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An Action Research Case Study: A Sociocultural Perspective on Native American Students Learning Mathematics in a Public Elementary School Classroom

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DISSERTATION

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Dedication

To my family and loved ones, especially my son, Jasper Tsuchiya Cook and companion, Alden Naranjo, Jr., who have supported and suffered with me through my many years of post-secondary education. To my elders and social justice advocates who bravely fought and made it possible for me to be a woman of color in the academy. To the past, current, and future students, educators, and scholars who engage in education and schooling to promote social justice and equity.

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ABSTRACT

This dissertation is a qualitative study utilizing action research methods to develop a case study on the experience of urban public elementary school Native American students in collaborative mathematics activities. Data was collected with observations, mathematics assessments, and interviews to study how public school Native first graders experience collaborative mathematics activities when culturally modified with Indigenous ways of knowing and being?

A major challenge in analyzing this work was finding a theoretical framework that could explain the experience of Native students in a multicultural public school. Sociocultural theory was selected because it operationalizes the key features of the study: Indigenous ways of knowing and being and the joint activity of learning mathematics in a public school classroom. The study suggests that Native students were heterogeneous learners and responded to cognitive pluralism, a variety of instruction, student practice

options and assessments, in differentiated ways. Furthermore, the collaborative activity of learning mathematics was influenced by the affective factors developed in classroom culture. The teacher designed the classroom as a caring community that acknowledged students' cultures with an appreciation and respect for the reality of student lives. The findings from this study suggest that collaborative mathematics activities can promote Native students' learning when teacher and student participation is varied in style and function, and when this joint activity is nested within a larger context of a supportive community classroom. Key to this premise is the concept of nested joint activities; where the synergy of learning operates within and between joint activities.

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Chapter 1

Introduction

Mathematics and Society

Mathematics is crucial knowledge in our society. Citizens with mathematical expertise have better work opportunities resulting in the power to make decisions in their lives. People without this knowledge have limited opportunities to participate fully in society. Mathematics literacy is an important civil right (Moses & Cobb, 2001). The National Council of Teachers of Mathematics legislative 2013 platform states,

> A strong pre-K–12 mathematics education for all students is increasingly important to our nation's economic stability, future national security, and workforce productivity. An economically competitive society recognizes the importance of mathematics learning to adult numeracy and financial literacy, and it depends on citizens who are mathematically literate. (2013 para. 1)

Numerous education reports like; *A Nation at Risk* (Goldberg & Harvey, 1983), *Everybody Counts: A Report to the Nation on the Future of Mathematics Education* (National Research Council, 1989) and the *Final Report of the National Mathematics Advisory Panel* (National Mathematics Advisory Panel, 2008) echo similar conclusions. The reports state that mathematics is foundational knowledge for science and technology. It has great social utility and is a major factor in career opportunities. Mathematics is a powerful cognitive strategy and a powerful tool in science and technology. "Science and technology have come to influence all aspects of life, from health and environment to financial affairs and national defense" (National Research Council, 1989, p. viii).

The strong connection between science and mathematics makes it a key factor to career opportunities. The growth in science and technology based jobs is increasing. "The National Science Board indicates that the growth of jobs in the mathematics-intensive science and engineering workforce is outpacing overall job growth by 3:1" (National Mathematics Advisory Panel, 2008, p. xii).

Mathematics Achievement – National

Nationally the U.S. has very low levels of student achievement in mathematics. The National Assessment of Educational Progress (NAEP) reports from 2013 indicate the nation's 4th grade students who attend public schools scored 42% at or above proficient, and 59% were at or below basic in mathematics. In the same year, 8th grade students who attended public schools scored 34% at or above proficient, and 66% were at basic or below basic in mathematics (National Center for Education Statistics, 2013). Proficiency rates increased over the years but low achievement has persisted since 1990 (NCES, 2013). Great disparities in U.S. mathematics achievement are evident when student data is disaggregated by race and socio-economic status. Students of color and students, and in free and reduced lunch programs typically score lower than White students [with the exception of Asian students] (NCES, 2013).

Mathematics Achievement American Indians and Alaska Natives

Terminology varies greatly for the original peoples of what is now known as the United States of America. The terms American Indian, Native American, Native, Indian, and Indigenous can all be found in the literature. In this dissertation, from this point forward, I use the term Native for the original people of the United States, including Alaska Natives and Native Hawaiians. I will also use the terms American Indian when not including Hawaiians and Alaska Natives. In addition, I will use the term Indigenous as a more inclusive word (national and international) to reference groups of people who inhabited lands before colonization and have maintained distinct cultural and social organizations (Castagno & Brayboy, 2008).

The majority of Native students attend public schools but the majority of Native research has been conducted in Bureau of Indian Education and tribally controlled schools (Swisher & Tippeconnic, 1999). American Indian and Alaska Native students have very low achievement in mathematics. In 2011, 22% American Indian students scored at or above proficient in fourth grade, and 17 % scoring at or above proficient in eighth grade (USDE, 2011a). American Indian and Alaska Native student proficiency rates are the second lowest as compared with other minorities. The *National Indian Education Study* reports that Native students in the mountain region of the U.S. have the lowest academic achievement of Native students in any other region in survey years 2005, 2007, 2009 (Grigg, Moran, & Kuang, 2010; USDE, 2011b). New Mexico is in the mountain region.

The state of New Mexico measures public school student academic proficiencies with the New Mexico Standards Based Assessment (SBA) (New Mexico Public Education Department, 2012a). In the 2011-12 academic year, American Indians had the lowest mathematics proficiency percentages of any other racial group with 33% at or above proficient state-wide for grades 3rd, 4th and 5th (NMPED, 2012b). Thirty seven percent of American Indian students were at or above proficient district wide in the city the study takes place in [1].

[1] This information came from an official state website but I am unable to cite the source(s) because of confidentiality necessary to the study.

Nationally Native students' dropout rate is more than twice the rate for White students with 13% of Native students who aren't in high school and don't have a diploma or alternative credential and as compared with 6% for White students (Chapman, Lard, Ifill, & Kewal Ramani, 2011). Native students are also underrepresented in requisite courses that prepare them for careers requiring higher-level mathematics knowledge. As result, American Indians are underrepresented in careers requiring higher-level mathematics and science (Smith, 1997).

Native Federal Relationship

Native peoples in the United States of American have a very long, complicated and nuanced history and relationship with the federal government. The following sections on Native federal relationship, education policy, and legislation are neither comprehensive nor summative but serve to highlight some issues that allude to the complexity and unique position that Native peoples have in this country. Education socializes children to dominant societal beliefs and values and is never neutral (Delpit, 1988). Mathews et al., (2005) write "mathematics education cannot be discussed without considering the whole context of Indigenous people particularly in relation to their history and experience with education" (2005, p. 3). Mathews et al. are Australian scholars studying Aboriginal mathematics education and international research is relevant to Native contexts because many Indigenous Peoples around the world have been confronted with the incursion of *Western Society* on their traditional way of life (Kawagley, 1995). The next section is dedicated to the Native and federal government relationship.

