersection Diagram. (B) Four-Tier Intersection Diagram Key. The single intersection in the exemplar MFD (Figure 3) is represented by a single arrow in the Monday Four-Tier Intersection Diagram.

A deeper analysis of the Monday and Friday Four-Tier Intersection Diagrams leads to the Three-Tier Change Diagram where the arrows and score build off the four-tier rankings. The Figure 3 exemplar is redrawn as the standardized Three-Tier Change diagram in Figure 7.

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Figure 22

Paper 3 Figure 7: Exemplar of Three-Tier Change Diagram from the Monday-Friday drawing by a middle school math teacher in Standing Rock (Figure 3) and Four-Tier Intersection Diagram (Figure 6).

A

Three-Tier Change Diagram

Score = 10

B

Three-Tier Change Diagram Key

Tier	Freehand Circles (Monday-Friday change)	Arrow Representation	Score
0	No change in intersection	No arrow	0
1	Two circles change one tier in 4-Tier diagrams	Standard arrow	1
2	Two circles change two tiers in 4-Tier diagrams	**Bold** arrow	2
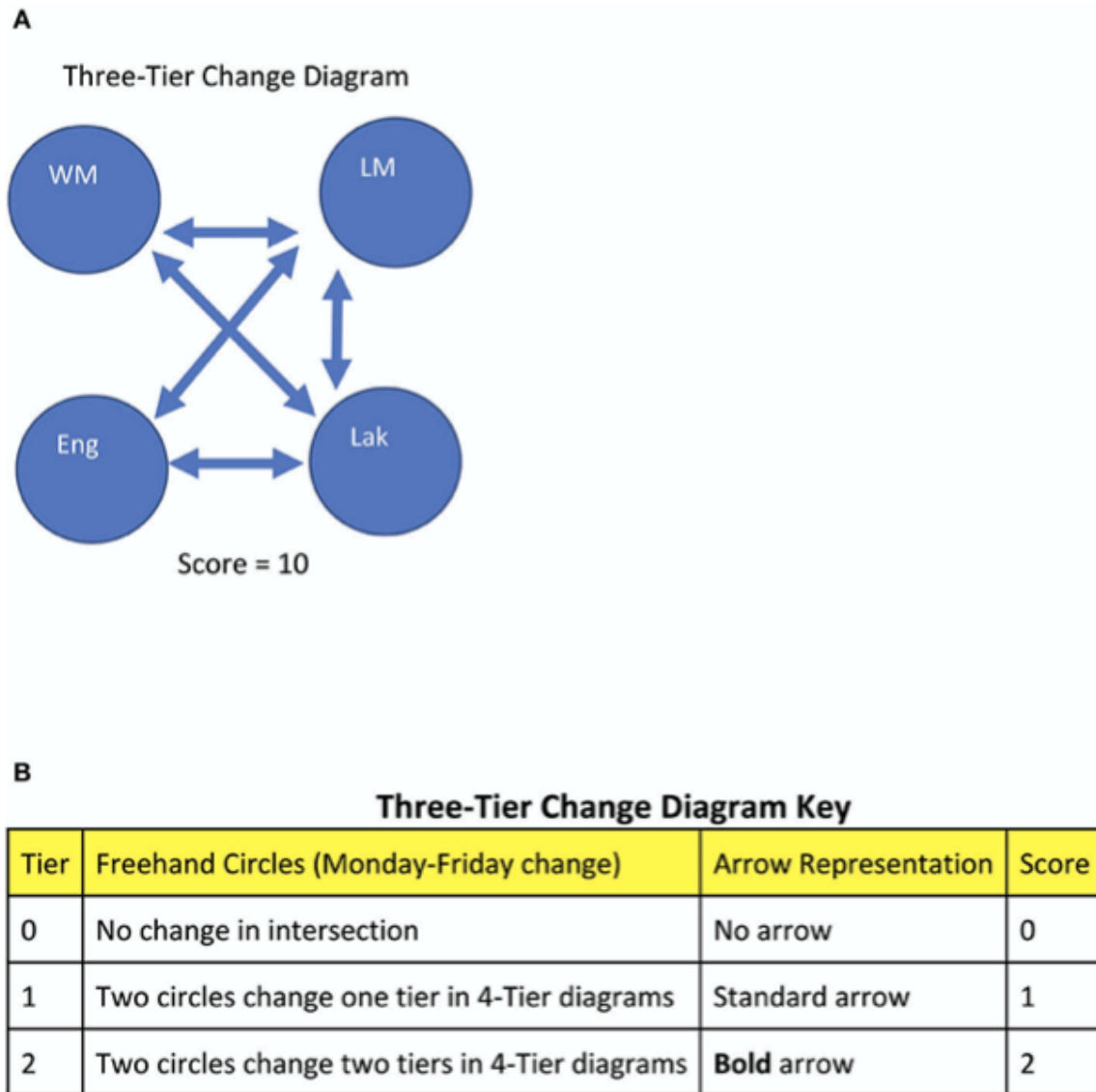
Note. (A) The Three-Tier Change Diagram. (B) Four-Tier Intersection Diagram Key. The single intersection in the exemplar MFD (Figure 3) is represented by a single arrow in the Monday Four-Tier Intersection Diagram.

The standardized Monday and Friday Four-Tier Intersection Diagrams and Three-Tier Change Diagram allow the relationships between any two circles to be visualized as well as compared across all MFDs. The scoring system is an arbitrary quantification (0, 1, 2, 3 chosen

for ease), yet it gives some sense of distinction when summing the arrows of each standardized diagram. The standardization and scoring system allow the diagrams to be compared across all MFDs. Specifically, the mean and median intersection scores can be averaged across all MFDs and dis-aggregated across each of the six connections and three groups of people (math teachers $n = 7$, language teachers $n = 5$, and all MFD participants $n = 17$) as shown in Figure 8.

Figure 23

Paper 3 Figure 8: Mean Scores Heat Map of Four-Tier Monday–Friday Intersection Diagrams.

Group	Diagram	E-WM	E-LM	E-L	WM-LM	WM-L	LM-L	TOTAL
All	Monday	1.8	0.9	1.8	0.9	0.5	1.3	7.2
All	Friday	2.1	2	2.4	2	1.3	2.4	12.2
Math	Monday	2	1.3	1.7	1	0.6	1	7.6
Math	Friday	2	2.6	2.6	2.4	1.6	2.1	13.3
Lang	Monday	1.8	0.8	1.8	1	0.6	1.4	7.4
Lang	Friday	2.2	2	2.2	1.8	1.2	2.6	12
4-Tier Calibrate		0	3					

Note. The heat map shows the mean scores disaggregated by each two-circle intersection (columns) and category of people (rows). A higher number represents a higher intersection score which means a greater amount of self-assessed intersection/connection among the circles. The far-right column is the sum of the means aggregated across all six intersections emphasizing the overall value for each category of people on Monday and Friday and is calibrated only among the included six numbers (7.2–13.3). The central disaggregated heat map is calibrated 0–3 to match the Four-Tier scoring.

There are multiple trends and notable singularities but only two will be highlighted for brevity. First, observe that the far-right column heat map that shows the average of every group moved toward a larger intersection score from Monday to Friday. Second, observe that the WM-L column has the most red (lowest intersection). Despite being the lowest connection, in the post-surveys, 15 out of 21 people specifically shared the value of vocabulary connecting Western math and Lakota when asked about the implementation of this project in your classroom. This observation could lead to the interpretation of bias from the standard depiction of the Four

Circles framework (Figure 1) not visually depicting E-LM and WM-L. However, this was

rejected due to the highest score in the table being 2.6 for E-LM.

The Three-Tier Change Diagram can also be analyzed across the six connections and

three groups of people (Figure 9).

Figure 24

Paper 3 Figure 9: Mean Scores Heat Map of Three-Tier Change Diagrams.

Group	Diagram	E-WM	E-LM	E-L	WM-LM	WM-L	LM-L	TOTAL
All	Change	0.2	1.1	0.5	1.1	0.8	1.1	4.8
Math	Change	0	1.3	0.9	1.4	1	1.1	5.7
Lang	Change	0.4	1.2	0.4	0.8	0.6	1.2	4.6
3-Tier Calibrate		0	2					

Note. The heat map shows the mean scores dis-aggregated by each two-circle intersection (columns) and category of people (rows). A higher number represents a greater change in the Four-Tier intersection score which means a greater amount of self-assessed change in intersection/connection among the circles. The far-right column is the sum of the change of means aggregated across all six intersections emphasizing the overall change for each category of people and is calibrated only among the included three numbers (4.6–5.7). The central disaggregated heat map is calibrated 0–2 to match the Three-Tier change scoring.

Again, there are multiple trends and notable singularities but only two will be highlighted

for brevity. First, observe that all numbers are positive, the most significant trend. This means a

positive growth of connections among all circles, albeit varying amounts per group of people and

connection. Second, observe the most red in the E-WM column. This means that this connection

changed the least throughout the week, which was anticipated with the focus of the project on

connecting with the Lakota language, culture, and values.

The median heat maps help accentuate additional details. Figure 10 is the median heat

map for the same data in Figure 8 mean heat map.

Figure 25

Paper 3 Figure 10: Median Scores Heat Map of Four-Tier Monday–Friday Intersection Diagrams.

Group	Diagram	E-WM	E-LM	E-L	WM-LM	WM-L	LM-L	TOTAL
All	Monday	2	1	2	1	0	2	8
All	Friday	2	2	2	2	2	3	13
Math	Monday	2	2	2	1	0	1	8
Math	Friday	2	3	3	2	2	2	14
Lang	Monday	2	1	2	1	0	2	8
Lang	Friday	2	2	2	2	1	3	12
4-Tier Calibrate		0	3					

Note. The heat map shows the median scores dis-aggregated by each two-circle intersection (columns) and category of people (rows). A higher number represents a higher intersection score which means a greater amount of self-assessed intersection/connection among the circles. The far-right column is the sum of the medians aggregated across all six intersections emphasizing the overall value for each category of people on Monday and Friday and is calibrated only among the included six numbers (8–14). The central dis-aggregated heat map is calibrated 0–3 to match the Four-Tier scoring.

Observe similar trends to the mean heat maps. Additionally, observe the same total median score of 8 on Monday for all three groups of people. Furthermore, observe that the total median score on Friday is not identical for math instructors and language instructors. The median heat map for Three-Tier Change Diagrams helps explain this difference (Figure 11).

Figure 26

Paper 3 Figure 11: Median Scores Heat Map of Three-Tier Change Diagrams.

Group	Diagram	E-WM	E-LM	E-L	WM-LM	WM-L	LM-L	TOTAL
All	Change	0	1	1	1	1	1	5
Math	Change	0	1	1	1	1	1	5
Lang	Change	0	1	0	1	0	1	3
3-Tier Calibrate		0	2					

Note. The heat map shows the median scores disaggregated by each two-circle intersection (columns) and category of people (rows). A higher number represents a greater change in the Four-Tier intersection score which means a greater amount of self-assessed change in intersection/connection among the circles. The far-right column is the sum of the change of medians aggregated across all six intersections emphasizing the overall change for each category of people and is calibrated only among the included three numbers (3–5). The central dis-aggregated heat map is calibrated 0–2 to match the Three-Tier change scoring.

Observe that language instructors have a median change of one for all three connections with D/Lakota math and a median change of zero for the connections with D/Lakota language. In contrast, math instructors also have a median change of one for the connections with the D/Lakota language. This is understandable as language instructors came into the course with a much stronger understanding of the language compared to math instructors and thus experienced less change. However, all groups self-assessed a median change of one for D/Lakota Math.

Furthermore, the median heat maps allow for visual representations similar to the exemplar's Three-Tier Change Diagram (Figure 7) for each of the three groups of people (Figure 12). Note that Figure 12 contains the same information as Figures 10, 11, but the numbers/colors are represented as different types of arrows following the same keys shared in Figures 6, 7. All the same observation trends from the heat maps can be visualized within these nine diagrams.

Figure 27

Paper 3 Figure 12: Median Four-Tier Intersection Diagrams and Median Three-Tier Change Diagrams.
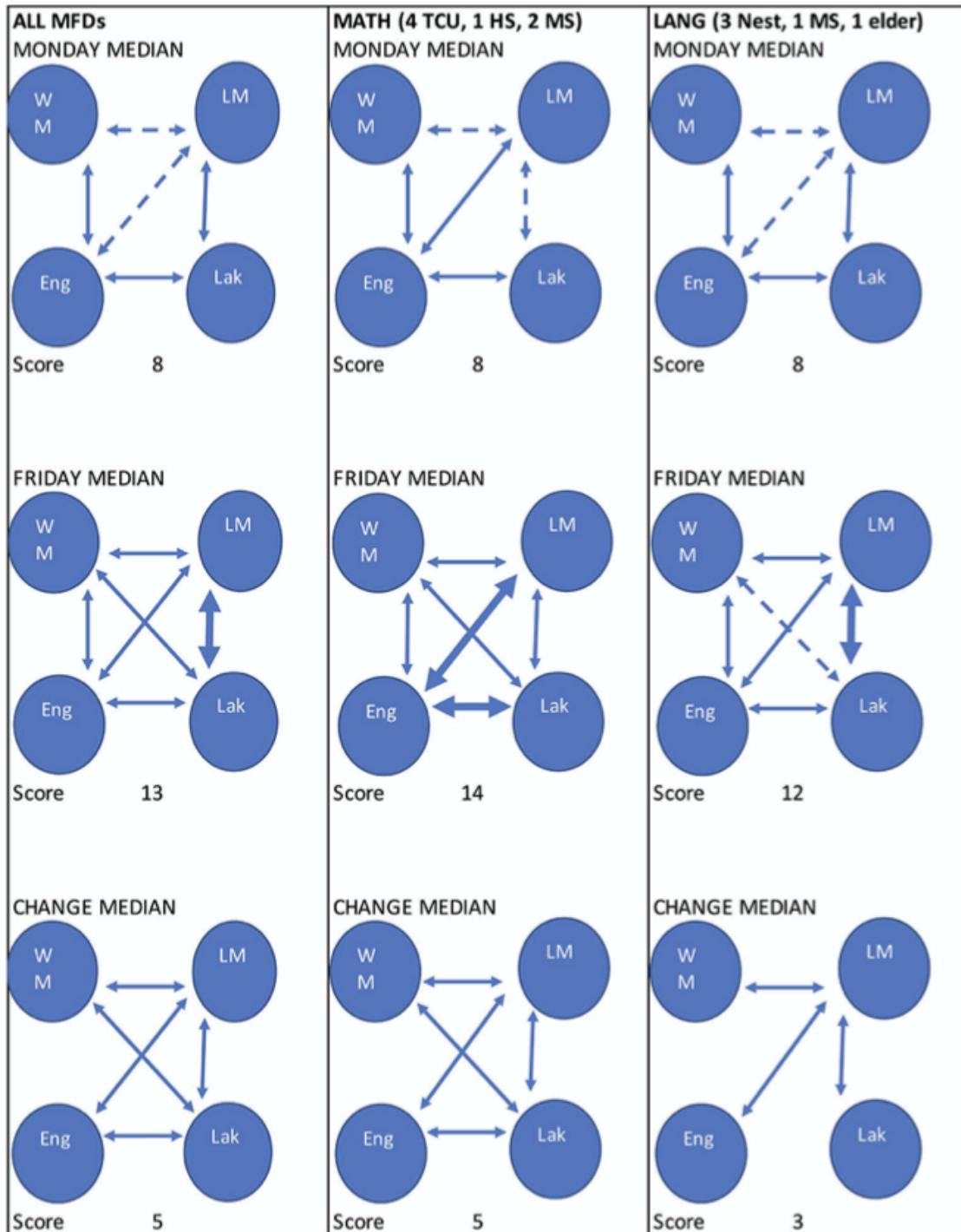
Note. Each column represents a group of participants (all MFDs, math instructors' MFDs, and language teachers' MFDs). Each row represents the Monday Four-Tier Intersection Diagram, the Friday Four-Tier Intersection Diagram, and the Three-Tier Change Diagram, respectively.