Native people have a long history with the U.S. federal government. This relationship evolved from over 400 "treaties and subsequent executive orders, congressional acts, and court decisions (that form) the legal basis for federal recognition and responsibility for Indian education" (Tippeconnic & Swisher, 1992, p. 75). Only federally recognized Native communities in the United States are considered sovereign nations. At present, there are 566 federally recognized American Indian and Alaska Native tribes and villages" (Bureau of Indian Affairs, 2014b). No other ethnic minority in the U.S. has sovereign status. Deyhle and Swisher write, "Sovereignty is the inherent right of a people to self-government, self-determination, and self-education. Sovereignty includes the right to linguistic and cultural expression according to local languages and norms…" (Deyhle & Swisher, 1997, p. 9).

Intertwined with Native sovereignty is federal trust responsibility. The U.S. federal government has a trust responsibility towards the welfare of tribal members and is based on treaties between Native nations and the federal government in exchange for land (Cross, 1999; Pevar, 1992). Federal trust responsibility is composed of three general aspects: Indian land and land use, sovereignty and self-governance, and social issues including health and educational services (National Congress of American Indians, n.d.). Native American education policy is based on the federal government relationship with Native peoples. The *Self-Determination and Educational Assistance Act* was passed in 1975 (Bureau of Indian Affairs, 2014a). This act allowed Native nations to control Bureau of Indian Education schools in their communities through contracts with the Bureau of Indian Education. While some tribes are exercising this option, most Native education is still controlled by the federal government. Federal control of Native education stands in stark contrast to the local control enjoyed by the rest of U.S. public education system (Deyhle & Swisher, 1997). This relationship and history distinguish Native peoples from other ethnic minorities in the U.S.

and it is this positionality that "is not clearly understood by the majority of mainstream America" (Deyhle & Swisher, 1997, p. 114).

Native Education History

Native societies have always had their own modes of communication and processes for transmitting knowledge (Juneau, Fleming, & Foster, 2013). History, culture, religion, and scientific knowledge is passed from elders to youth through oral traditions,

> Traditional Indian education emphasized learning by application and imitation…learning by sharing and cooperation…Tribal histories told and retold an Indian people's origin myths and how they spurred the people to great deeds…children were located within a loving and caring natural environment…where respect for his elders, was …a central part of an Indian child's traditional education. (Cross, 1999, pp. 947-948)

Traditional Native teaching and learning took place in "very high-context social situations (Cajete, 1999). Teaching and learning depended on the situation and environment. Specific content was taught in the appropriate context and at the appropriate time. Teaching and learning was embedded is all aspects of community life (Cajete, 1999).

Traditional American Indian education systems were fundamentally impacted by an intrusion process enacted through European contact, religious fervor, federal policies, and Indian treaties (Juneau et al., 2013). A very long and tragic history exists for federal American Indian education beginning in the 1500s with mission schools to federal boarding schools in the 1800s, to self-determination era of the 1970's. Raymond Cross (1999) describes American Indian Education as "the terror of history" (p. 941). The essential goal of past federal American Indian education efforts was to civilize and assimilate American

Indian children. Torture, multilation and death were methods used to reach this goal (Curcio, 2006-2007).

Education goals changed over the years from assimilation to cultural survival, yet systematic failure persists in American Indian education. Reports of gross inadequacies and a generally poor state of Native education have existed since the 1920's. In 1928, the Meriam Report: *The Problem with Indian Administration,* found Indian boarding schools grossly inadequate and called for the end of these schools. The report recommended assimilating American Indian children into mainstream schools (Meriam, 1928). Despite these findings boarding school student populations grew through the 1970's (Reyhner & Eder, 2004).

In 1966, the Commission on the Rights, Liberties, and Responsibilities of the American Indian published the report titled *The Indian: America's Unfinished Business* (Brophy & Aberle, 1966). This report stated that schools were failing to assimilate American Indian children. In 1969, the Kennedy Report: *A National Tragedy-A National Challenge* reported that the state of Indian education changed little over the years (Congress of the U.S. Washington D.C. Senate Committee on labor and Public Welfare, 1969). In 1991, the *Indian Nations at Risk: An Educational Strategy for Action Report* found some improvements in American Indian education however; they still found Native students at risk. In 2003, the U.S. Commission on Civil Rights issued a comprehensive report titled, *A Quiet Crisis: Federal Funding and Unmet Needs in Indian Country*. This study found:

> As a group Native American students are not afforded educational opportunities, equal to other American students. They routinely face-deteriorating school facilities, underpaid teachers, weak curricula, discriminatory treatment, and outdated learning

tools. In addition, the cultural histories and practices of Native students are rarely incorporated in the learning environment (U.S. Commission on Civil Rights, 2003, p. 9).

Native Education Legislation

Decades of federal legislation have been passed to support Native education and cultural survival. Recent legislation includes but is not limited to the *Native America Languages Act* (NALA) 1990 and 1992, *Elementary and Secondary School Act* (ESEA) 2001 reauthorization, and the *Esther Martinez Native American Languages Preservation Act* of 2006. The *Native American Languages Act* of 1990 recognizes the language rights of American Indians, Alaska Natives, Native Hawaiians, and Pacific Islanders. Congress passed the *Native American Languages Act* (NALA), recognizing that “the status of the cultures and languages of Native Americans is unique and the United States has the responsibility to act together with Native Americans to ensure [their] survival” ("Native American Languages Act," 1990 § section 102-1).

The 1990 act, promised to preserve, protect, and promote Native Americans’ rights to use their Indigenous languages anywhere, including as a medium of instruction (Klug, 2012). The 1992 *Native American Language Act* legislation added grant funding. This was an important change in the law since the original act did not fund its directives. The *Esther Martinez Native American Languages Preservation Act* of 2006 helps to keep Native American languages alive by providing federal grants to Native American language immersion programs ("Esther Martinez Native American Languages Preservation Act ", 2006). This act was not reauthorized in 2012.

Title VII of Elementary and Secondary School Act addresses American Indian, Native Hawaiian, and Alaska Native Education and applies to Native students attending public schools. The purpose of the act is to support local education agencies to meet the educational needs of Native students ("Elementary & Secondary Education Title VII - Indian, Native Hawaiian, and Alaska Native Education," 2004). Klug (2012) writes despite claims that *Title VII of Elementary and Secondary School Act* respects "the right of Native communities to incorporate their own language and culture into their children's education, but many of its mandates actually contradict those laid out in Native American Languages Act and impede the success of immersion schools" (para. 7). The central barrier involves the act's requirement to hire highly qualified teachers. Most Native language speakers are tribal elders who do not meet this requirement (Klug, 2012).

Several United States presidents signed executive orders addressing Native education. The latest is Executive Order 13592, 2011, *Improving American Indian and Alaska Native Educational Opportunities and Strengthening Tribal Colleges and Universities*. The order authorizes The White House Initiative on American Indian and Alaska Native Education. The Initiative, is part of the Department of Education and "seeks to support activities that will strengthen the Nation by expanding education opportunities and improving education outcomes for all American Indian and Alaska Native (AIAN) students" (U.S.D.E. 2011b).

It should be noted that the school site of this research study resides in a district that complies with Title VII provisions through a district sponsored Indian Education department. This department offers a variety of programs including an Indian Education committee, an Indian parent committee, and student programs for leadership, reading, mathematics, science, and Native languages. It is interesting to note there was no evidence that any of these programs engaged with or had an impact on the Native students in the research study. In fact, the teacher reported that a study student parent contacted this department requesting academic assistance and was told no services were available despite her child's enrollment as a tribal member of a federally recognized tribe.[2]

Conceptual Framework – Sociocultural Theory

Sociocultural theory is the theoretical framework most helpful in explaining the findings of this study. Classrooms are social spaces and can be examined with sociocultural theory (Nieto, 2002). Sociocultural theory is most closely associated with the work of Lev Vygotsky. Vygotsky's work explains the dynamic interdependence of social and individual processes (John-Steiner & Mahn, 1996). In this perspective, the unit of analysis moves from the individual to the active participation of people in learning spaces, (Rogoff, 1990b) and to the processes of the social activity and not the product of those processes (John-Steiner & Mahn, 1996). Smagorinsky (2007) notes, thinking is social in origin and is the product of cultural practice, "it is understanding how people learn to think" (p. 63).

Sociocultural theory focuses on contexts of learning, the processes that occur, and the way culture shapes both context and actors in those contexts. This focus makes the theory about contextualization and the contexts of learning, rather than on universal notions of individual development (John-Steiner & Mahn, 1996). I selected sociocultural theory for this study because it allowed me to consider culture in understanding the phenomena occurring among Native students participating in culturally modified mathematics activities. A larger discussion of sociocultural theory is provided in Chapter 2, Literature Review, and in

[2] This information came from an official school district website but I am unable to cite the source (s) because of the confidentiality necessary to the study

Chapter 4, Findings-The Context, and Chapter 5, Findings-Mathematical Thinking and Learning

Mathematics Education

The most recent movement to reform mathematics education started in the 1980's and sought to improve student mathematics achievement nationwide. The National Council of Teachers of Mathematics promotes reform mathematics and is the largest educator organization leading these efforts (NCTM, 1989b). The Council describes itself as "a global leader and authority in mathematics education, ensuring that all students have access to the highest quality mathematics teaching and learning (NCTM, 2009). The National Council of Teachers of Mathematics mission states it "is the public voice of mathematics education, supporting teachers to ensure equitable mathematics learning of the highest quality for all students through vision, leadership, professional development, and research" (NCTM 2012).

To accomplish its mission the National Council of Teachers of Mathematics developed "a set of standards for school mathematics that address content, teaching, and assessment. These standards are guidelines for teachers, schools, districts, states, and provinces to use in planning, implementing, and evaluating high-quality mathematics programs for pre-kindergarten through grade 12" (NCTM, 2009 para 2). The National Council of Teachers of Mathematics standards have been articulated in a series of publications from 1989 to 2000.

In 2000, the National Council of Teachers of Mathematics published *Principles and Standards for School Mathematics* (NCTM, 2000a). This publication "is intended to be a resource and guide for all who make decisions that affect the mathematics education of students" (NCTM, 2000a, p. 11). The principles describe significant features of high-quality mathematics education, and the standards describe the mathematical content and processes that students should learn (NCTM, 2000a). The National Council of Teachers of Mathematics promotes learning mathematics with understanding that privileges conceptual knowledge but acknowledges procedural fluency as a necessary skill. Students need both types of knowledge to effectively apply mathematical knowledge and be mathematically literate (NCTM, 1989b).

Productive mathematical practice develops mathematical power. Mathematical power is a student's ability to explore, conjecture, reason logically, and apply these skills effectively to solve routine and non-routine problems (NCTM, 1989b). Practice of these skills develops dispositional characteristics of successful students of mathematics (NCTM, 1989b). The National Council of Teachers of Mathematics (1989) cites the following dispositions as goals for students:

- Learning to value mathematics
- Becoming confident in one's own ability
- Becoming a mathematical problem solver
- Learning to communicate mathematically
- Learning to reason mathematically (NCTM, 1989a para 1)

The latest set of national mathematics standards is called *Common Core State Standards* and was published in 2010. This publication was authored by the National Governors Association Center for Best Practices & Council of Chief State School Officers and includes a set of mathematical practice standards (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). Common Core State Standards for mathematical practice include all the National Council of Teachers of

Mathematics disposition goals for students and a second strand of standards developed from the National Research Council's report *Adding It Up*: Helping Children Learn Mathematics (National Research Council, 2002). The second strand of goals includes adaptive reasoning, strategic competence, conceptual understanding, procedural fluency, and productive disposition. The Common Core State Standards combine both sets of mathematical practice standards in the following eight standards.

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
3. Construct viable arguments and critique the reasoning of others.
4. Model with mathematics.
5. Use appropriate tools strategically.
6. Attend to precision.
7. Look for and make use of structure.
8. Look for and express regularity in repeated reasoning. (NGAC, 2010 para. 2-9)

Reform mathematics researchers describes three best practice features of classroom practice "(a) shaping classroom mathematical discourse (b) developing classroom norms that support engagement around the mathematical ideas (c) developing relationships with students and the class in a way that supports opportunities for participation in the classroom's mathematical work" (Franke, Kazemi, & Battey, 2007, p. 230).

Productive mathematical discourse is promoted with: revoicing, interrogating for meaning, student autonomy in choosing and sharing problem solving methods, appreciation of the value of mistakes as sites for learning for everyone, recognition that authority lies in mathematical logic and reasoning and not in the status of the person. Revoicing is when a teacher repeats student comments and modifies what they say to clarify questions or organize the comments. Teacher revoicing is a strategy that publically organizes and aligns student ideas for productive mathematical conversations (Franke et al., 2007). National Council of Teachers of Mathematics principles and standards and Common Core State Standards have national impact in public schools. Their influence impacts Native students in three ways. First, the majority of Native students attend public schools (Swisher & Tippeconnic, 1999). Second, neither effort considers the student's cultural ways of knowing and being. Lastly, the national norms, values, and dispositions are presented as culturally neutral goals and there is no acknowledgment that these goals are culturally biased.

Critiques of Reform Mathematics

Proponents of the national standards argue that mathematical development is best facilitated when students develop dispositions and practice norms as described in the organizations standards (NCTM, 1989a; NRC, 2002; NGAC, 2010). To develop a reform mathematics identity, educational environments should be dominated with discourse, and that discourse should engage students in questioning, challenging and interrogating all aspects of the learning experience, including peers, teachers, and textbooks (NCTM, 1989a). If reform mathematics classroom practices develop mathematical knowledge and power in students, I question whether reform mathematics classroom practices support all students. What happens when classroom practices are at odds with student social and cultural ways of knowing and being.