Altogether, it seems that the week-long course provided participants the opportunity to learn more about each topic area individually and also provided participants the opportunity to see that there are indeed connections across the four content areas. Elders, Lakota language instructors, and math instructors all ended up with essentially the same outcomes that there are Dakota/Lakota math connections and that their math and language fluency grew together.

5.4.3. Participants Influence Framework

In what ways, if any, did the participants influence the framework?

This subsection is further divided into three subsections.

Three-color emphasis activity.

Naming the four circles.

Significant teachings from elders.

5.4.3.1. *Three-Color Emphasis Activity*

Similar to the MFDs, the Three-Color Emphasis Activity asked participants on Friday to rank their perceptions of the course through the lens of the framework. Together, the MFDs and Three-Color Activity are the main methods of data collection using the framework. The MFDs are an interesting tool because no assumption is made that participants enter the course in the balanced state that the framework posits. Similarly, the Three-Color activity makes no assumption that the facilitators taught the course (implicitly and explicitly) from a place of balance. This activity makes clear the perceptions of the participants on what was explicitly and implicitly included/emphasized within the week-long course. The Three-Color Activity allows the participants to evaluate the course and thus influence the framework.

The participants were asked to color three distinct levels (minimal, somewhat, and a lot)

showing their perception of the Four Circles and their intersections as experienced through the

course. Figure 13 shows an exemplar from a fluent elder.

Figure 28

Paper 3 Figure 13: Three-Color Activity Exemplar from a Fluent Elder.
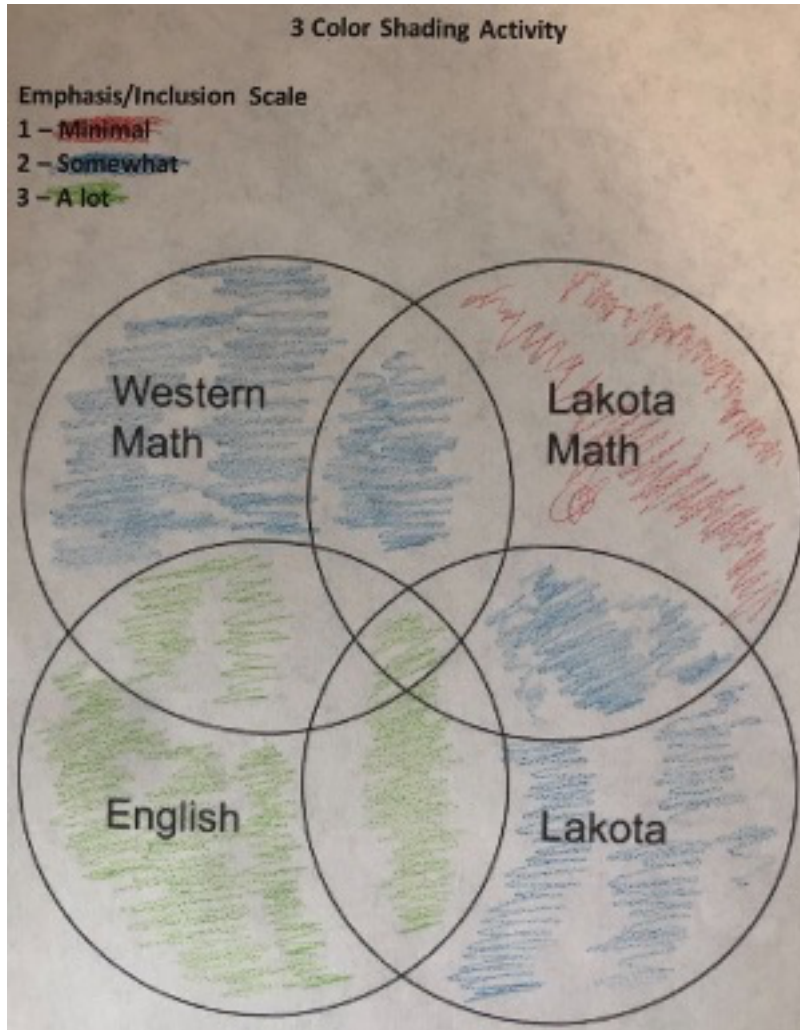
Note. The three colors of shading following the emphasis/inclusion scale in the top left. Here,
green means emphasized/included "a lot" and a score of 3. Red means emphasized/included in a
"minimal" way and a score of 1.

The Three-Color Emphasis Activity was analyzed into a 3x3 heat map where 1 is

"minimal" and 3 is "a lot." Similar to the MFDs, only the major intersections of two circles are

included to make a 3x3 table. The four smaller intersections of three circles and excluding one

are not included in the analysis. Furthermore, by the de facto design of a four-circle Venn

diagram, two major intersections are missing (Western Math and Lakota, as well as Lakota Math

and English). Figure 14 shows the 3x3 heat map representation for a participant in each group of

people.

Figure 29

Paper 3 Figure 14: Three-Color Activity Analysis Exemplars for an Elder, Math Instructor, and Language Instructor.

Note. Here are three exemplars of analyzed three-color emphasis activities from a fluent elder, a math instructor, and a language instructor. The key follows the standard depiction of the Four Circles framework.

The analysis across all participants reveals the perception of the course through the lens

of the framework (Figure 15).

Figure 30

Paper 3 Figure 15: Three-Color Activity Analysis Across All Participants.

Key	WM		LM		Mean	2.5	2.2	1.7
		C			All	2.5	2.2	2.2
	E		L		n=21	2.8	2.5	2.1
Calibrate	1	3						
Mean	2.2	2.1	1.5		Mean	2.6	2.0	1.7
Lang. Instr.	2.5	2.1	2.1		Math Instr.	2.4	2.0	2.0
n=8	2.8	2.5	2.1		n=7	2.7	2.6	2.1
Median	3	2	1.5		Median	3	2	1
Lang. Instr.	3	2	2		Math Instr.	2	2	2
n=8	3	2.5	2		n=7	3	3	2
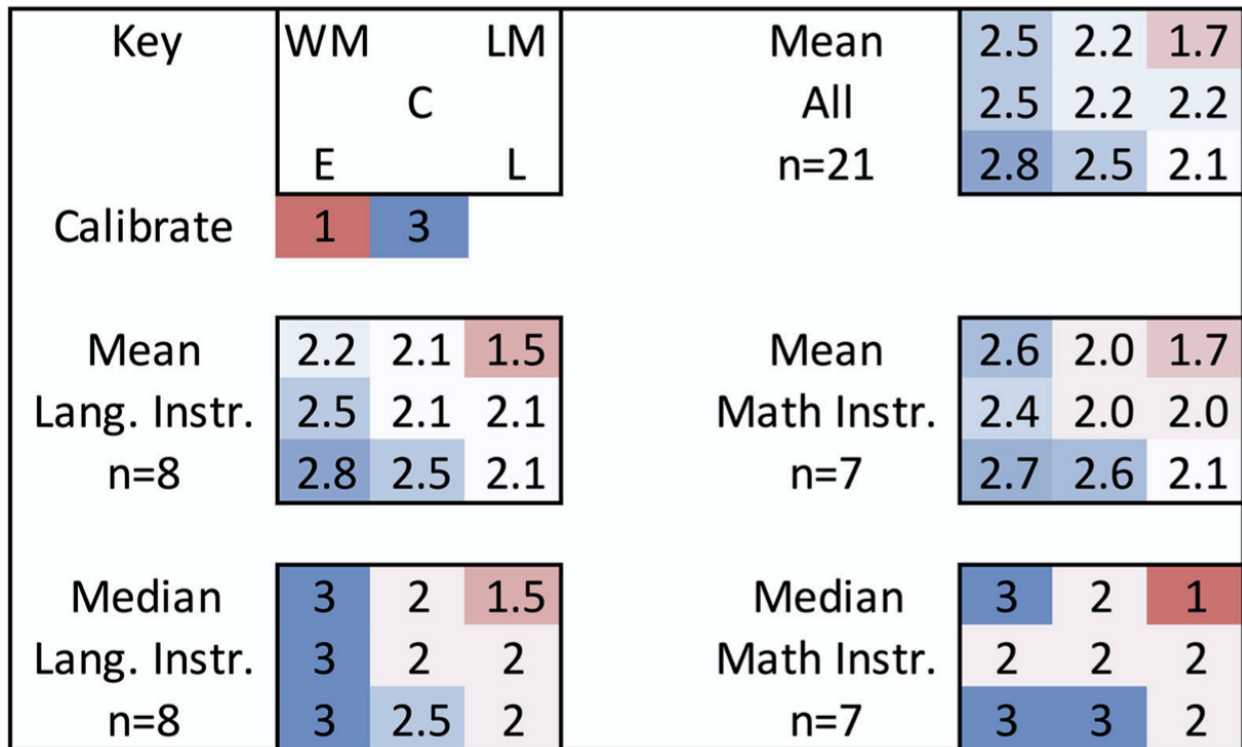
Note. Six 3x3 heat maps show the key and five variations of mean and median and groups of people. The heat maps are calibrated between 1 and 3 because the activity allowed those values of coloring.

Observe more blue (higher numbers) on the Western side of the four Circles framework. This means participants perceived that Western Math and English were the most highly emphasized/included. The medium of communication was English almost entirely, except for one small group on 1 day, the medium was Lakota when the math instructor was absent at that moment.

Next observe that Lakota Math is the most red (lowest number) and Lakota language a light pink, light blue, or white. Lakota Math was perceived (and thus evaluated) as the least emphasized or included within the course. This corroborates/triangulates/encircles with what one language instructor shared publicly during the Friday Talking Circle. The language instructor

shared about the value of holding space where we can think and discuss traditional Lakota math. There is constant pressure in our colonized society to learn and over-value Western ways of knowing, but if Lakota Math is going to continue we need to learn to hold space and emphasize Lakota math without seeking justification from Western math and English. The language instructor continued by asking how we can make connections to the Lakota math circle without first strengthening it.

Finally, observe that there is basically no substantial difference among the participants when disaggregated into subgroups. The mean values for all participants, the math instructors, and the language instructors had negligible differences.

5.4.3.2. Naming the Four Circles

The MFDs and Three-Color Activity were specifically designed from the D/Lakota Math Connections framework. However, during the week, the course was called "Lakota Math Connections" and the framework was called the "course and research framework." This subsection will share every circle name used across all participants; 11 of the 17 used the names given in the instructions/framework, however, six did not.

One language teacher and elder wrote "DM" and "Dak Math" for their "LM-Lakota Math" circle. This participant's naming along with encouragement from Standing Rock Iyapi brought about the official name change of the circle and framework to "D/Lakota Math" and "D/Lakota Math Connections," respectively. Furthermore, recall that the summer course happened during a larger language institute called the "D/Lakota Summer Institute."

One language teacher wrote "Colonial math" in replacement of "WM-Western Math." The emphasis on colonization through mathematics aligns with the 1990 article by Bishop titled, "Western mathematics: the secret weapon of cultural imperialism." Some in academia prefer the

titles "global math," "near global math," or "conventional math." Most participants seemed fine

using Western math for simplicity and to not miss the colonizing nuance of the term

Western. D'Ambrosio (2000) makes an analogy of Western Math being like "a great river shored

up by its tributaries, water from the tributaries being the contribution of many diverse non-

Western peoples, cultures, and societies… However, in the process of building mathematical

knowledge, many of the contributions of non-Western cultures have been rendered invisible and

have been appropriated, marginalized, lost, silenced, and/or hidden" (p. 79). This language

teacher does not miss the nuance in the term "Western math" and chooses to write "Colonial

math" in its stead.

Three participants (a community member, math instructor, and language instructor) wrote

"M" or "Math" in replacement of "WM-Western Math." Writing "Math" and "Lakota Math" on

the same drawing gives privilege to Western math, whether the naming was intentional or

subconscious. It conveys Western math as the "normal" math and D/Lakota math which stood

strong for millennia on this continent as the marginalized way of mathematical thinking. The co-

authors feel that another reason why the term "Western math" is currently being used in the

framework instead of the alternative names such as "near global" or "conventional math" for

"Western Math" is that they seem to convey the same sentiment as replacing "Western Math"

with just the title "Math," privileging that over D/Lakota math.

Finally, one elder who completed the MFDs wrote "EM" which is assumed to mean

"English Math." This could potentially be an alternative to "Western Math" because it puts the

focus on language for both math circles. It is inferred that this elder saw "D/Lakota math" as

referring to the D/Lakota language more than the D/Lakota people.

5.4.3.3. Significant Teachings from Elders

The fluent elders are 100% essential to the D/Lakota Math Connections project. Every day began "in a good way" with an elder offering a prayer (in Lakota traditions it is customary for an elder to offer a prayer at a formal gathering that includes the phrase "in a good way"). Their spiritual and intellectual input, wisdom, and guidance cannot be overstated. The co-facilitators, language instructors, math instructors, and everyone in the course deferred to the elders and listened to their stories and contributions. Their contributions and stories hold both the content knowledge of the Lakota language and Lakota math as well as guide the entire course and research process. Their continued participation, sharing of stories and the language, and encouragement to continue the D/Lakota Math Connections project beyond the pilot course described in this study is the single most significant factor in the evaluation of the course, framework, and research process.

Specific stories and input shared by the fluent elders are included here. The co-facilitators asked elders one time to complete any formal surveys, evaluations, or activities, but did not force anything upon them. Each elder chose how to give their own response and input, as described in Indigenous Storywork (Archibald, 2008). That being said, here are some specific stories and input shared by some of the elders. As a note, Lalá means my grandpa, Uŋčí means my grandma, Lekší means my uncle, and all are used as terms of respect.

One fluent elder (who preferred not to be identified) shared a story about hunting a buffalo with a bow and arrow. It was something that he never grew up doing but was given the opportunity later in life. He said he was prepared not because he had done that exact activity before but because he had done many things surrounding that activity. He had made traditional bows and arrows, hunted deer with great accuracy, built the body and arm strength to use a

sinew-backed bow, and had relationships with the community that gave him the opportunity. Furthermore, he mentioned some activities that encircled the traditional buffalo hunts including the following:

Making sinew-backed bows and arrows.

Learning accurate, instinctive shooting from the hip while riding the horse.

Building body and arm strength to shoot a bow while riding the horse.

Riding horse bareback with no hands on the horse so hands could remain on the bow.

Building the bravery/courage to ride into the buffalo stampede.

Tracking and training the nose to smell where the game was located (we have lost the skill of smell today but were told that if you can smell a skunk, then you can train your nose to smell every small animal).

Knowing the land and terrain of where one is riding and recognizing what is up ahead.

He described his story about his buffalo hunt as well as describing past buffalo hunters with the phrases "learn all the peripheral… to really have the center stick," "you prepare for something by knowing/doing everything around it," and "you really know something if you understand all the peripheral [relationships/connections]."

This fluent elder's way to describe a buffalo hunt has become the metaphor for defining/encircling both "higher order math concepts" and "D/Lakota Math." The center (that is, a specific vocabulary word) is not defined as a static object but instead through the relationships and peripheral connections. This is similar to how Wilson (2008) describes an Indigenous research paradigm, "I also need to be clear that I am not promoting this book as a model of Indigenous research or data analysis; it is only one presentation of the view shared by my friends

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and myself as co-researchers… The very nature of our epistemology is that it will be different in other contexts" (p. 136). He shares the relationships that he has made with the central idea throughout the book but does not claim a single, final definition. There cannot be such a definition because it is dependent on context, that is, all the relationships in that place that give the central idea shape and form. As the fluent elder shared, if you want to really know something, you must encircle it, that is strengthen/learn about all the relationships and connections that make up its web of existence in that place.

Based on an Indigenous research paradigm and because of this fluent elder's story, some of the relationships that the course and co-authors connected to "D/Lakota Math" include:

D/Lakota language.

Western math.

Six universal math activities (counting, designing, locating, measuring, playing, and explaining).

Embodied and activity-oriented math, instead of a static body of knowledge.

Math is from nature and a way to describe nature.

Relationship-oriented (action and verb-oriented), instead of object-oriented (noun and definition-oriented).

Emphasis on stories.

Emphasis on spirituality.

Furthermore, some of the peripheral relations that encircle the term "higher order math concepts" include:

College-level math, not just at the elementary level.

Building upon the dissertation of Sanders that expressly began looking at base math

concepts connected to the language and culture (Sanders, 2011).

Conceptual strand in the Five Strands of Math Proficiency (National Research

Council et al., 2001).

Higher levels of student mathematical thinking in APOS (action-process-object-

schema) theory (Martin et al., 2010).

Again, none of these individual relationships make the whole concept. Instead, each one of the relationships informs the central activity/idea in some way by someone. Not every person makes all the relational connections and some people emphasize and/or understand one connection far greater than another connection. Overall, encircling the central idea to gain greater understanding fits in with the Indigenous way of thinking that is more relationship-oriented vs. object-oriented.

Uŋčí Ruby Shoestring and Uŋčí Grace Draskovic have consistently been part of translating and editing the videos and data from the summer course to develop the math resource for curriculum development from Dakota/Lakota culture, values, and language (see follow-on study). During these times of collaboratively watching video snippets from the course and translating and describing aspects of the language, multiple discussions around the D/Lakota Math Connections framework emerged. Specifically, three conversations will be shared and taken altogether to have perhaps the largest impact on how the framework is now viewed.

First, co-author Luecke was describing to Uŋčí Grace and Uŋčí Ruby aspects of the D/Lakota Math Connections framework and specifically the Western math circle. Luecke described that some people believe that math has no values attached to it and is distinct/separate from all cultural matters. Uŋčí Grace responded "Héčhetu šni." Freely translated this means,

"That's not right." Her two-word sentence reinforces the Four Circles framework. Her comment implies that math from a Lakota perspective includes Lakota values and culture, including the Lakota language.

Second, a while later, Uŋčí Ruby shares a comment about her grandparents. She said, "My grandparents never went to [a formal] school but did math all the time." On the surface, this demonstrates a distinction between Western math and Lakota math, the former being in school, at a desk on paper, and the latter not. At a deeper level, this implies a description of Lakota math as being outside, activity-based, embodied, and experienced. Uŋčí Ruby repeated her statement/sentiment another time later in the discussion.

Third and finally, as Uŋčí Grace and Uŋčí Ruby were working on developing Lakota words for abstract math words, a discussion began about the task. Together they described, "we can translate whatever we want. It's a descriptive language." This sentiment contains multiple components. First, it says the Lakota language is descriptive in contrast to the English language, which may be considered a definition-based language. Lakota describes what's happening (verb-oriented) and the context instead of a static definition (noun-oriented). Second, their sentiment conveys that the Lakota language is capable of translating whatever is desired by the Lakota people. The language is strong enough and dynamic enough for translation from any other language, including English and Western math. Third and finally, it depends on the desires of the Lakota people and fluent elders specifically. If collectively decided upon, then it can and will happen.

These three quotes from Uŋčí Ruby and Uŋčí Grace describe a powerful description to re-define and re-understand the D/Lakota Math Connections framework. After being introduced to the framework, having some experience using it and thinking through it, their three quotes

hugely influence the overall comprehension of the framework and its applications in math classrooms, language classrooms, and the continual development process.

Finally, two stories are shared from Lekší Kevin Locke's experience with the course and framework. When asked to complete the Three-Color Emphasis Activity to evaluate what aspects the course explicitly and implicitly emphasized/included through the Four Circles framework, he shared extremely valuable feedback in his own way. Instead of ranking the circles and intersections via three colors, he used the three colors to make a pretty design with the four-circle Venn diagram and said something like, "I cannot rank these different circles and their intersections separately, they are all interconnected." By not completing the survey, he powerfully made a statement about the intersections and interconnectedness of all the circles, that black lines on paper can never separate these circles in a Lakota reality. His feedback impacts the framework and specifically helps re-define and re-understand the initial statement "Each circle is connected to all the others."

Lekší Kevin also shares his thoughts at the Friday Talking Circle that impacts the understanding of the Four Circles framework and its use in future. He shares:

> I think it's a brilliant concept, Lakota Math Connections. Cause you know the main thing about the Lakota culture is making, creating relationship, understanding relationship and interrelationship. And then, so we do that through language. And math is a language. The way I understand it's [math] a language that we can really precisely describe the physical creation. But then we look at how that is applied by the dominant culture, I just call it dominant culture, it's pretty much been used to trash out our creation, trash out the world, and everything has gone haywire in the world. So there needs to be this balance, so we can use this powerful language, math to describe the physical world

but then we have to infuse it with that understanding of the relationship that we have with the physical creation. So that's why I thought that was such a unique, I've never seen this whole thing, "Lakota Math Connections." That's a really interesting word. The word Lakota, they say in the books it means allies, but it doesn't mean that. That's false, that's erroneous, that's a different word. You can say allies, kȟolákičhiyapi, there are other words to describe ally. But that's not what Lakota means, so then, I was reading in that book by Albert White Hat, the way he grew up, Lakota means people who pray, people who pray. Then when I asked Mary Louise Defender what does that word "Dakota" mean? It means people who are civilized, people who are civilized. And then, I ask other people and they say Lakota means people who have faith, people who have covenant, people who understand laws. And now, now we can use math, we can express that relationship with the laws and add that insight into the world. It's just kind of like a vision, a dream. It's wonderful because I know that a lot of kids have a hard time with math and we can use it in this way. I think these ways, these perspectives that we have been looking at this week are just fantastic. Epiphanies, that's a good word. Iglúbleza. [Lakota-word-for-epiphanies] (laughing out loud). Insights you could say. Insights that we have, to see new connections, use that to expand our, broaden our thinking. Héčhetu yeló. [Lakota-phrase-to-end-speaking].

Again, Lekší Kevin's comments during the Friday Talking Circle describe how the framework is understood. He describes math as a language to describe nature and infuses the Western understanding of math with an understanding of the relationship to care for nature instead of to destroy nature. He describes how math connects to D/Lakota identity and the power of the phrase "Lakota Math Connections." He encourages the continuation of the D/Lakota Math

Connections process and connects it to the math classroom for D/Lakota students. Lekší Kevin's insight, stories, and wisdom guide the D/Lakota Math Connections project. Before this study was written, Lekší Kevin took his journey to the next world and one of his daughters was consulted for the inclusion of this quote [personal communication, January 2023].

Another second language learning elder, Uŋčí June Szczur, shared during the Friday Talking Circle. She discussed the connection between math and nature, the human relationships strengthened during the week, the hope she has from seeing the younger people being successful in Western math and in the language, and finished with this quote, "I was thoroughly confused by some of the math terms that were thrown out there, but after we started saying the Dakota/Lakota names for some of them, it made a little more sense to me. Those are the things I'll remember." Again, the values of D/Lakota Math (linked to nature) and the power of connecting D/Lakota language with math is evident in this quote. Furthermore, the connection among the participants is also paramount. Additionally, she shared a metaphor for the strength, value, and applicability of the intersection of D/Lakota Math and Western Math as steel coming from iron, that indeed something stronger comes out when taken in together.

All these stories and insights from fluent and language learning elders re-define the understanding of the Four Circles framework. The elders' validation of the research approach and framework is the strongest and most significant confirmation. No other endorsement or research validation is needed. Altogether, math teachers, language teachers, and elders influenced the framework, sometimes confirming initial assumptions and sometimes expanding and adding new relationships to the framework.

5.5. Discussion

Circular data collection and synthesis follow an Indigenous research paradigm. The results section is both the process and product. The discussion section will answer the two reciprocal research questions that encircled the initial confirmation of the framework.

5.5.1. How Did the Framework Impact the Participants?

Two major impacts of the framework on participants are synthesized from the results. Math fluency and language fluency did grow together for all individual participants. Second, may relationships were formed among people from different areas of expertise.

Through self-assessment, participants shared their growth in knowledge of math and language. Furthermore, they shared growth in the connection between math and language (and culture). Math fluency and language fluency did grow together for all participants, especially in the areas of D/Lakota math and the D/Lakota language. It happened for math teachers, language teachers, and fluent elders. One TCU math instructor said during the Friday Talking Circle, "I used to focus on content and realized this [connection to language and culture] isn't taking away from the content but enhancing it." This demonstrates that math and language fluency growth is possible not only for the participants/instructors but also for their students as well. Not only did math fluency and language fluency grow together but the lens of two fluency areas connecting also proved to be a successful avenue to engage fluent speakers with math concepts and to engage math teachers with understanding math in a way new to them. Two different areas of expertise, separated in Western ways of knowing, teaching, and learning, were steered back toward relationship and interconnection, which are essential to a D/Lakota way of knowing, teaching, and learning. This growth and connections of math fluency and language fluency

(Western and D/Lakota) by participants influence their teaching and learning of mathematics with Indigenous students.

Second, this all happened within the context of relationships. Focusing on human-to-human relationships, people from every group discussed the value of being with and learning from everyone present. Math teachers, language teachers, and elders built relationships with each other that continue past the course and research. Each group saw that their input and area of expertise were valued. Elders encouraged the process and relationships to continue. Luecke was subsequently hired as a math consultant Wahóȟpi Kiŋ at Sitting Bull College. Language teachers strengthened relationships with math instructors. Math instructors strengthened relationships with language instructors and elders and are now more able to join the language revitalization efforts of the community.

5.5.2. How Did the Participants Influence the Framework?

Three major impacts from participants on the framework are synthesized from the results. First, there is a greater understanding of the nuances and themes of the framework including a stronger understanding of D/Lakota math. Second, the framework is confirmed, both through an initial synthesis of relationships and by encircling the two research questions, for continued use in teaching and learning mathematics at Sitting Bull College and Standing Rock Nation. Third, the participants determined the future direction and implications of using the framework.

Participants experiencing the course and framework were able to better understand, define, and describe the nuances and themes of the framework, including that of D/Lakota Math. Participants gave specific examples, to be elaborated upon in the follow-up study on math resources connected to D/Lakota culture, values, and language. Participants' examples and greater definition of the framework through the MFDs, Three-Color Emphasis Activity, written

and oral quotes, and so on helped bridge the epistemological misalignment between Western math (that claims to be culture-free) and the Sitting Bull College mission of D/Lakota culture, values, and language as the guide for every course, including STEM and math. No precise definition for D/Lakota math was shared but a fluent elder discussed a relational metaphor of hunting buffalo to describe/encircle the relationships and themes of D/Lakota math. Another fluent elder emphasized that even though our grandparents did not go to school, they did math all the time. Their math was from nature, relational, through stories, spiritual, action/activity-based, embodied, linked to the language, and now since settler colonialism in this place linked to Western math.

Furthermore, as far as the co-authors are aware, this is the first use of an Indigenous research paradigm in research on undergraduate math education, a collaborative effort among math teachers, language teachers, fluent elders, and facilitators. However, in the context of colonialism's unceasing pressure to overvalue Western Math and English as the main medium of communication, nearly all participants evaluated the course implementation to have an over-emphasis on the practice of English and Western math. Many conversations begin with Western math through English to the D/Lakota language and eventually to D/Lakota Math. What would other directions look like, starting with D/Lakota math or the D/Lakota language? The participants confirmed that despite the framework claiming a balance, the actual experience still can easily favor Western ways of knowing and doing.