A sociocultural perspective recognizes that learning goals and norms reflect particular cultural values that may be in stark contrast to values and norms of some cultures (John-Steiner & Mahn, 1996). If all students can and should learn mathematics and all student have a right to high quality instruction and genuine opportunities to learn; what happens to students caught in this tension? This culturally based tension could impede student participation in the classroom's mathematical work and impede learning itself by not attending to culturally based ways of processing and learning (Pewewardy, 2002).

Problem Statement

The reform mathematics movement seeks to improve mathematics education in the United States. The National Council of Teachers of Mathematics outlines what should be done in its principles and standards. Mathematics reform research promotes strategies to facilitate mathematical understanding. What happens if these strategies come into conflict with student social and cultural ways of knowing and being? Indigenous education research has identified elements of potential conflict between reform mathematics classroom norms and Native learning styles and process preferences (Pewewardy, 2002; Trumbull, Nelson-Barber, & Mitchell, 2002). Asset pedagogies like culturally relevant and responsive teaching align education to specific cultures (Gay, 2000; Ladson-Billings, 2009). However, asset pedagogies do not address multicultural contexts like public schools where the majority of Native students attend public schools but the majority of Native research has been conducted in Bureau of Indian Education and tribally controlled schools (Swisher & Tippeconnic, 1999). This dilemma poses challenges for Native education in general however, for the purpose of this study, I will focus on this tension for Native students learning mathematics in public schools.

Need for the Study

Current mathematics educational practices result in very low mathematics achievement for Native students. Research is needed to understand and address this problem

(USDE, 2012). The majority of Native students attend public schools but the majority of Native research has been conducted in Bureau of Indian Education and tribally controlled schools (Swisher & Tippeconnic, 1999). Research is lacking on the experiences of Native students in public schools. In addition, mathematics education research predominantly focuses on cognition and achievement. Sociocultural mathematics research is needed to address the inequities in the education of students of color (Gutierrez, 2007).

Research Question

How do public school Native first graders experience collaborative mathematics activities when culturally modified with Indigenous ways of knowing and being?

Chapter 2

Review of Literature

This study examines how public school Native first graders experience collaborative mathematics activities when culturally modified with Indigenous ways of knowing and being. In this chapter, I review literature on sociocultural theory and select it as the conceptual framework for the study. Next, I reviewed constructivism and social constructivism and discuss their influence on the field of mathematics education. After that, I reviewed literature on cultural capital theory, the *culture of power*, community in school, the game of school, to understand the culture of school. Next, I reviewed literature on reform mathematics, mathematics education research, and the reform oriented mathematics interventions Math Recovery and Cognitively Guided Instruction. I discuss these programs reform with the lens of sociocultural theory. In the last section, I review literature on following Native and Indigenous education issues: Native and Indigenous epistemology, Native learning styles, and Native and Indigenous mathematics education research.

Sociocultural Theory

Sociocultural theory explains human development as a dynamic of social activity and individual processes. Learners are not genetically predisposed to be one way or the other, they learn how to learn through socialization processes that occur within societies and communities (Vygotsky, 1986). This is in contrast to stage theorists who explain human development as innate processes that occur in individuals (Rogoff, 1990a). Werstch (1991) cites three major themes in Vygotsky's theory.

- Individual development, including higher mental functioning, has its origins in social sources

- Human action on both the social and individual planes, is mediated by tools and signs
- The first two themes can best be examined through genetic, or developmental analysis. (p. 192)

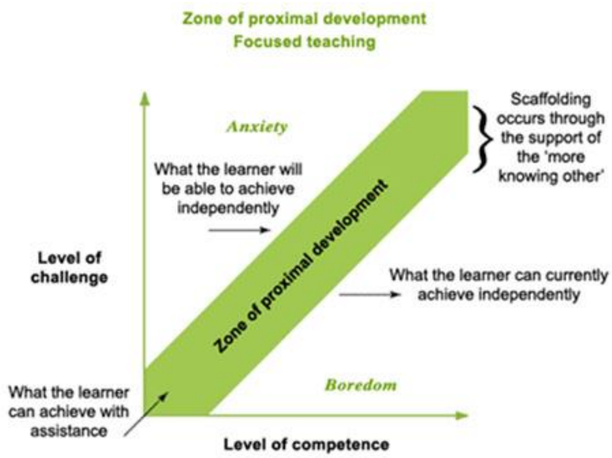
Individual development occurs in two stages first, at the social level and then at the individual level. Valsiner (1987) writes:

> "every function in the cultural development of the child comes on the stage twice, in two respects; first in the social, later in the psychological, first in relations between people as an interpsychological category, afterwards within the child as an intrapsychological category…All higher psychological functions are internalized relationships of the social kind, and constitute the social structure of personality" (p. 670).

The process of learning starts in shared social activities. In the case of young children, this means with their families. For Native children learning starts while watching, and then by participating in shared family, community, and tribal activities (John-Steiner & Osterreich, 1975).

Semiotics and psychological tools mediate the process of social learning. Semiotics is the study of signs and symbols, what they mean, and how they are used (Cambridge University Press, 2014). When the learner learns in a shared activity, the knowledge becomes internalized into psychological tools. The development of meaning through the use of tools is called semiotic mediation. Semiotic mediation occurs through the use of external signs like language, counting systems, symbols, diagrams, drawings or any representation used in a social activity (John-Steiner & Mahn, 1996). Mediation is how "human mental functioning is tied to cultural, institutional, and historical settings…they are *carriers* of sociocultural patterns and knowledge" (Wertsch, 1994, p. 204). Genetic analysis is the study of semiotic mediation. This analysis focuses on processes and not the product of internalized development.

Psychological tools are elements in the dynamic system of development. Cultural ways of knowing and being are psychological tools, and Native learning styles are descriptions of these tools (John-Steiner & Osterreich, 1975). John-Steiner notes that semiotic means and psychological tools are diverse because they develop from a diversity of cultures. She calls this diversity *cognitive pluralism* (John-Steiner, 1991). John-Steiner and Mahn (1996) note that *cognitive pluralism* is of particular interest in multicultural settings. Sociocultural theory is the idea that the process of internalization is transformative rather than transmissive (John-Steiner & Mahn, 1996). Initially, beginning learners depend on more experienced learners, like adults, in shared activity but over time children take more responsibility for their learning and participation in joint activity (Lave & Wenger, 1991). When the joint activity of learning supports novice learners to solve problems that they could not otherwise solve on their own, this phenomenon can be described with the term zone of proximal development (John-Steiner & Mahn, 1996). Vygotsky (1978) defines the terms as "the distance between the actual developmental level as determined through independent problem solving under adult guidance or in collaboration with more capable peers (p. 86)



Adapted from Hill & Crevola (unpublished)

Figure 2.1 Zone of proximal development focused teaching

As cited in Overview of Literacy Learning webpage (Department of Education and Early Childhood Development, 2007). The Zone of proximal development is the process with which newcomers master knowledge and skill, and move toward full participation and this is called *legitimate peripheral participation* (Lave & Wenger, 1991, p. 29). Learners practice joint activity with others as the external stage and develop knowledge, mastery and skill as the internal stage. Rogoff (1991) describes joint activity;

> …the routine arrangements and interaction between children and their caregivers and companions provide children with thousands of opportunities to observe and participate in the skilled activities of their culture. Through repeated and varied experience in supported routine and challenging situations, children become skilled practitioners in the specific cognitive activities in their communities. (p. 135)

Learner development occurs through a synthesis of multiple influences and in numerous opportunities to practice in a wide variety of shared activities. It is by "internalizing the effort of working together, the novice acquires useful strategies and crucial knowledge" (John-Steiner & Mahn, 1996, p. 192). It is the day-to-day experiences that children view and participate in that facilitate learning. It is from these initial experiences that young children develop cultural ways of knowing (*semiotic means*) and being (*psychological tools*). Children bring their culturally shaped psychological tools with them to school. Unfortunately, public schools employ psychological tools shaped by White middle class culture (Pewewardy, 2002). When Native students try to engage in the shared activity of learning in public schools, they are at a disadvantage because their psychological tools and semiotic means are not typically recognized nor utilized.

The zone of proximal development also involves affective factors in learning (Mahn & John-Steiner, 2002). Learning in the zone of proximal development involves acting, thinking, feeling, and teaching in the zone by instilling confidence in students through offers of caring support, so learners will be willing to take risks (Mahn & John-Steiner, 2002; Wells, 1999). Some scholars describe the zone as the *collective zone of proximal development* where interwoven processes for the co-construction of knowledge in cooperative environments includes cultural tools, varied forms of social interaction, and accessing interpersonal knowledge (scaffolding) (John-Steiner & Mahn, 1996; Moll & Whitmore, 1998; Wells, 1999). Mahn and John-Steiner (2002) describe the zone of proximal development as:

> A complex whole, a system of systems in which the interrelated and interdependent elements include the participants, artifacts, and environment/context, and the participants' experiences of their interactions within it. In addition, we suggest that the complementarity that exists between these elements plays a central role in the construction of the zpd (sic). When a breach in this complementarity occurs because

> the cognitive demands are too far beyond the learner's ability or because negative affective factors such as fear or anxiety are present, the zone in which effective teaching/learning occurs is diminished. (p. 48)

Understanding the dynamic of affective factors in learning is especially important for non-dominant society students who may be experiencing learning in a new culture and new language (Gorgorió & Planas, 2005; Mahn & John-Steiner, 2002). Key to addressing this tension is teaching that focuses on the aspects of social interdependence, human connection, and caring support that fosters the development of competence (Mahn & John-Steiner, 2002). Effective teaching in the zone of proximal development requires understanding students' lived experiences (Mahn & John-Steiner, 2002). Mahn and John-Steiner (2002) use the word *perezhivanie*, which means lived or emotional experience. This term "describes the affective processes through which interactions in the zpd (sic) are individually perceived, appropriated, and represented by the participants" (2002, p. 48). Teachers who collaborate with students in creating environments for transformative teaching and learning attempt to understand their students' lived experiences, knowledge, and feelings (Mahn & John-Steiner, 2002). Getting to know students in this way helps reveal the complexities of students' cognitive and emotional development. "A teacher's awareness of students' ways of perceiving, processing, and reacting to classroom interactions – their *perezhivanija* (plural for *perezhivanie*)- contributes significantly to the teacher's ability to engage the students in meaningful, engaging education" (Mahn & John-Steiner, 2002, p. 52).

Understanding teacher perezhivanie is also important. Thinking is social in origin and people often assume that their cultural ways of knowing and being are the norm, or archetype of human nature itself (Smagorinsky, 2007). Teachers who have not examined their own values and assumptions may “judge people who have developed other ways of thinking through their immersion in a different culture as having lower character, as being poorly behaved, as being *behind* in their social evolution – in short, as being lesser people” (Smagorinsky, 2007, p. 64).

Constructivism and Social Constructivism

Constructivism and social constructivism are the historically dominant theories used in reform mathematics education, and continue as central components of qualitative mathematics research (Cobb, 1994; Ernest, 1997; Simon, 2009). Constructivism is founded in the work of the psychological constructivism of Ernst von Glaserfeld (Cobb, 2000). This theory is based on the principle that “knowledge is not passively received but is actively built up by the cognizing subject” (Ernest, 1997, p. 29). Learning is the active process of developing ways of knowing through the process of mental constructions and sense making (Sherman, 2000). Constructivist theory focuses on individual cognitions, processes, and development (Cobb, Wood, & Yackel, 1990).

The emergent perspective is constructivist based theory that evolved from teaching experiments conducted by Paul Cobb and Lesile Steffe (1983) in the 1980’s. The experiment was designed as one-on-one clinical interviews with a student and a researcher to examine the child’s mathematical development by analyzing cognitive reorganizations the child makes during the interview with the researcher. The researcher strategically guided the students’ ways of thinking to develop increasingly powerful mathematical ways of knowing (Cobb & Steffe, 1983). Subsequent research with the constructivist teacher experiment involved examining individual children’s mathematical learning reorganizations while interacting with a teacher in a classroom (Cobb & Yackel, 1996). The researchers noted that the social context impacted individual student conceptions and student conceptions impacted the social interactional norms of the class in the experiment in a mutually reflexive process. Observations in the classroom teaching experiment led to the development of the emergent perspective. The Math Recovery intervention is directly modeled after the emergent perspective and the experiments of Cobb and Steffe.

The social constructivist perspective in mathematics education centers on the idea that "student mathematical development occurs in the social context of the classroom" (Cobb & Yackel, 1996). Social constructivist theory defines features of reform mathematics classrooms to be the social norms, classroom practices, dispositions, and other norms specific to the development of mathematical thinking (Franke et al., 2007). Classroom practice involves shaping classroom mathematics discourse, developing norms that support engagement around mathematical ideas and developing relationships with students that support opportunities for participation (Franke et al., 2007). The National Council of Teachers of Mathematics, Common Core State Standards, and reform mathematics researchers describe the development of mathematical thinking as an outcome of specific sociomathematical norms. Furthermore these norms are described as culturally neutral and universal and appropriate for all students. Consequently, this body of work does not examine the inherent biases and cultural foundations of the recommended sociomathematical norms. Cobb (2000) notes that social and sociomathematical norms are developed through classroom practices but he does not mention how a person's culture impacts or is impacted by classroom practice.

Comparing Sociocultural Theory and Social Constructivism

John-Steiner and Mahn (1996) note that social constructivist theorists like Cobb and Yackel (1993) characterize sociocultural theory as a transmission model. The authors argue that this interpretation "reduces and simplifies the mutuality of learning and its interpersonal and intergenerational dynamics" (p. 197). Sociocultural theory describes the complex roles of teachers and students, as mutual learning that is bidirectional activity, where learning is transformed in a synthesis of co-constructed knowledge (John-Steiner & Osterreich, 1975). Teachers teach and influence students and student participation influences teacher instruction in cycles of joint activity.