Second, the framework was confirmed for continued use at Sitting Bull College and Standing Rock Nation through both the initial synthesis of relationships and encircling the two research questions. The framework meets the challenge of epistemological misalignment for math instructors at TCUs and math instructors at any level teaching D/Lakota students. This

prepares the math department to develop a curriculum aligned with the mission of Sitting Bull College. Multiple elders shared the certainty of math and culture and language being interconnected. Not solely for Sitting Bull College, the framework and course are one concrete answer to the call from the American Indian Science and Engineering Society literature positing "improved educational outcomes for Native and non-Native students result when STEM instruction is culturally-relevant, rooted in Indigenous ways of knowing, linked to place, and embedded in community" (American Indian Science Engineering Society, 2020, p. 12). Additionally, the framework meets a need for language teachers and especially those who are teaching math to young children, for example, at Wahóȟpi Kiŋ. Furthermore, the framework was encouraged by elders through their presence, their stories and quotes, and by a continual engagement with the project to this day. They see an area needing more development and are willing to contribute and learn more. Benefits to math instructors and language instructors for the teaching and learning of mathematics and the affirmation from elders confirms the continual use and value of the framework in Standing Rock and other Indigenous communities.

Finally, the participants impacted the framework by giving four future directions for its use. First, participants shared that more work needed to be done specifically in encircling D/Lakota Math. This circle was perceived to be the least emphasized of all circles and intersections (Figures 11–15) and self-assessed as the circle with the most growth in knowledge and new connections (Figures 5, 9, 11, 12). The combination of these two demonstrates a need for more work in this area. Additionally, even though the most growth happened in D/Lakota Math, it is still the lowest in overall ordering (Figure 4), thus needing more attention to pursue balance. Furthermore, participant quotes share the idea that one cannot make "D/Lakota Math Connections" without strengthening "D/Lakota Math," first by focusing on D/Lakota fluent

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elders explaining their thinking around mathematical and traditional activities. A math/language course in summer 2022 and 2023 was titled "D/Lakota Math" to follow this path.

Second, participants (math and language teachers) see the value of and have the desire for the framework and process to work toward developing D/Lakota words for Western math terms. Elders shared that their language is capable of translating whatever is desired and that the math concept could be better understood with D/Lakota words. A math/language course in summer 2022 and 2023 was titled "Math Neologisms" (neologisms is the linguists' way to describe developing new words or expressions for modern concepts) to follow this path.

Third, participants emphasized the D/Lakota value of connectedness and relationship. The Four Circles are not meant to be defined, understood, or used in isolation but rather in connection. An elder shared that the Lakota way is that of inter-connectedness and you cannot even discuss/evaluate one circle in isolation because they are all tied together. Furthermore, instead of seeking to define the circles (object/definition-oriented), the intersection areas and relationships among the circles is the future focus area, especially due to its links to teaching and learning mathematics and language in both the math and language classrooms.

Fourth and finally, the participants impacted the framework by guiding its future use to develop a math resource based on D/Lakota culture, values, and language. The framework and course provide the structure and content for the resource. A team of math instructors, language instructors, and fluent elders have been translating/editing specific examples from the course. Examples in the intersections of the four circles, and especially the center spot connecting all four circles, are shared through the lens of the Four Circles framework and called "D/Lakota Math Connections." The examples and resources are the focus of the follow-up study.

5.6. Conclusion

When experienced and evaluated by TCU math instructors, D/Lakota language teachers, and elders, the D/Lakota Math Connections framework proved valuable for teaching and learning mathematics in the math department and language department at Sitting Bull College. Specifically, the framework meets the need of TCU math instructors to have the math content and classroom guided by local culture, heritage, and languages. Furthermore, the framework meets the need of language teachers in the area of mathematics, especially those who are teaching math in the language to young children, for example, at immersion schools and in future D/Lakota-medium schools.

The framework was confirmed and re-defined by the stories and input of fluent elders. Following an Indigenous research paradigm, the framework was both a process to follow (used in the course and as a survey structure) and a product of encircling and fuller understanding as a result. Data collection and data synthesis followed a circular and reciprocal pattern. Through the process, the framework was initially confirmed, encircled by the two research questions, and re-understood in a more full and connected way. Similarly, the theme of math fluency and D/Lakota language fluency growing together was confirmed, encircled, and re-understood in a more full and connected way. Overall, through an Indigenous research paradigm for research in undergraduate math education, the power and value of the D/Lakota Math Connections framework for teaching and learning mathematics with Indigenous communities/students was experienced and confirmed in the context of the Sitting Bull College community.

5.7. Post-Manuscript

5.7.1. Data Availability Statement

The datasets presented in this article are not readily available because of data sovereignty. One may view the datasets with written permission from the Standing Rock Iyapi, a branch of the Standing Rock Sioux Tribe Department of Education. Requests to access the datasets should be directed to info@standingrock.org.

5.7.2. Ethics Statement

The studies involving human participants were reviewed and approved by Sitting Bull College IRB and North Dakota State University IRB. The patients/participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

5.7.3. Author Contributions

DL and DS contributed to the design and facilitation of the pilot course and framework. DL organized the logistics for the course and invited DS to co-facilitate and co-author. DL analyzed all the data and wrote the first draft. DS analyzed all the Monday–Friday Drawings, some videos, and wrote additional sections. All authors contributed to the manuscript revision and approved the submitted version.

5.7.4. Acknowledgments

There are too many people to name who have had a direct influence in shaping us and our relationships with the ideas we explored in this article. Yet, a few people particularly stand out. We want to thank everyone at Wahóȟpi Kiŋ (the Lakota Language Immersion Nest) at Sitting Bull College. Without them, this project would not have ever happened. In particular, DL thanks

the elders who really influenced him while being at Wahóȟpi Kiŋ and contributed greatly to the D/Lakota Math Connections project: Lalá Tom Red Bird, Uŋčí Grace Draskovic, Uŋčí Ruby Shoestring, and the late Lekší Kevin Locke. Furthermore, we want to thank Sunshine Carlow for opening the door for us to co-facilitate the course and for creating the path for the D/Lakota Math Connections project. Also, we are thankful for all the leaders and employees at the D/Lakota Summer Institute. We want to thank all the participants in the D/Lakota Math Connections project in the summer 2021 pilot course and the summer 2022 and 2023 follow-up courses. Truly, we view you all as co-researchers who have influenced and taught us much about the framework, D/Lakota math, the language, and the community. Next, we want to thank the editors of our drafts as we prepared for the final version. Your input in editing this article was invaluable. Thank you Hollie Mackey, Warren Christensen, and Dina Horwedel. Furthermore, DL sincerely and wholeheartedly thanks Hollie and Warren as his Ph.D. mentors in helping him navigate academia, his research, and his identity. And most of all, we each thank our families, children, and spouses. You each are a gift in our life and we are so thankful for you. We would not be the same without you. Thank you for your love and support. With gratefulness, DL and DS.

5.7.5. Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

5.7.6. Publisher's Note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the

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6. PAPER 4 – D/LAKOTA MATH CONNECTIONS: A COMMUNITY-BASED MATH RESOURCE

The fourth paper of this four-paper dissertation is in review in the open-source, peer-reviewed journal titled "The Tribal College and University Research Journal." I am the sole author on this paper. The manuscript was submitted as blind, but the unblinded version is shared here.

6.1. Cover Page and Abstract

Dakota/Lakota Math Connections: Results from Developing a Community-based Math Resource

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6.1.1. Abstract

Following an Indigenous research paradigm, the Dakota/Lakota Math Connections project at Sitting Bull College, a Tribally Controlled University (TCU), is a collaborative effort amongst TCU math instructors, language instructors, and fluent elders. Following an earlier paper on the D/Lakota Math Connections framework and course, this paper will share the process to develop a community-based math resource and examples of D/Lakota math connections. The full results can be found at www.othokahe.com, a web portal under the Standing Rock Iyapi, a branch of the Standing Rock Sioux Tribe Department of Education.

6.2. Introduction

Tribally Controlled Colleges and Universities (TCUs) have and continue to seek out connections between the local heritage and culture and the mainstream education content (American Indian Higher Education Consortium, 2023). At Sitting Bull College (SBC) in the Standing Rock Nation, a portion of the mission statement reads, "Guided by Lakota/Dakota culture, values, and language, Sitting Bull College is committed to building intellectual capacity through academics" (Sitting Bull College, 2023). This mission applies to all STEM courses and specifically math. Across all TCUs and Indigenous communities, there are efforts to connect STEM with place-based, community-specific culture, language, and knowledge at the TCU as well as K-12 level (American Indian Science and Engineering Society, 2020; Boyer, 2011; Lipka et al., 2005; S. Meyer & Aikenhead, 2021a,b).

At the K-8 level, the Yup'ik in Alaska have taken major strides in developing their curriculum called "Math in a Cultural Context" (Lipka et al., 2005). The decades of work within this project answered the call for math and local culture integration and were able to demonstrate its many benefits from increased cultural identity for students to increased math exam scores (Kisker et al., 2012; Lipka & Adams, 2004; Lipka et al., 2007).

At the college level, calls for culture to be more integrated into the math classroom have been met with epistemological challenges as well as a dearth of math and local culture resources (Garcia-Olp et al., 2019; S. Meyer & Aikenhead, 2021a,b; Pfahl & Funkhouser, 2015; Ruef et al., 2020; Stevens, 2021; Webb et al., 2017). If Western math is assumed to transcend culture and contain all mathematical knowledge, as it often is presented within mainstream Western education, then how can TCU math classrooms connect with Indigenous culture? (Aikenhead, 2017; Bishop, 1990; Ernest, 2021). More specifically, in what ways can Sitting Bull College

math classrooms connect with D/Lakota culture, values, and language? The D/Lakota Math Connections (DLMC) research project addresses both challenges of epistemological misalignment and the scarcity of college level D/Lakota math resources.

This paper will specifically introduce a math resource guided by D/Lakota culture, values, and language. The research to develop the DLMC resource specifically builds upon Oglala Sioux Nation tribal citizen David Sanders' dissertation which brought together both the idea of a Lakota view of mathematics and the action of a math curriculum designed to follow the community desire of local control and self-determination in (math) education (2011). In an earlier paper, Luecke & Sanders (2023) focused on the first challenge of epistemological misalignment between place-based [context-specific and not universal] and holistic [including mind, heart, body, and spirit] ways of knowing with Western assumptions of mathematics as universal and objective [isolated from spiritual and personal connection]. This work is in alignment with other Indigenous researchers who "... posit improved educational outcomes for Native and non-Native students result when STEM instruction is culturally relevant, rooted in Indigenous ways of knowing, linked to place, and embedded in community" (American Indian Science and Engineering Society, 2020, p. 12).

The DLMC project was developed as part of my (Luecke) doctoral program. The first paper in my three-paper dissertation, titled "Circulating Conversations Methodology: Co-Connecting Knowledge to Develop Research Questions at Sitting Bull College" (Luecke et al., 2022), dives deeply into what an Indigenous research paradigm is and how it can be applied to research in undergraduate math education. The Circulating Conversations Methodology laid the groundwork for this research and led to the D/Lakota Math Connections framework and course (Luecke & Sanders, 2023).

The research questions developed through the Circulating Conversations Methodology (Luecke et al., 2022) answered in this paper are:

In what ways can Western higher order math concepts be identified within Dakota/Lakota space, place, and language, to inform possible Sitting Bull College math curricular/pedagogical adjustments?

In what ways can Dakota/Lakota culture and language be identified within Western higher order math concepts, to inform possible Lakota Language Immersion Nest curricular adjustments?

In what ways can Dakota/Lakota space, place, and language represent non-Western higher order math concepts?

The D/Lakota Math Connections resource gives answers to these three questions. Presenting this resource while answering the research questions is the goal of this paper.

6.3. Methods

The Methods section is organized in four subsections answering the following questions.

What is the context for the research questions, process, and responses?

How was a community-based math resource determined as the product?

How was the content and categorization of the resource determined?

How are the data/results shared in a way that supports tribal self-determination and data sovereignty?

6.3.1. What Is the Context for the Research Questions, Process, and Responses?

The Circulating Conversations Methodology (Luecke et al., 2022) lays out the process for collaboratively developing the research questions. This process was based on Wilson's (2008) description of an Indigenous Research Paradigm emphasizing relationships forming reality,

being accountable to all our relationships, and valuing the process as the product. Along with my coauthors, we collaboratively developed the research questions as a group made up of a math faculty, an Indigenous education faculty, and a language immersion instructor. The tribal college focused research beginning in the professional society, "Research in Undergraduate Math Education," shifted to remain accountable and reciprocal amongst TCU math instructors and Lakota language immersion instructors. Altogether, we experienced the Circulating Conversations Methodology that led to stronger relationships amongst ourselves as well as the development of the four research questions, the creation of the research questions diagram, and determined the method to answer the research questions.

The D/Lakota Math Connections course was the week-long summer 2021 course as the method to answer the research questions. The course sought to bring math instructors (pre-k immersion to college-level), language instructors at every level, and fluent elders together to discuss math connections within D/Lakota culture and language. Sanders' (2011) dissertation on Lakota perspectives of Bishop's (2012) six universal math activities (counting, designing, locating, measuring, playing, and explaining) was both the framework of content development and the beginning for course conversations. All course interactions were recorded and became the main data sources used to answer the research questions, and eventually becoming the content for DLMC resources. Furthermore, three additional process questions were asked to increase accountability to participants/collaborators: (1) Does this course benefit TCU math instructors in connecting to D/Lakota language, culture, and values? (2) Does this course benefit language instructors at any level teaching math concepts? (3) Do the fluent elders approve of the approach and project in general?

The course followed and was evaluated by the DLMC framework (Figure 1).