The advantage sociocultural theory has over social constructivism is its operationalization of historical contexts both in the cycles of the shared activity and cultures that learners come from. In social constructivism, learning and understanding are inherently social and cultural activities and social interactions serve as a catalyst for otherwise autonomous intellectual development (Cobb & Yackel, 1996). The word *cultural* is mentioned in descriptions of the theory but the conceptual use of the word is very narrow. My study considers *culture* in a broader sense by including ethnic culture, classroom culture, and historical influences to culture.

Culture of School - Cultural Capitol

Culture and socioeconomic class impact student participation in schools. In one study, White upper-middle class students were better able to participate in some aspects of reform mathematics than other groups of students (Lubienski, 2000). This phenomenon is a function of cultural capital. Cultural capital is the familiarity with high culture and is learned by high status children in high status families. This concept was developed by Pierre

Bourdieu and Jean-Claude Passeron (Lamont & Lareau, 1988). Cultural capital is characterized by the use of "high status cultural signals [their use] used in cultural and social selection" (Lamont & Lareau, 1988, p. 153). It consists of general cultural knowledge, language, language patterns, manners, and skills. Schools are not socially neutral institutions but reflect the experiences of the dominant class (Bourdieu, 1977). A *culture of power*, functions when unspoken rules and codes for participation are enacted in classrooms (Delpit, 2006). The rules of the *culture of power* reflection dominant society and this bias is frequently unacknowledged and perpetuated unconsciously by those in power. Educators need to become more aware of it and then act to balance cultural norms in the classroom as a way to create more equitable learning contexts across cultures.

Cultural capital is uncritically assumed to be the normative characteristics of well-behaved high achieving students. "Social and cultural resources of family life shape academic success in a subtle and pervasive fashion …(and)… neutral academic standards are laden with specific cultural class resources acquired at home" (Lamont & Lareau, 1988, p. 154). Student success is influenced by the degree to which they are associated with the *culture of power*. Students who are ignorant of cultural capital cannot utilize it. "Differences in academic achievement are normally explained by differences in ability rather than by cultural resources transmitted by the family…[and] social transmission of privilege is itself legitimized, for academic standards not seen as handicapping lower class children" (Lamont & Lareau, 1988, p. 156). Variation in cultural capital stratifies educational achievement (Lamont & Lareau, 1988). It should be noted Lareau (2003) found cultural differences by social class and did not see differences between ethnic nor racial groups.

Culture of Power

Delpit (1988) asserts a *culture of power* exists in society in general and in the educational environment in particular. The *culture of power,* as articulated by Delpit, has five aspects:

1. Issues of power are enacted in classrooms.
2. There are codes or rules for participating in power; that is, there is a 'culture of power'.
3. The rules of the culture of power are a reflection of the rules of the culture of those who have power.
4. If you are not already a participant in the culture of power, being told explicitly the rules of that culture makes acquiring power easier.
5. Those with power are frequently least aware of – or least willing to acknowledge its existence. Those with less power are often most aware of its existence. (1988, p. 282)

Delpit discusses the aspects of the *culture of power* in the debate on process versus skill orientated teaching methods in language arts education. She contends that teaching all students in ways that reflect liberal, middle-class values and aspirations ensure that the *culture of power* remains in the hands of those who already have it. In her research, Delpit found families of color and the poor want the schools to provide their children with discourse patterns, interactional styles, spoken and written language codes that will allow them success in dominant society (1988). She insists that she is not advocating *basic skills* approaches because these children are capable of critical and higher-order thinking and reasoning. Instead, she suggests school should provide non-dominant society children "the content that other families from a different cultural orientation provide at home. This does not mean separating children according to family background, but instead, ensuring that each classroom incorporate strategies appropriate for all the children in its confines" (Delpit, 1988, p. 286). To address these issues Delpit (1988) suggests that students need direct instruction on the codes needed to participate fully in dominant society, "not by being forced to attend to hollow, inane, decontextualized subskills but rather within the context of meaningful communicative endeavors" (p. 296). Teachers must be aware of their orientation to the *culture of power* and mentor students in learning the norms and practices of the culture. In the shared activity of developing these skills "educators must open themselves to, and allow themselves to be affected by, these alternative voices" (Delpit, 1988, p. 296).

Community in Schools

School connectedness "is the belief by students that adults and peers in the school care about their learning as well as them as individuals" (Centers for Disease Control and Prevention, 2014). Students who feel connected to school are more likely to attend school regularly, stay in schools longer, and less likely to engage in smoking, using alcohol or drugs, and anti-social behaviors (Battistich, 2010; CDCP, 2014). School connectedness can be developed in efforts to create communities in schools (Walkingstick & Bloom, 2013). Research in this field has primarily been conducted with adolescents but related research with elementary aged children confirmed the importance of school connectedness (Lewis, Schaps, & Watson, 2003). The Child Development Project (CDP) is an elementary school program designed to develop a sense of community in school with four basic principles:

- Build warm, stable, supportive relationships among and between students, teachers, and parents;
- Provide regular opportunities for students to collaborate with others;

- Provide regular opportunities for students to exercise “voice and choice,” (i.e., influence and autonomy);
- Articulate, discuss, and encourage reflection on core values and ideals (Lewis et al., 2003, pp. 2-3)

Classrooms with a community focus manage behavior with developmental discipline. This approach recognizes that the development of children’s social skills are learned much in the same ways as academic skills (Lewis et al., 2003). Community focused classrooms believe children will respond to kind and respectful treatment. Students are taught to consider their behavior and how that behavior impacts fellow class members and on their own learning. Mutually agreed upon expectations are taught to students and referred to when solving problems. Mediation and peaceful problem solving are modeled by the teacher and practiced by students (Walkingstick & Bloom, 2013).

Community in Schools and Academic Achievement

Muller (2001) found little association between perceived teacher caring and student achievement in the general population. In contrast, students considered at-risk had significantly greater mathematics proficiency if they perceived their teachers cared about them and taught with a strong academic emphasis. Strong norms and high expectations encouraging academic effort and achievement is known as academic press (Schaps, 2005). Lee and Smith (1999) found a sense of community in school alone did not improve academic achievement for low income students. It was the union of a caring community and academic press that produced improvement. Shouse (1996) observed that a similar relationship exists between low-income students mathematics achievement, and the combined effects of academic press and community culture.

Schaps (2005) argues for three priorities for schools; academic press, building community in school, and academic support. He promotes the idea for academic support in the form of instruction that integrates conceptual understanding and skills development, essential content, specific student interests, and didactic and experiential teaching methods. The classroom teacher had high expectations for her students coupled with academic support in an overall atmosphere of caring in a community classroom setting. From a sociocultural perspective caring, academic press, and academic support are the semiotic means that transform learning in mediation into internalized psychological tools that manifested as improved achievement.

The Game of School

Fried (2005), the game of school is an unspoken pact between teacher and students where "school learning equals game playing" (Fried, 2005, p. xi). He argues, the *game of school* "eclipse(s) the spirit of learning" (p. xi) and "replaces authentic learning" (p. xiii). Fried (2005) writes,

> The *game of school* is the paralysis of intellect and meaningful inquiry…People think they're teaching and learning. Students and teachers earnestly comply with what they feel to be their duty. But nobody is really learning much beyond what it takes to pass…unengaged compliance crowds out the gold standard of self-initiated learning…unconsciously/uncritically they develop the "false self of the pseudo-learner (or pseudo-teacher)…Pseudo-teachers fail to see students as 'natural born learners'…the false-self emerges whenever teachers feel obligated to cut discussions short, to short circuit a student's divergent or contradictory question, or to gloss over a conflict between the textbook version (pp. x-xv)

Fried argues students and teachers must fight for authentic learning and passionate teaching. Teacher must “adopt a stance that support our students, emotionally, and intellectually, as we invite them to become partners in learning endeavors” (p. 200).

Ladson-Billings (2014) expresses similar sentiments when she discusses the academic death of students. She describes this concept as disengagement and academic failure resulting in expulsion and dropping out “Academic death leaves more young people unemployed, underemployed, and unemployable in our cities and neighborhoods, and vulnerable to the criminal justice system” (p.77). Ladson-Billings ideas reflect the eventual result of playing the *game of school* for students of color.

Mathematics Education - Reform Mathematics

Reform mathematics education seeks to develop students who see mathematics as a tool for describing the world and solving problems. This knowledge is deeper than the mere memorization of formulas and procedures. Reform mathematic educators seek to develop students who are confident in their ability to tackle difficult problems, are flexible in exploring mathematical ideas, and are willing to persevere when tasks are challenging (NCTM, 2000a). These students are also autonomous learners who take control of their own learning. Reform educators use sociomathematical classroom norms in order to develop mathematical proficiency with five components: conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition (NRC, 2002).

Mathematical communication and discourse is considered a critical feature of mathematical classroom practice (Franke et al., 2007; NRC, 2002). Features of mathematical discourse include teacher revoicing of student ideas, mutual interrogating for meaning, student autonomy in choosing and sharing problem solving methods, appreciation of mistakes as sites for public learning, recognition that authority lies in logic and content and not personal positionality (NRC, 2002). The use of mathematical discourse is heavily emphasized in reform mathematics classrooms (Franke et al., 2007; Schoenfeld, 1992).

The National Council of Teachers of Mathematics (National Council of Teachers of Mathematics, 2000b), publication has six principles and the equity principle is considered the core element of the total vision. “Equity requires high expectations and worthwhile opportunities for all…accommodating differences to help everyone learn mathematics, and resources and support for all classrooms and all students” (NCTM, 2000a, pp. 12-14). The organization states in its position statement that,

> Excellence in mathematics education rests on equity…Policies, practices, attitudes, and beliefs related to mathematics teaching and learning must be assessed continually to ensure that all students have equal access to the resources with the greatest potential to promote learning. A culture of equity maximizes potential of all students. (NCTM, 2009)

The National Council of Teachers of Mathematics defines equity as equitable access to mathematics education. “Equity does not mean that every student should receive identical instruction; instead, it demands that reasonable and appropriate accommodations be made as needed to promote access and attainment for all students” (NCTM, 2000a, p. 12). While the principle specifically addresses access to mathematics, the vision section of the publication explains that equity also includes equity of opportunity. The specific goal of the equity principle is to increase mathematics knowledge and skill for all students. An indirect goal of the equity principle is to increase opportunities for all students in order to improve social equity. The National Council of Teachers of Mathematics is committed to the equity principle, but I question how this goal will be achieved without identifying and addressing the underlying cultural values and assumptions of sociomathematical norms and how that impact non-dominant society students. The tension between Native learning styles and sociomathematical norms is discussed later in this chapter. I contend, when the sociomathematical norms of practice are not aligned or are in conflict with a student's cultural ways of knowing and being, then students may not be able to operate in these unfamiliar ways. Neither social constructivist theory, nor reform mathematics standards address the cultural source of the norms and the impact these norms have in multicultural settings.

Mathematics Education Research

Equity maybe a major focus in national standards, however, equity has not been a major focus of the mathematics education field. Research in this area has focused primarily on cognition and achievement, in grades K-12, with little attention to issues of ethnicity and class (Lubienski & Bowen, 2000; Reyes & Stanic, 1988). Cognitive theory is a psychology based learning theory. Cognitive theory examines how people think, understand and know things with a focus on how internal representations affect behavior (Feldman, 2007). Typically the cognitive perspective is devoid of cultural considerations. The field of mathematics is founded in positivist philosophy (Ernest, 2009). Positivism holds that science is a knowledge base of things that can be observed and measured. Science knowledge is seen as the "truth", unbiased by culture or position of the scientist (Ernest, 2009). A positivist view of mathematics sees the field as pure and culture free. The combination of theoretical bias of constructivism and the belief positivist that mathematics is culture free contributes to the omission of cultural issues in mathematics education research. The majority of research on ethnicity or socioeconomic class is related to achievement outcomes in general (Lubienski & Bowen, 2000) and achievement gaps in specific (Gutierrez, 2008). The dominance of mathematics achievement research in ethnicity and class scholarship gives one “the impression that researchers look primarily at outcomes of these equity groups and rarely examine how schooling experiences contribute to these outcomes” (Lubienski & Bowen, 2000, p. 631).

Achievement data reveals large disparities exist in mathematics achievement for most students of color (USDE, 2012). This information helps to inform research on the state of mathematics education but focusing only on closing the racial achievement gap as a solution has its flaws. In 2013, only 54 % of all White 8th grade students in the nation were at or above proficient, as reported by National Assessment of Educational Progress. Only 9% of 15 year old U.S. students scored in the top performing percentages, and 26% of 15 year old U.S. students scored below the baseline proficiencies level on the Program for International Student Assessment (NCES, 2012b).

Achievement gap goals presume inferiority assumptions about students of color who perform below White students. Lastly, to adopt the recommended mathematical identities that develop mathematical knowledge students of color “must become less African American, Native American, and Latino, and more like White and Asian students, in terms of their dispositions and values” (Martin, 2009, p. 298). This ideology assumes that low achieving students of color need to act more like their White counterparts to be successful. Closing the achievement gap is a problematic and limited goal. These limitations support a need for different goals and perspectives for understanding mathematic education for students of color.

Math Recovery

Math Recovery (MR) is an early childhood mathematics intervention founded in constructivist learning theory (U.S. Math Recovery Council, 2010a). Math Recovery is an intervention developed by Robert Wright and designed to address chronic and widespread low mathematics achievement (USMRC, 2010b). While all students can benefit from this program, Math Recovery is intended for low achieving students. Math Recovery programs identify struggling young students with "the objective … to intervene as early and quickly as possible before these at-risk students fall too far behind their peers" (USMRC, 2010a, para. 1). The Math Recovery program has a copyrighted "assessment system that allows educators to know exactly where students are in their mathematical development and apply necessary short-term intervention strategies" (USMRC, 2010). Math Recovery has a series of programs that deliver different levels of intervention services. Math Recovery Intervention Specialist program is a certification program that focuses on the delivery of intensive services through one-on-one clinical interview tutoring sessions with low achieving students (USMRC, 2010a, para. 5). Add+Vantage Math Recovery is a professional development program that focuses on implementing Math Recovery in classroom settings (USMRC,2010a, para. 6).