Figure 31

Paper 4 Figure 1: D/Lakota Math Connections Framework
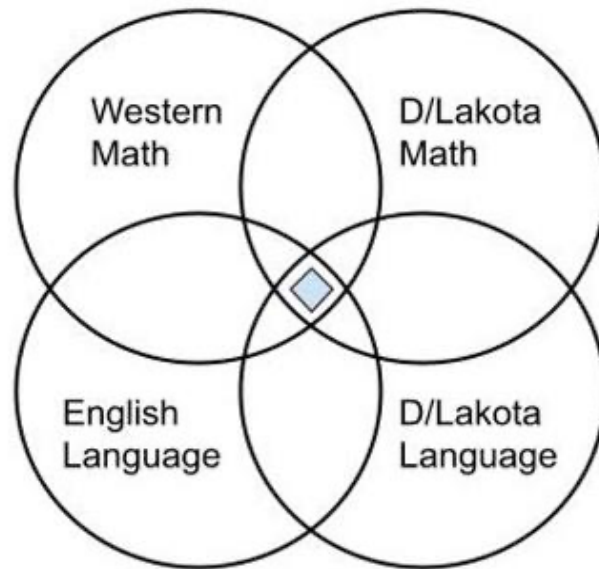
Sanders and I co-facilitated the course and, in our preparation, co-developed the framework from the research questions diagram. Qualitative and quantitative methods based in an Indigenous research paradigm/methodology confirmed the development and use of the framework. The framework is a four circle Venn diagram where each circle is distinct, self-sufficient, equivalently valuable, and fully interconnected with each circle. A central belief is that math fluency and language fluency can grow together (Luecke & Sanders, 2023).

6.3.2. How Was a Community-Based Math Resource Determined as the Product?

The Circulating Conversations Methodology and DLMC course followed a set of values from Wilson's description of an Indigenous research paradigm (2008). The values were set and the process was determined, but the specific product was revealed through the process. The course included a Friday Talking Circle, post-surveys, and post-interviews. The Friday Talking Circle was an open-ended, public (within the course) closing statement from each participant

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about any aspect of the course. The post-survey asked specific questions about many aspects of the course including the value of each course activity, the course structure, and products/next steps. Each post interview followed the conversational interview approach (Kovach, 2010) and specifically asked two questions: What do you (as TCU math instructor, immersion instructor, fluent elder) suggest for next steps for the DLMC project? What product would you (as TCU math instructor, immersion instructor, fluent elder) want to see come out of this work?

During the Friday Talking Circle, the post survey, and the post-interviews no single response suggested research articles for a next step or product. As a doctoral student, I (Luecke) knew that I would have to write research articles but now it was clear that these articles were for my benefit. To remain accountable to the relationships developed through the research, the need to develop a community product/resource emerged. I can not progress in my doctoral responsibilities without equivalently reciprocally pursuing community accountability with the TCU math instructors, language instructors, and fluent elders.

Synthesizing the data from the sources led to the next step of additional summer courses and the product of the DLMC resource. Three summer courses were planned for summer 2022, including a course focused strictly on traditional D/Lakota Math, a course focused on developing Lakota words for math terminology, and a course for teachers to implement the results more easily into their curriculum (see resource page "DLMC Process")

The product desired by research participants/collaborators was synthesized through conversational interviews (Kovach, 2010). The outcome of these interviews was a desire for a reference guide teachers could utilize to look back on and be reminded of all the D/Lakota math connections discussed throughout the week. There was a general recognition that curriculum couldn't be developed for such a wide array of teachers (math and language teachers from pre-k

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immersion to college-level mathematics). Further, some expressed that even if a curriculum was developed by an outside researcher, there would be skepticism of it and unlikely implementation. Thus a co-developed resource was more likely to overcome community skepticism. A community-developed math resource would allow the variety of teachers to connect to their specific standards, lesson plans, and courses as desired while ensuring the content is accessible beyond the contributors to instructors across all D/Lakota communities.

6.3.3. How Was the Content and Categorization of the Resource Determined?

After the community product of a math resource was confirmed, what to include and how to organize it were the next key questions. Conversations within the DLMC course did not follow a linear path talking about one isolated topic at a time. Rather, conversations filled with story and laughter meandered through many mathematical ideas and making a variety of connections along the way. For example, when small groups were prompted to discuss nested sets many interweaving topics were articulated. For the nested set discussion, this included examples in nature, such as buffalo circling up and a bird within an egg within a nest within a tree, along with negative numbers, odd and even, intersection and union, and the whole number system, and lastly with family structure (tiwáhe, tióšpaye, oyáte). In Western math, these examples connect to nested sets of numbers all the way up to Ring theory categorization of domains. These rich interactions/conversations are modeled below (Figure 2) as a non-linear web. The connections (lines of the web) between topics attempts to match some of the multiple topics discussed in a particular conversation. Further, the web matches the nature of math as a web of knowledge and the cyclical/non-linear process of writing the reference pages. Each reference page has a 'Writing History' section to help demonstrate that. Lastly, the DLMC resource represented as a web diagram allows readers to self-select any start and end point.

Figure 32

Paper 4 Figure 2: D/Lakota Math Connections Resource Diagram
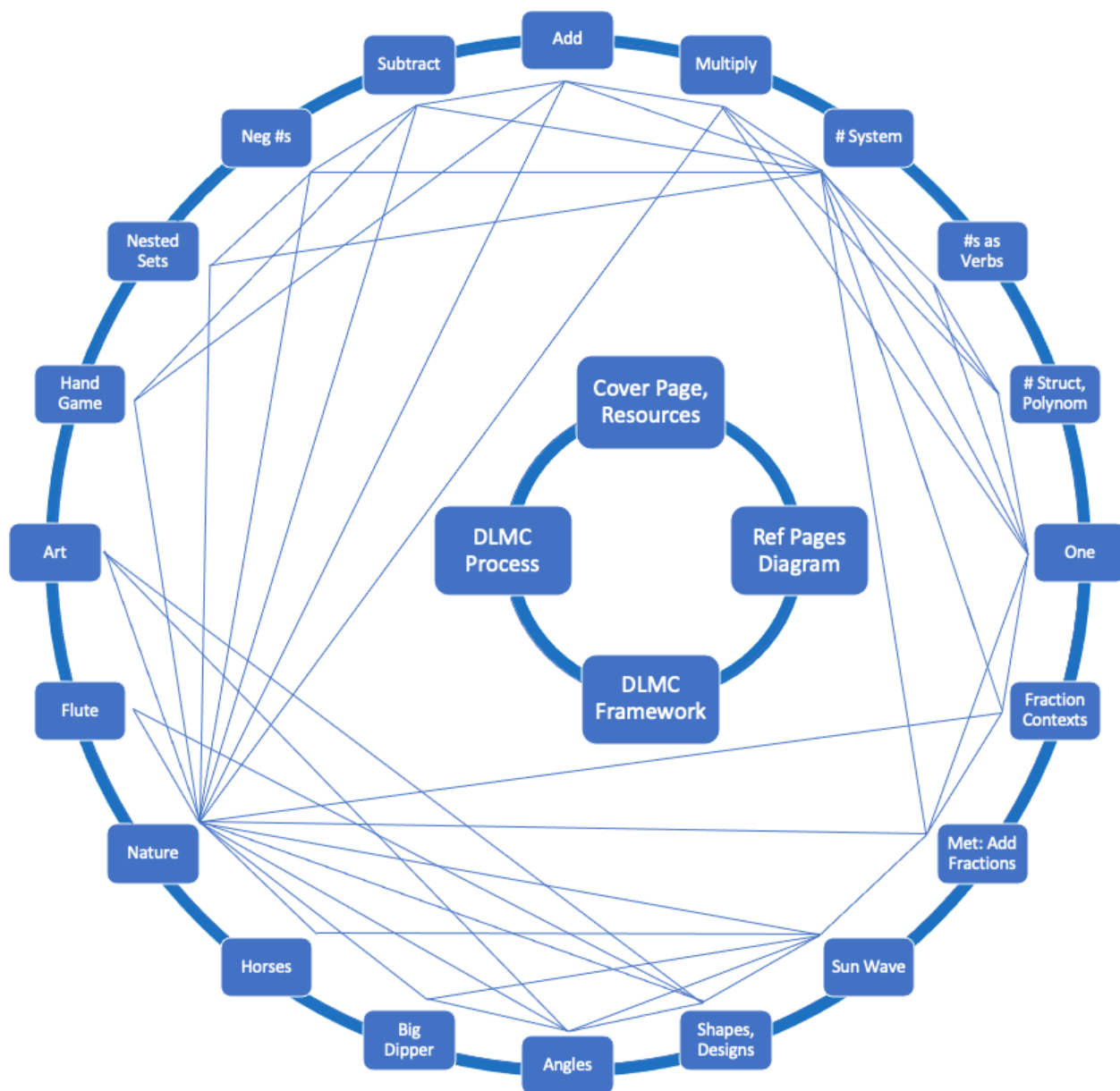
The topics currently part of the DLMC resource all originated in the summer 2021

DLMC course conversations. These topics/pages were synthesized through a variety of inputs

and sought to remain accountable to all the project's relations. On each reference page, there is a

section about the reasons for writing that page. Altogether they include the following:

The post-survey questions on the value of each topic during the course were quantitatively analyzed to determine key topics.

The Friday Talking Circle and post-interviews from language instructors and TCU math instructors qualitatively highlighted key topics.

Wahóȟpi Kiŋ (the Lakota language immersion Nest) at Sitting Bull College desired certain topics that could be immediately applied within their curriculum.

The topic was a desired and accessible example of traditional D/Lakota math activity.

The topic was highlighted in the summer 2022 courses.

My (Luecke) PhD Committee expects certain content as it was part of my PhD proposal.

The Translation/Editing Team (consisting of fluent elders, language instructors, and myself watching video snippets together to prepare first drafts and then later finalize reference pages) suggested certain topics from a list of over 50 options.

Altogether these many inputs were synthesized to keep relational accountability and determine which pages/topics would be further prioritized to be included in the Translation/Editing Teams' limited work time and eventually into the DLMC resource.

6.3.4. How Are the Data/Results Shared in a Way that Supports Tribal Self-Determination and Data Sovereignty?

Lastly, after the resource was developed through the Translation/Editing Team, the key question became with who and how should the resource be shared to align with community values of tribal self-determination and data sovereignty. The DLMC resource was collaboratively determined among course and project stakeholders to be hosted on Standing Rock Iyapi's (a branch of the Standin Rock Sioux Tribe's Department of Education) web portal called Othokahe,

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which means 'a beginning' and 'taking the lead'. Othokahe was designed to support D/Lakota

language revitalization efforts within Standing Rock including the summer language courses.

Being hosted by Standing Rock Iyapi allows the language leaders in the community to have final

authority on what and how the DLMC resource is shared. This contrasts with putting all the

reference pages in a public dissertation where the authority is held by North Dakota State

University, my PhD-granting institution. Standing Rock Iyapi determined, via their priorities and

the course consent forms, that the DLMC resource would be accessible to everyone who created

an Othokahe user account and completed their data sovereignty quiz/consent form. The data

sovereignty quiz emphasizes relational accountability to the D/Lakota people, language, and

knowledge. This allows D/Lakota people, educators in D/Lakota communities, and Indigenous

peoples more broadly to have easy access to the content while challenging anyone who may use

this content for personal profit over D/Lakota people.

6.4. Results

The full results of the DLMC resource can be accessed at https://othokahe.com. Anyone

who creates an Othokahe user account and completes the data sovereignty quiz can view the

DLMC resource. The results section of this paper will share a few examples from the reference

pages as exemplars in answering the three research questions. Additionally, limitations to the

project will be discussed.

6.4.1. In What Ways Can Western Higher Order Math Concepts Be Identified within Dakota/Lakota Space, Place, and Language, to Inform Possible Sitting Bull College Math Curricular/Pedagogical Adjustments?

This research question described in terms of the DLMC framework fits in the intersection

of multiple circles. Obviously, it is interconnected to the English circle as this is written in

English and English is currently the medium for math instruction at Sitting Bull College. Further, the following two examples are interconnected with both the Western Math and D/Lakota Math circle. The first example will additionally be interconnected to the D/Lakota language circle. These two examples, and all exemplars in this paper, demonstrate the interconnection of all four circles: D/Lakota math, D/Lakota language, English, and Western math.

Further, the research questions go beyond understanding the connection and interconnection between the four circles of the DLMC framework and ask for what purpose these interconnections may be applied in a school setting. Within the first two reciprocal research questions, the end goal of curricular adjustments at Sitting Bull College math classrooms and Wahóȟpi Kiŋ (Lakota language immersion Nest) are specifically stated.

6.4.1.1. Example 1: Series/Partial Sums Connected to D/Lakota Number System

Higher order mathematical thinking by the D/Lakota people is demonstrated in the expression of large numbers in the D/Lakota language. The number structure stands on its own as higher order mathematical thinking and needs no justification from Western Math. However, there are strong connections between the pattern for expressing large numbers in the language and Western math concepts such as polynomials (ubiquitous throughout Western math) and partial sums (part of mathematical series often first introduced in Calculus II). These ideas are all connected but not one-to-one or a direct translation of one another. Teaching the D/Lakota number structure for the sole purpose of teaching Western math is appropriation (Abtahi, 2022) and is something to be avoided. As the DLMC framework asserts, the D/Lakota number structure is valuable on its own and worth learning in the math classroom. The D/Lakota number structure does not need to be connected to Western math concepts to be considered worthwhile. The DLMC framework encourages one to break away from thinking that Western Math is the only

way to think mathematically. That being said, this example demonstrates how the

pattern/structure of expressing large numbers in the D/Lakota language can be a culturally

relevant teaching tool to understand polynomials and partial sums/series.

The number system to express large numbers in the D/Lakota language has a clear

structure. To express the number 402,016 it would be said as

402,016   kȟoktá opáwiŋǧe tópa sáŋm kȟoktá núŋpa sáŋm wikčémna sáŋm šákpe

                     (1,000)   (100)   (4) (more) (1,000) (2)   (more) (10)   (more) (6)

The following connections can be seen between the number structure and polynomials

(i.e., $x^2 + 4x - 11$) and series/partial sums (i.e., $\sum_{k=0}^{3} a\,r^k = ar^0 + ar^1 + ar^2 + ar^3$).

6.4.1.1.1. The use of 'terms' forming an additive structure.

The word 'term' has a specific definition in polynomials and series/partial sums to mean

variables and/or numbers multiplied together separated by addition. Each term is separated by

sáŋm. The base 10 number system separates each term by a multiple of 10 in contrast to a

polynomial separated by the exponent on the variable and index of a partial sum. For example,

10^5 4 + 10^3 2 + 10^1 1 + 10^0 6 has a similar structure to $x^4 + 3x^2 + 7x + -4$. Large numbers in

D/Lakota are expressed by term in contrast to numbers in English expressed through grouping

(four hundred and two thousand, sixteen). Grouping-based expression of large numbers in

English may be less syllables in pronunciation but hides the underlying structure. Term-based

expression of large numbers can be used as a teaching tool for polynomials and partial sums and

series, all expressed without grouping.

6.4.1.1.2. Assumed multiplication.

Large numbers expressed in D/Lakota (term-based expression), large numbers expressed

in English (grouping-based expression), polynomials, partial sums, and series are all similar in

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their use of assumed multiplication. Kȟoktá núŋpa literally reads 'thousand two' and means 'two multiplied by a thousand.' Similarly, $3x^4$ literally reads 'three x to the 4th power' and means 'three multiplied by x^4.' Further, large numbers expressed in D/Lakota and English, polynomials, partial sums, and series all assume one when no coefficient/digit is explicitly stated before the term name, it is one. For example, 'kȟoktášiča' which means 'million' assumes that it is one million when stated as a number just like x^6 assumes one multiplied x^6 when seen in a polynomial. The same goes for omitting terms that have coefficient/digit zero as in zero times opáwiŋǧe (hundred) in the example above.

6.4.1.1.3. Ordering of terms.

Both partial sums and the expression of large numbers in D/Lakota have a specific order to the terms. Once a partial sum is identified from an infinite series, the terms can be rearranged without changing the value. Similarly, the terms to express a large number in D/Lakota could be moved around without changing the value, but numbers are not customarily expressed in this way. They follow a descending order. Similar can be said for polynomials.

Overall, the term-based additive structure with assumed multiplication within expressing large numbers in D/Lakota can be an option for culturally relevant instruction of polynomials, partial sums, and series. More importantly though, the additive structure of expressing numbers in D/Lakota demonstrates higher order mathematical thinking by the D/Lakota people.

6.4.1.2. Example 2: Conditional Probability within Hand Game

Higher order mathematical thinking by the D/Lakota people is demonstrated in the playing of strategic games. Haŋpápečhuŋpi (Hand Game) stands on its own as higher order mathematical thinking and needs no justification from Western mathematical descriptions of probability. However, there are multiple connections between basic probability and the results

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from a single guess in Hand Game. Hand Game is a team game that involves the community, pattern recognition, reading people, ignoring distractions, spirituality/medicine, and song. During the summer 2021 D/Lakota Math Connections course, it was described as a game of patterns. Each player has a pattern for guessing and for hiding. Some players claim to guess based on the hiding pattern of their opponent and others claim to hide based on the guessing pattern of their opponent. Either way, everyone has a pattern. A major compliment to an opponent would be hiding the bones randomly, that is hiding without knowledge of how you hid the bones. This is a concession that your opponent knows your pattern even better than you know yourself. Hand Game is not a 'guessing game' that insinuates being trivial or random, but rather is a game of skill. Some players and teams are better at Hand Game than others. Like in poker it is not just the random deal of the cards that determines the winner. It's a game of skill, reading people, and intuitively recognizing and applying patterns in real time.

Even though Hand Game is not simply a guessing game, the sample space (Figure 3) for a single guess can be described through the Western math concept of conditional probability, which is often a challenging topic for math students.

Figure 33

Paper 4 Figure 3: Sample Space for a Single Guess in Hand Game

S_1		C_1	C_0	
S_2	C_2	C_1	C_1	C_0

S_2 and S_1 stand for two sets or one set of bones in play for that guess respectively. C_2, C_1, and C_0 stand for the amount bones correctly guessed as 2, 1, 0 respectively. The probability of two, one, or zero correct guesses can be described through Western mathematical symbols.

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$P(C_1) = 3/6$ and describes the probability of three possibilities of one correct guess for six total options in the sample space. $P(C_2|S_2) = 1/4$ and describes the conditional probability of the one possibility of correctly guessing both sets of bones that are in play. Along with probability, the hand signals to guess outside, middle, left, and right can be connected to the foiling of binomials. In conclusion, learning and playing Hand Game in math class can be an experiential teaching tool for unconditional and conditional probability.

6.4.2. In What Ways Can Dakota/Lakota Culture and Language Be Identified within Western Higher Order Math Concepts, to Inform Possible Lakota Language Immersion Nest Curricular Adjustments?

The first research question demonstrates the interconnection of all four circles with the purpose of potential curricular adjustments for TCU math instructors. The second reciprocal research question is similar but for the purpose of curricular adjustments at Wahóȟpi Kiŋ (Lakota language immersion Nest) at SBC. In early conversations at Wahóȟpi Kiŋ, an instructor shared a story of being told 'math is in everything, including the culture,' but when she asked the person to *articulate* a specific example, they were not able to (Luecke et al., 2022). One of the goals of this research question is to *articulate* the mathematical concepts/thinking embedded within D/Lakota culture and language to strengthen the math curriculum at Wahóȟpi Kiŋ.

First, the previous two examples of number structure/expression and Hand Game can both be examples of Western math and D/Lakota math being interconnected for use at the immersion school and in the language revitalization movement in general. The previous two examples and all the examples of this paper seek to go beyond surface level connections such as using the tipi as a cone to teach surface area and volume.

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6.4.2.1. Example 3: Adding Fractions Metaphor

Multiple fluent speakers during the summer 2021 D/Lakota Math Connections course discussed the use of analogy to describe precise Western math concepts. Though the analogy and the concept are not identical, they both can be better understood together. The following metaphor for adding fractions using realized/unrealized vocabulary had mixed reactions from the Translation/Editing team for the DLMC resource. At best, the presented metaphor demonstrates a naïve understanding of the language and at worst the metaphor is an unethical misuse and appropriation of the language. The metaphor of realized and unrealized D/Lakota vocabulary is still shared because its significance in the beginning of the D/Lakota Math Connections process, its already public presentation at the Lakota Language Summit, and its potential for connecting the language with the sometimes-challenging topic of adding fractions. Further it can encourage everyone to self-reflect on the ethics of when and how to connect the D/Lakota language with Western math concepts. Lastly, the questionable connection of realized/unrealized vocabulary with adding fractions does not negate the notable higher order mathematical thinking embedded within the language (realized/unrealized pattern) that has been embodied and passed down for generations.

Within the D/Lakota language, there is an emphasis placed on if something is realized or not. Different vocabulary is used for when an event has/is certainly happening and when an event is not certain yet. Relating to adding fractions with different denominators, the crux of the problem is determining the 'special expression' of one to multiply to each term as seen in (1).

$$\frac{1}{4} + \frac{2}{5} = \left(\frac{1}{4} * 1\right) + \left(\frac{2}{5} * 1\right) = \left(\frac{1}{4} * \frac{5}{5}\right) + \left(\frac{2}{5} * \frac{4}{4}\right) = \frac{5}{20} + \frac{8}{20} = \frac{13}{20} \qquad (1)$$

The transition from unrealized vocabulary **to** realized vocabulary is when the event actually happens. The transition from wanting (and not knowing) **to** having in hand (precisely knowing) the exact expression of this 'special one' is the central component to solving any fraction addition problem. Further, the problem-solving technique of multiplying by a 'special one' to change the expression of the fraction is also seen in rationalizing the denominator, multiplying by the conjugate more broadly, and in a variety of upper-level proofs.

Incorporating this realized/unrealized metaphor to teach fractions allows the emphasis of language learning to be present in the math classroom and therefore encourages language learning overall. Instead of rote memorization of a mathematical algorithm to add fractions, emphasizing and learning about realized and unrealized vocabulary in the math classroom prompts conceptual understanding of adding fractions, critical thinking, and language learning. However, there are multiple and serious concerns, as well, in connecting adding fractions (finding the 'special expression' of one) with realized/unrealized vocabulary. One of the concerns brought up by the Translation and Editing Team was that this metaphor is too abstract and grammar-focused and does not directly connect to the physical world like many analogies do (like the nested set analogies above). Further, the distinction between realized/unrealized vocabulary is not as clear cut and straightforward as this metaphor describes. This metaphor continues to emphasize symbolic, decontextualized math over embodied, contextualized math. Thus, in this example, the language may be inappropriately used here as a smokescreen to teach what is considered more valuable within this metaphor, Western assumptions and perspectives of math in adding abstract, symbolic, de-contextualized, fractions.

6.4.2.2. Example 4: Process Continuation through D/Lakota Math and Neologism

Development

When participants were asked about next steps for the D/Lakota Math Connections

project in the post interviews, strengthening the D/Lakota math circle and developing neologisms

(new words) for math concepts were two major themes. In response, two courses continued

during the summer of 2022 and 2023. One course focused on centering and holding space for

D/Lakota math without connection/justification from Western math and one course on math

neologisms for math concepts. For the math neologisms course, fluent speakers from across

D/Lakota country gathered to discuss math terminology in Lakota including negative numbers,

subtraction, fractions, decimals, multiplication, and division. For the D/Lakota math course,

topics such as horse racing, caring for horses, flute playing, and tahokmu (a traditional art

composition strategy) have all been highlighted thus far through the summer 2022 and 2023

courses. The discussions and outputs from both the D/Lakota math courses and the math

neologisms courses inform possible curricular adjustments at Wahóȟpi Kiŋ. To learn more about

these examples, the full results of the DLMC resource can be accessed at https://othokahe.com.

6.4.3. In What Ways Can Dakota/Lakota Space, Place, and Language Represent Non-Western Higher Order Math Concepts?

This question could be re-written in terms of the DLMC framework as 'in what ways do

Dakota/Lakota language, land, and culture describe the D/Lakota Math circle as distinct from the

Western Math circle?' During the closing talking circle in the summer 2021 DLMC course, an

instructor at Wahóȟpi Kiŋ questioned can we even connect to D/Lakota math if we don't

strengthen and further understand that circle first? With the constant pressure of colonial

thinking to overvalue Western math, we need a space to center D/Lakota math distinct from

colonial pressures to evaluate all mathematical knowing through Western math. As already

shared, the D/Lakota math course is designed to do just that. The examples of horse riding, flute

playing, flute making, and tahokmu are all activities that embed and employ D/Lakota

mathematical thinking. The remainder of this section will share two final examples of D/Lakota

math.

6.4.3.1. Example 5: The Sun Cycle

During the summer 2021 D/Lakota Math Connections course, Tom Red Bird, a fluent

elder and instructor at Wahóȟpi Kiŋ, shared a story of his grandpa marking the sunrise each day

on his log home windowsill. Throughout the year, the sunrise location moves up and down (left

and right, north and south) the eastern horizon. As the sun moves north (up) the days get longer,

until it slows down, appearing to stop and then changes directions back to the south (right). This

marks the summer solstice, a significant time for ceremony. Sun, as well as star, observations

follow annual cyclical patterns that determined a cyclical pattern of movement for D/Lakota

people as well as the timing of certain ceremonies. Many other cycles and patterns were

understood through nature as well. Even though all these annual cyclical patterns directly

connect to the sine wave, especially the location of the sunrise on the horizon, connecting to

Western math and the sine wave is not the goal. Rather, place-based observations are valuable in

understanding the time of year and timing of certain ceremonies.

6.4.3.2. Example 6: Numbers as Verbs

In general, within the D/Lakota language, numbers can be seen as both nouns and verbs,

depending on the context. This contrasts with English and Western Math that views numbers as

only nouns, adjectives, or abstract quantifiers, but never as action words. Those fluent in Western

math, like myself and the math faculty on my committee, almost certainly have never seen or

thought of numbers as verbs. Before sharing some examples, a significant language note is the

notion of a noun and verb weren't introduced to the D/Lakota language until English was used to

describe the D/Lakota language. In general, a single D/Lakota word can be a noun, verb,

adjective, etc. without any change to the word depending on the sentence context. For example,

the word tȟaspáŋ in the following table is acting as both a noun and a verb.

Table 2

Paper 4 Table 1: Example of Noun/Verb Flexibility

Lakota	English (Literal)	English (Equivalency)
Hé tȟaspáŋ.	That / is being apple	That is an apple.
Hé tȟaspáŋ tȟózi.	That / apple / is being green	That apple is green.

`Numbers follow this similar structure of noun/verb flexibility as shown in the following

first two rows. The next three rows give examples of numbers being conjugated with affixes and

suffixes making them the verb of the sentence.

Table 3

Paper 4 Table 2: Examples of Numbers as Nouns and Verbs

Lakota	English (Literal)	English (Equivalency)
Tópa wačhípi.	Four / are dancing	Four are dancing.
Čhiŋčá tópa.	Her children / are being four	She has four children.
Waníyetu matópa.	Year / I being four	I am four years old.
Záptaŋpi.	They are being five.	There is five of them.
Oyáte niwáŋžipila.	People / you one all only	You are one people.

6.4.4. Limitations

There are strengths and concessions inherent in all research paradigms and

methodologies, including an Indigenous research paradigm. Limitations can describe the

concessions of one methodology compared to another as well as the implementation of the

desired methodology. As it relates to Indigenous research paradigms within academia,

"Indigenous epistemologies challenge the very core of knowledge production and purpose. While this is not a matter of one worldview over another, how we make room to privilege both, while also bridging the epistemic differences, is not going to be easy" (Kovach, 2009, p. 29). To not privilege one worldview over another, I attempt to share some of our assumptions made from the start.

> All cultures do math, and exemplified in Lakota through exploring the activities of counting, designing, measuring, locating, playing, and explaining (Sanders, 2011). Higher order math concepts are embedded within D/Lakota language and culture. Math fluency and Dakota/Lakota language fluency can grow together. Discussion amongst fluent elders, language instructors, and math instructors will illuminate/articulate examples of D/Lakota math connections.

Another limitation according to some critics is the localized nature of the results to Standing Rock Nation. But "as with most researchers, those operating under an Indigenous paradigm recognize patterns that transcend the local and particular. However, the difference is that those ascribing to tribal methodology will likely return to the particular and local to validate claims because our truths are found in our places" (Kovach, 2009, p. 140). The results of this project are validated by local fluent elders and community. Further, the themes and processes can be shared with other D/Lakota communities and/or Indigenous communities pursuing place-based, language-specific research in undergraduate math education where the local fluent elders and community will validate the work in their specific place.

Similarly, the exploratory nature of this research to articulate examples of D/Lakota math connections can be viewed as a limitation, not following the gold standard of research of control group comparisons. However, the assumptions and purposes of this research align more with the

exploratory efforts to articulate connections through conversations among fluent elders, language instructors, and math instructors.

Secondly, this study takes place in the United States with its environment and incessant pressure to value Western math as the superior, normative, and the only way to think mathematically. Unfortunately, the widespread myth of Western math transcending culture and language prevails today and is one of the most powerful weapons of cultural imperialism (Aikenhead, 2017; Bishop, 1990; Stevens, 2021). This socio-political environment will continually be a limitation and threat to the D/Lakota Math Connections project.

Limitations of project implementation stemmed from the environment as well as the researcher. I am not Lakota nor grew up in the Standing Rock community. I do not currently live in Standing Rock. I am a learner to both research and to ceremony (Wilson, 2008). I am a beginner in learning the D/Lakota language. I have a long way to go in embodying my Choctaw identity as a person and a scholar. This is important as "the sacredness of Indigenous research is bound in ceremony, spirit, land, place, nature, relationships, language, dreams, humor, purpose, and stories in an inexplicable, holistic, non-fragmented way, and it is this sacredness that defies the conventional" (Kovach, 2009, p. 140). Despite following Wilson's mantra which states, "if research doesn't change you as a person, then you haven't done it right" (2008, p.135), I have far to go in my personal decolonization. My Western general education experience which values secularism, segmentation, and abstraction, my math training which values definition-based and decontextualized math over verb-based and contextualized math, my conditioning to elevate Western forms of following Jesus, and my infancy to Indigenous knowledges can all be viewed as limitations. I am continually concerned these limitations are leading me to repeat harmful research practices and not achieve the goal of self-determination in math education and Native

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nation building. In response, I whole-heartedly seek to listen to the contributors and project partners, be reflective, and pursue community control of my work.

For data collection, a one-week course for discussions amongst fluent elders, language instructors, and math instructors as well as only having a handful of fluent elders participating, was certainly a limitation of this study. For example, some small groups only had one fluent elder which could not foster dialogue in Lakota about math. Many more topics could have been discussed if we had more time.

6.5. Discussion

The goal of this paper was to share the D/Lakota Math Connections resource available on Othokahe. A few examples from Othokahe were provided to answer the research questions and further understand the D/Lakota Math Connections framework. Some details about the process and limitations were also discussed.

In the future, more work with fluent speakers is needed to articulate more examples of D/Lakota math and discuss math terminology in the D/Lakota language. Further, this research does not look at how the DLMC resource can be implemented by math and language teachers nor its impact on student learning of math and language as well as student identity. All these areas need further research at the K-16 level. Personally, I believe that the process and themes of this study are generalizable as they have been implemented at Turtle Mountain Community College to develop Ojibwe math courses as another approach towards Indigenous math revitalization.

Overall, the results from developing a community-based math resource have been shared as an example of self-determination in math education. However, all further details remain under Standing Rock ownership and authority through their web portal. A community product, that is

not just research articles, follows from relational accountability to all the research participants/contributors. My goal in this research project is articulated by Wilson (2008) who writes:

> "Many things in our modern world try to force us to be separated, isolated individuals. We separate the secular from the spiritual, research and academia from everyday life. It is my dream that we may turn away from this isolation to rebuild the connections and relationships that are us, our world, our existence. We need to recognize the inherent spirituality, as well as the everyday applicability, in our research. Indigenous research needs to reconnect these relationships. (p. 137)

I pray the D/Lakota Math Connections project has and will continue to reconnect these relationships.

6.6. Post Manuscript

6.6.1. Acknowledgements

6.6.2. Author Biography

Danny Luecke is the developer/instructor for the bachelor's degree in Secondary Math Education at Turtle Mountain Community College. He is completing his Ph.D. in math and math education at North Dakota State University currently. His research focuses on Dakota/Lakota Math Connections at Sitting Bull College. He was born and raised in Fargo, North Dakota. He is an enrolled member of the Choctaw Nation of Oklahoma and has ancestry from multiple European nations as well. He believes he is honoring all his ancestors and Creator through his life and work with the Standing Rock and Turtle Mountain communities.

6.6.3. Author Statement

The Author Statement [blind] should articulate (1) the reasons why you undertook this research, (2) how you view the importance of your research, and (3) the ways in which you would like to strengthen the manuscript through the editorial process.

> 1. Research in undergraduate math education is a special interest group of the Mathematical Association of America (SIGMAA). This SIGMAA is part of my PhD program at my PhD-grant university. Initially, in conversations with TCU math instructors, I was introduced to the portion on most TCU syllabi about connection to the culture and the difficulty of the that for many TCU math instructors. Then the research questions and methods were collaboratively determined by a small group (TCU math instructor, language instructor, and Indigenous research paradigm specialist). Personally, Indigenous math education is of interest because of my enjoyment of math, the desire to follow the community (not follow the money), and especially because of my continuing journey of learning to not neglect my [Indigenous nation] heritage.

2. An Indigenous research paradigm (Archibald 2008, Kovach 2009, Wilson 2008) has yet to be applied to research in undergraduate math education in general and specifically at a tribal college/university. Indigenous communities seek an education, including mathematics, that centralizes self-determination and local culture, heritage, and language (American Indian Science and Engineering Society, 2020). In mainstream society and education, unfortunately the widespread myth of Western math transcending culture and language prevails, which devalues Indigenous ways of thinking mathematically. This culture-free math myth is one of the most powerful weapons of cultural imperialism (Aikenhead 2017, Bishop 1990, Garcia-Olp et al. 2019, Stevens 2021). Efforts have been successful at the K-8 level to connect math with culture and self-determination (Lipka & Adams, 2004; Lipka et al. 2005, 2007; Ruef et al., 2020). The [Indigenous Nation (not my own)] Math Connections framework is a pathway for teaching and learning mathematics at the university level. The framework posits that higher order mathematical thinking is embedded within [Indigenous Nation (not my own)] language and culture, that math fluency and [Indigenous Nation (not my own)] language fluency grow together, and the need to strengthen [Indigenous Nation (not my own)] math. I believe both the process can be valuable for those interested in following an Indigenous research paradigm in generally and especially in STEM-related research. I believe that the results and themes can be valuable for TCU math instructors and language instructors at the pre-K-12 level and at the TCU.

3. I am over the 25-page limit by about 3 pages (once un-blinded) and I will need a

lot of help in the editing process to shorten the article without losing the main

messages. I haven't been able to see where to cut it down.

6.6.4. Author Positionality

The Positionality Statement [blind] should articulate how the author(s) position themselves in the research and within the community.

I am an outside, Indigenous researcher/graduate student to the [Indigenous Nation (not my own)] community. I am not [Indigenous Nation (not my own)] nor grew up in the [Indigenous Nation (not my own)] community. I do not currently live in the reservation area of [Indigenous Nation (not my own)]. The relationships with [Indigenous Nation (not my own)] citizens that began before any research and the relationships that began because of the research will all continue past the research. I am a learner to both research, as a graduate student, and to ceremony, as one who did not grow up with any traditional teachings (Wilson, 2008). I am a beginner in learning the [Indigenous Nation (not my own)] language. I have a long way to go in embodying my [Indigenous Nation] identity as a person and a scholar. I seek to follow Wilson's mantra which states, "if research doesn't change you as a person, then you haven't done it right" (2008, p.135). However, I have far to go in my personal decolonization. I am fluent in Western Math and educated in the Western system. Overall, I am a visitor to [Indigenous Nation (not my own)], not in the sense that I'm just passing through town, but in the sense of not being local. I pray that I can be a good visitor to the [Indigenous Nation (not my own)] community and land.

7. DISCUSSION AND IMPLICATIONS

This chapter will be presented in four sections. Throughout this four-paper dissertation, written in story, there are stories that go between and intertwine the four papers. As Tafoya is quoted in Wilson (2008), "Stories go in circles. They don't go in straight lines. It helps if you listen in circles because there are stories inside and between stories" (Tafoya, 1995, p.12). The four sections of this chapter try to emphasize the stories between and throughout the four distinct papers/chapters. The sections include:

The Process (answering research question 1)

The Product (answering research questions 2-4)

Comments on Peer-Reviews

Implications Going Forward

This chapter is not a synthesis of the most significant results. Rather it seeks to synthesize some of the most significant relationships that were strengthened for me. Knowledge is subjective and dependent on both the author/storyteller and reader/listener. I cannot determine the most significant results for you as the reader because I don't own this knowledge, it belongs to the cosmos, that is all the relationships that give it form. My role for this dissertation, and this chapter in particular, is not to say 'this is the most important result.' Rather, I will share the most significant relationships to me. Wilson describes the position of author/storyteller by saying "My role is not to draw conclusions for another or to make an argument. My role, based upon the guidelines of relationality and relational accountability, is to share information or to make connections with ideas… as many connections or relationships available as possible and to respect the reader's ability to take in what they are ready to receive" (Wilson, 2008, p. 133). You as the reader are responsible for your listening, learning, and being accountable to all your

relations. I assume that each listener/reader will process and receive what their relationships have prepared them for (Archibald, 2008; Kovach, 2009; Wilson, 2008).

7.1. The Process

Research Question 1 was developed through the process of using an Indigenous research paradigm and is a process-oriented question. It reads:

> In what ways can Indigenous Research Methodologies lead an individual researcher towards more ethical and impactful (beneficial and actionable) research in undergraduate math education at tribal colleges and universities?

My entire PhD research process is part of answering this research question. Specifically, Ch. 3, 4, 5 are especially process focused and thus answer the first research question. The question both stems from and is answered by the phrase shared amongst Wilson and his co-researchers that "the process is the product." Like in Calculus, or any math class, just the answer '7' by itself is insignificant, but rather the problem, process, and solution are all essential to make them valid and valuable altogether.

Similarly, the process and product are equally valuable throughout this research project. If knowledge is power, then knowledge production is also power. Further, process and product are not just equally valuable, but inseparable. The process of Circulating Conversations Methodology, the D/Lakota Math Connections summer 2021 course, the Translation/Editing Team for collaborative data synthesis, creating the D/Lakota Math Connections resource on Othokahe, and writing the four papers and this dissertation for my PhD are all inseparable and inter-dependent upon one another. One could not nor would not happen without the other. Further, instead of viewing the process as the way to reach the end product (also said as the means lead you to the end), the means to get to the end is the end product. Without the path to

reach the destination, that destination would not be in relationship with the learner/researcher. Further, the process of strengthening relationships amongst people, with the content, with our place, etc. is the product. Relationships can't be strengthened (knowledge gained in other ways of knowing) without a process, experience, and place. When relationships form reality, one does not *have* relationships, but rather one *is* (a web of) relationships. Thus, the process of strengthening relationships is synonymous to the product of strengthened relationships. Process/product of strengthening relationships are one in contrast to a methods section and results section being viewed as separable activities of action and knowledge, respectively. Increased understanding does not come from triangulating an object's location/definition, but rather encircling (strengthening relationships) with the central idea/activity. The answer then to this research question is the process I followed.

One specific of the process that happened throughout the process for increased ethical decision-making and beneficial and actionable results for research in undergraduate math education was an emphasis on local control and self-determination. Research that was done by, for, and with the local community/Nation. Further, Windchief and Pedro (2019, p. xv) quote Archibald in saying "Elders will direct the learning process for those who ask." (Archibald, 2008, p.24). Throughout my process, I consistently sought to listen to fluent elders, knowledge keepers, and language leaders in the community. Not that I did this perfectly, but it certainly has been my goal to not just ask, but listen to the fluent elders and community leaders responses and enter into relational accountability with them. The following quote has often pushed me to think deeper about research by, for, and with Indigenous communities. "As the Elders say, it is important to listen with 'three ears: two on the sides of our head and the one that is in our heart' "(Archibald, 2008, p. 8). Local control and self-determination are far more complex and in-depth

than an individual researcher but these larger ideas influenced me greatly. Because of them, I was moved to be in greater and greater relational accountability with the Standing Rock community and leaders.

Listening to my academic elders, that is Indigenous academics working with an Indigenous research paradigm and/or in Indigenous communities, also led me to use 1st person and story in presenting my work. I seek to listen with my heart and follow a growing number of Indigenous researchers use 1st person and story in presenting their work as well as learn from Long Feather's research of a L/N/Dakota model of oratory (2007). How you hear/read about an Indigenous research paradigm applied to research in undergraduate math education will influence your understanding of the topic. If knowledge is power, then knowledge transmission is also power. Just as the process of the US education system teaching through unspoken Western beliefs that leads students to learn these Western beliefs as the unspoken norm, the process of how one presents their research influences their understanding of the research. Kovach sums up much of storying to me in saying "Stories are who we are. They are both method and meaning. Stories spring forth from a holistic epistemology and are the relational glue in a socially interdependent knowledge system" (Kovach, 2009, p. 108). Kovach expanded by saying, "I knew from a Nêhiýaw point of view that knowledge and story are inseparable, and that interpretative knowing is highly valued, that story is purposeful" (Kovach, 2009, p. 98). Story as method, methodology, meaning, knowledge, and presentation is a form of self-determination. That is, Indigenous scholars determining how they want to both do and present their work to follow their own research paradigm. Kovach warns of "the risk of tribal epistemologies being morphed into something that it is not, merely to become palatable to mainstream academic evaluation" (Kovach, 2009, p. 84). This caution of minimizing, essentializing, or shape-shifting

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Indigenous knowledges, including a research paradigm, to appease whitestream academia has been and continues to be my greatest concern in doing any research within an Indigenous research paradigm, especially as it relates to research presentations and writings.

Lastly, a significant relationship I experienced through the process that led to more ethical, beneficial, and actionable research was the changes in me as a person and as a researcher. Wilson and co-researchers shared the adage "If research doesn't change you as a person, then you haven't done it right." (Wilson, 2008, p. 135). I have changed so much in these past five years including a greater understanding of this quote with a reality formed by relationships. If I don't *have* (or gain) knowledge like it is an object or commodity, but rather am in existence as a web of relationships and knowledge, then I could not learn or gain knowledge without the relationships of who I am changing. Further, it highlights that in an Indigenous research paradigm, knowledge and knower are intertwined and interdependent.

Specifically, for me, despite knowing I was Choctaw my whole life, it rarely connected to my self-perception or identity. I enrolled in Choctaw Nation of Oklahoma during my early graduate school years. Further, I now feel confident in saying I am an Indigenous researcher/scholar and feel confident in my mixed identity as both Native and non-Native. I am comfortable with the ambiguity of it, at least a majority of the time. Additionally, as I reflect at Grande's five key beliefs in the Western knowledge system and their five implications for schooling, I see how I have become more and more aware of these unspoken norms/beliefs within Western society, my education, and my spirituality. These five beliefs and implications moved from invisible assumptions once taken as the only way for the 'modern' educated human to visible assumptions that can be removed (or added) without decreasing one's intelligence. Like any upper-level math proof, I am learning to identify my assumptions and not add any

undeclared assumption. However, I have far to go and much to still learn. I close this paragraph

and section with a few of the First Peoples' Principles of Learning that now are core to my

understanding of learning and knowledge, "Learning requires exploration of one's identity" and

"Learning is holistic, reflexive, reflective, experiential, and relational (focused on connectedness,

on reciprocal relationships, and a sense of place).

7.2. The Product

Research Question 2, 3, and 4 in applying an Indigenous research paradigm to research in

undergraduate math education at Sitting Bull College focus more on content. The process and

product are intertwined. The three research questions read:

> In what ways can Western higher order math concepts be identified within
>
> Dakota/Lakota space, place, and language, to inform possible Sitting Bull College
>
> math curricular/pedagogical adjustments?
>
> In what ways can Dakota/Lakota culture and language be identified within Western
>
> higher order math concepts, to inform possible Lakota Language Immersion Nest
>
> curricular adjustments?
>
> In what ways can Dakota/Lakota space, place, and language represent non- Western
>
> higher order math concepts?

The process strengthened relationships amongst the participants/contributors, our

knowledge, the land, etc. Plus, the knowledge has no individual owner. Thus, I cannot

authoritatively share the results/product of this research. The newly formed web of relationships

that is the product of this research does not belong to me, nor can I be aware of every

contributor's web of relationships that collaboratively connected to form this new set of

relationships. Instead, I can share some significant relationships I have with answering these three research questions.

First, we experienced that much of answers to these three research questions were the examples/connections made. The connections made between fluent elders, math instructors, the land/place/nature, math, language, D/Lakota perspectives, Western perspectives gave form to a variety of types of different examples. Overall, the research project was exploratory, seeking to make new connections, that is articulating D/Lakota math connections. Limitations in exploratory research is always time. More time with the collective group of TCU math instructors, language instructors, and fluent elders would certainly allow for more connections to be made.

One answer/product from the research questions was the D/Lakota Math Connections framework which gives a visual and symbolic representation (four circles) as one way to think about the new connections and strengthened relationships. Sitting Bull College, and TCU in general, math instructors can not only use the examples, that is D/Lakota math connections, but the framework in connecting local heritage and culture with their classroom. The D/Lakota Math Connections framework and specific D/Lakota math connections gives Sitting Bull College math instructors one way to specifically follow the Sitting Bull College syllabi template eliciting the cultural relevance for every course. Further, a fluent elder shared the metaphor of encircling the activities around hunting buffalo. This metaphor of encircling gave definition to 'higher order math concepts', 'D/Lakota math', and 'D/Lakota math connections' by not defining the term but rather teaching that to understand the center, one must identify its relations and connect with those. Additionally, two fluent elders' part of the Translation/Editing team confirmed in three distinct stories that math (content and instruction) is linked to culture, D/Lakota math is distinct

from Western math, and the D/Lakota language is fully capable of describing D/Lakota math and Western math.

Every example of a D/Lakota math connection that was collaboratively decided upon by the Translation/Editing team is at www.Othokahe.com. Not every example fit within the four papers, nor by Indigenous data sovereignty of Standing Rock Nation, is every example shared within this dissertation held by North Dakota State University. Every example is freely available to all who make an account on Othokahe, the web portal for the Department of Education of Standing Rock Nation. The reference pages within the D/Lakota Math Connections resource include:

Negative Numbers

Subtraction

Addition

Multiplication

Number System and Dialect Variations

Numbers as Verbs

Number Structure as a Western Math Teaching Tool

Understanding One

Fraction Contexts

Adding Fractions Metaphor – Realized and Unrealized

Sun Wave

Shapes and Designs

Angles

Big Dipper

Horses

Nature

Flutes

Handgames

Nested Sets

Altogether the D/Lakota Math Connections resource has specific examples related to certain undergraduate math topics including:

Conditional probability

Series/partial sums

Polynomials

Multiplicative identity

Set theory including nested sets

Polar coordinates

Permutations

If time allowed for more research, symmetry groups in weaving and the math of music and scale of the D/Lakota flute would both be areas of future research in D/Lakota Math Connections. This gives specific examples for Sitting Bull College math instructors to inform possible curricular/pedagogical adjustments.

Further, the D/Lakota Math Connections project is continuing beyond this initial PhD work based on the community and fluent elder participation and desire. The product of this research is the continuation of the process. Going forward, two focus areas will be annually emphasized. Developing/confirming D/Lakota language for math vocabulary will continue to give specific examples/words for D/Lakota language instructors informing possible curricular

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adjustments for immersion schools. Secondly, further understanding/defining/strengthening relationships with D/Lakota Math distinct from Western Math and embedded within D/Lakota cultural activities will continue to give understanding to non-Western higher order math concepts. These will build upon some explicit examples in the D/Lakota Math Connections resource such as numbers as verbs, the sun cycle, flute making and playing, caring for and racing horses, mirroring of what is above and below (spirituality of math), the wholeness/interconnected nature of math, and math embedded in nature. A further area of research could be the universal math activity of "explaining" using the D/Lakota language and logic as initially described by Sanders (2011).

7.3. Comments on Peer-Reviews

The peer review process is a story between and throughout each published paper that sometimes is overlooked. This section will highlight some of the themes from the five reviewers, especially on published paper 2 and 3, chapter 4 and 5 respectively. The first theme was that everyone was very respectful to me and the work. Reviewers sought to strengthen the work instead of tear it down. Reviewers attempted to take on the assumptions of an Indigenous research paradigm to evaluate the work, albeit multiple shared/confessed the difficulty in that. I am abundantly thankful for each reviewer. Their comments, critiques, and questions have dramatically strengthened the first drafts to the final copies that were published and part of this dissertation.

Often while reading reviewers comments one quote would come to my mind. The quote encompasses the themes I took away from many of the reviews. Relating Indigenous research paradigms to academia, "Indigenous epistemologies challenge the very core of knowledge production and purpose. While this is not a matter of one worldview over another, how we make

room to privilege both, while also bridging the epistemic differences, is not going to be easy" (Kovach, 2009, p. 29). Many of the reviewers' comments dramatically helped me re-write to further bridge the epistemic differences. However, requests from reviewers sometimes included more linear research (process and product separate), more linear writing (more direct communication with less context and story), use of Western validation/credibility approaches, and comparing and/or justifying Indigenous research paradigms with other research paradigms. All these requests pushed me to thinking about the challenge of articulating an Indigenous research paradigm that does not align with Western views of knowledge. For almost all of these type of reviewer comments, I did not follow their specific request. Rather I was prompted towards further articulating my understanding of an Indigenous research paradigm.

In articulating an Indigenous research paradigm, Wilson quotes Tafoya to help describe some of the difficulty. "Terry Tafoya (1995) said, when speaking with people from another culture it often takes longer to explain the context, background, or meaning of a story than it does to actually tell the story. On the other hand, when communicating with people who share the same culture, too much explanation or background detail could be seen as disrespectful of intelligence of the listener" (Wilson, 2008, p.7). I do not know who will read my work and so I attempt to write in balance to all types of listeners, but inevitably one must make assumptions about what the readers already know. Please forgive me for my miscommunications, offenses, and errors.

Using story as both process and product recognizes that assumptions must be made in knowledge production and transmission. Story recognizes knowledge is subjective. Further, Indigenous scholars recognize not only the power of story communicating, but the power of citation practices as a larger story. I sought to highlight Indigenous academics whenever possible

as a political act of saying an Indigenous research paradigm should be evaluated through the lens of an Indigenous research paradigm, not any other paradigm.

Writing in story while seeking to bridge to those who are unfamiliar with the assumptions of an Indigenous research paradigm is not easy. It is worth the effort I believe. Tuck and Yang believe that "Storywork is Native futurity in practice." (Tuck & Yang, 2019, p. xi). Further, "As Archibald (2008, p. xi) reminds us, 'Indigenous story work is not easy.' As scholars speaking with others and with the knowledge that their storywork will be picked up by still more readers, the authors must be clear about what is being shared and why, without offering up knowledge to be simply expropriated out of context" (Windchief & Pedro, 2019, p. xi). Forgive me for the ways I have mis-represented storywork or Indigenous knowledges.

7.4. Implications Going Forward

A few implications for the future are highlighted here. First, as part of answering research question 1, applying an Indigenous research paradigm to research in undergraduate math education bolsters the credibility and applicability of an Indigenous research paradigm in STEM fields. For example, this story-based dissertation is hosted officially in the North Dakota State University math department.

Further, this study pushes back against the incessant pressure in the United States education system and beyond to overvalue Western math and devalue (or ignore altogether) any other way of mathematical thinking. Western math is valuable, but not the only way to think mathematically. It's not wrong to make the assumptions of Western math like making assumptions at the start of a proof. However, it is wrong when those assumptions are not declared and then assumed and used as the basis for understanding. I believe that Western math has been used as one of the strongest and most devious tools of colonization. The colonizing

force says that any math that is not Western math, is not 'real' math at all. It is lesser is some way. Western math has created the myth that its assumptions are not assumptions at all but the only way for 'modern' humans to think logically/rationally. The story 'Coyote Searching for the Bone Needle' (Archibald, 2008, pp. 35–36) powerfully helped me see the seductive and destructive force of maintaining the status quo of Western math/knowledge superiority. This entire dissertation study pushes back against Western math normalcy and superiority.

This study also highlights the value of inter-disciplinary and trans-disciplinary research and learning in general. Math fluency and language fluency do grow together. The D/Lakota Math Connections framework was confirmed. This view of math and language fluency could transform the currently siloed education experiences of math class and language class for K-16 students in the United States. Indigenous language revitalization efforts could not only be in the K-16 language classroom, but Indigenous language revitalization efforts should be happening within the math classroom and every classroom in D/Lakota communities.

This PhD study will also continue into the future through following the suggested next steps. A partnership between the Sitting Bull College Teacher Education Department and the D/Lakota Math Connections project has begun to continue building on the work from this PhD study. More math vocabulary in the D/Lakota language will be developed. Further, D/Lakota math will be further articulated through encircling, that is strengthening its relationships and our relationship with D/Lakota math. This PhD study was only the beginning. The D/Lakota Math Connections project will continue.

This study is further opening the door for research in Indigenous mathematics. Research in Indigenous mathematics would be a new area of study within the Special Interest Group of the Mathematical Association of America (SIGMAA) on Research on Undergraduate Math

Education (RUME). Research in Indigenous mathematics would challenge the myth of Western math superiority. For example, an Introduction to Proofs course theme could not only be framed as 'formalizing logic' to being framed as sharing a story with a specific audience where specific assumptions are stated and other assumptions are not stated because considered trivial to the audience of the proof/story. Assumptions not stated in upper-level math proof courses change depending on the audience of the proof as the content gets more advanced. Additionally, research in Indigenous mathematics would expand beyond Western mathematics that "deals with thinking only of content, whereas indigenous mathematizing deals with thinking, doing, living, and being with the content (Aikenhead, 2018)." (American Indian Science and Engineering Society, 2020, p. 5).

Further, research in Indigenous mathematics has already influenced other Indigenous communities beyond Standing Rock. As a faculty of math and math education at Turtle Mountain Community College, my experiences and knowledge of this research have prompted the creation of the course sequence Ojibwe Math I, Ojibwe Math II, and Ojibwe Math III at Turtle Mountain Community College. Further replications within other communities/TCUs looking at place-based, language specific mathematics could happen also. TCUs could further link their missions' statements about community and culture with the math classroom.

This PhD study in Indigenous mathematics is limited in multiple ways, but it could develop into an entire research field. One week of exploratory discussions amongst math teachers, language teachers, and fluent elders and then collaborative data synthesis afterwards is only a start. These three years demonstrated the need for more research around D/Lakota Math Connections. The quantitative research in Paper 3 (Chapter 5) showed that D/Lakota math was perceived by the participants as the least emphasized circle in the initial summer course while

also being the perceived circle with greatest area of learning for the participants. Further, the relationships at Sitting Bull College that initiated this research are still desiring that work to continue by helping to write grants and support the next steps.

Not only could the D/Lakota Math Connections project extend beyond one week into multiple PhD research projects and an entire field of research, the implementation of Indigenous mathematics into the K-16 math classroom is yet to be explored. The Yup'ik in Alaska and the Show Me Your Math project have begun to look at Indigenous mathematics taught in the K-8 classroom but I am unaware of any examples in high school or college. To follow TCU mission statements that link culture and language with every class at the college, the area of implementing Indigenous mathematics in the TCU math classroom needs to be encircled, that is strengthening its relationships. Research in Indigenous mathematics and its implementation at K-16 level could become an entire research area.

7.5. Conclusion

I am not presenting this dissertation is the one way to think about D/Lakota math, nor the one way to apply an Indigenous research paradigm to research in math education at TCUs. What I present is only the relationships that were strengthened/encircled for me through qualitative and quantitative methods. Wilson shares at the end of his book on an Indigenous research paradigm that "this study is not intended to impose conclusions on other people or to be a manual of techniques for their research. This would narrow their thinking. I hope that an Indigenous research paradigm provides a foundation from which to work but not a ceiling or walls to enclose or encage others. What is presented in this book is only one version of an Indigenous research paradigm. The very nature of our epistemology is that it will be different in other contexts"

(Wilson, 2008, p.136). I pray that you will be able to draw conclusions of your own that fit your place, context, and web of relations.

This section is not saying 'this is the most important result.' Rather, I close by sharing some of most significant results for me. Academic rigor in applying an Indigenous research paradigm comes from aligning all decisions to relationality and relational accountability. Further, I experienced the process as the product. "If research doesn't change you as a person, then you haven't done it right" (Wilson, 2008, p.135). I am certainly a different person then when I began. I now see that not only knowledge is power but knowledge production and knowledge transmission are also power. I believe now that math fluency and language fluency do grow together. I believe that the multiple examples within the D/Lakota Math Connections framework in Othokahe answer the research questions and are an example of self-determination in math education.

My ultimate goal in this research project is well articulated by Wilson (2008) who writes: "Many things in our modern world try to force us to be separated, isolated individuals. We separate the secular from the spiritual, research and academia from everyday life. It is my dream that we may turn away from this isolation to rebuild the connections and relationships that are us, our world, our existence. We need to recognize the inherent spirituality, as well as the everyday applicability, in our research. Indigenous research needs to reconnect these relationships. (p. 137). I pray the D/Lakota Math Connections project has and will continue to reconnect these relationships.

Thank you. Yakoke. Philámayapilo.

Héčhetu yeló (that is it).

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