Math Recovery was developed from constructivist teaching experiments conducted by researchers Cobb and Steffe (Wright, Cowper, Stafford, Stanger, & Stewart, 1994). Services are delivered in two different models, Math Recovery Intervention Specialist and Add+Vantage Math Recovery. Math Recovery Intervention Specialist services are delivered in pullout sessions with individual students. Add + Vantage Math Recovery delivers Math Recovery services in whole class and small group instruction in the students classroom. Culturally modified Add+Vantage Math Recovery is the format to be examined in the study.

Central to Math Recovery assessments and instruction is the Learning Framework in Number. The Learning Framework in Number is a progress map of learning trajectories that provide a description of skills, understandings, and knowledge in a sequence in which they typically occur, thus giving a virtual picture of what it means to progress through an area of learning. This progress map can be used to monitor development over time. A student's location on the framework can be used as a guide for determining the types of learning experiences that will be most useful in meeting the student's individual needs at that particular stage in their learning. The Learning Framework in Number provides a description of the knowledge and skills characterizing major stages of development in each of these components (Bobis, 2009).

The Learning Framework in Number has four divisions:

Table 2.1 Learning Framework in Number

Part A	• Stages of early arithmetical learning • Base ten arithmetical strategies
Part B	• Forward number word sequences and number word after • Backward number word sequences and number word before • Numeral identification
Part C	• Structuring numbers 1 to 20
Part D	• Early multiplication and division

(U.S. Math Recovery Council, 2010b, p. 20)

Math Recovery assessments are based on interviews designed to reveal where students lie on the Learning Framework in Number. The goal of the assessment is to "account for the child's development of increasingly powerful mathematical ways of knowing by analyzing the cognitive restructuring he or she makes while interacting with the researcher" (Cobb & Yackel, 1996, p. 6). Math Recovery teaching is guided by nine principles (1) problem and inquiry based teaching, (2) initial and on-going assessment, (3) teaching just beyond the cutting edge, (4) selecting from a bank of teaching procedures, (5) engendering more sophisticated strategies, (6) observing the child and fine-tuning teaching, (7) incorporating symbolizing and notating, (8) sustained thinking and reflection, (9) child intrinsic satisfaction (USMRC, 2010a). Particular interest to this study is Math Recovery heavy use of direct questioning to reveal student thinking and the routine use of competitive games. Direct questioning occurs in the interview assessments, and instruction and competitive games occur in student practice. I chose to study the Math Recovery intervention for three reasons. First, it is a national intervention that claims to work for all children but does not consider culture. Second, it is in use in the study district. Lastly, I can culturally modify the intervention by changing instructional practice and student activity with modified activity materials and game designs.

Cognitively Guided Instruction

In the study I observed students having difficulty solving and representing written solutions for word problems in the regular curriculum activities and tests. Math Recovery uses verbal word problems and students are instructed to answer verbally. In the study I noticed students had difficulty transferring verbal problem solving skills to written representations. Researchers Elizabeth Fennema, Thomas Carpenter, Penelope Peterson, and Megan Franke developed Cognitively Guided Instruction (Fennema & others, 1992). The program investigated how knowledge on children's thinking impacted teacher practice. Cognitively Guided Instruction assumes "Children start school with a conception of basic mathematics that is much richer and more integrated than that presented in most traditional mathematics programs" (Fennema & others, 1992, p. 3). Children's informal or intuitive knowledge of mathematics can serve as the basis for developing formal mathematics knowledge (Carpenter & Fennema, 1996). "Children learn number facts in the process of solving problems and develop mathematical concepts "not as isolated bits of information, but in a way that builds on the relationships between facts (Fennema & others, 1992, p. 3)" Teacher practice includes:

- Eliciting and making public student thinking
- Eliciting multiple strategies
- Focusing on solving word problems
- Using what is heard from students to make instructional decisions that lead to the development of student understanding. (Franke et al., 2007, p. 243)

The authors found that "teachers who listened to their students' explanations, and asked for multiple strategies to problems had higher achieving students on written measure of skill and problem solving" (Franke et al., 2007). Cognitively Guided Instruction articulates research-based trajectories within particular whole number domains in the form of a progression of problem types (Franke et al., 2007). The trajectories serve as a framework that helps teachers follow the development of student's mathematical thinking. The Cognitively Guided Instruction progression of problem types is different than the Learning Framework in Numbers, but they both function as a schedule of mathematical development teachers can use to map the progression of student learning. Math Recovery is similar to Cognitively Guided Instruction in the ways teachers listen to student mathematical thinking and shape instruction to specific student needs based on a map or progression of learning. Math Recovery does not emphasize word problems or written solutions.

Cognitively Guided Instruction poses a progression of problem types that develop the use of symbols and abstractions in student written solutions. It is for this reason I decided to try Cognitively Guided Instruction progression of problem types and had the students draw representations of their solutions. I used the following problem types for addition and subtraction problems.

- Joining action
- Separating action
- Part-part-whole relations
- Comparison situations

A larger discussion on Cognitively Guided Instruction and the use of problem types is in Chapter 3: Methodology and Chapter 5: Findings-Mathematical Thinking and Learning

Sociocultural Theory and Mathematics Programs

Math Recovery and Cognitively Guided Instruction were designed with constructivist and social constructivist theory. In this section I will examine Math Recovery and Cognitively Guided Instruction through a sociocultural lens. Both programs routinely conduct instruction and exploration in social groups. Math Recovery uses social groups for both instruction and student practice. Cognitively Guided Instruction uses social groups for solving word problems. Both programs function as communities of learners where students and teachers take on various roles while making contributions to the solving mathematical tasks. Students in both programs are encouraged to ask questions, analyze solutions, and make predictions as they solve mathematical tasks.

Math Recovery and Cognitively Guided Instruction use language as the dominant form of symbolic representations of thought (semiotics). Math Recovery also uses finger patterns, counting schemes, manipulatives and graphics like *five and ten frames.* See Figure 2.2

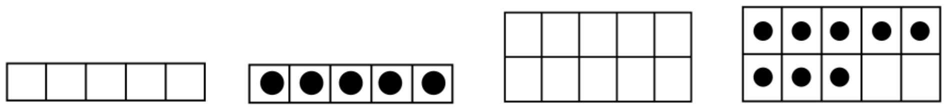


Figure 2.2 Five and Ten Frame Examples

Cognitively Guided Instruction uses symbols and abstractions in student written solutions as a means of semiotic mediation. These examples are the external tools used in social activity that support the transformation of information into internal knowledge. Students demonstrate new psychological tools when they master new skills and concepts. For example, students in Math Recovery progress from unitary to composite strategies for solving arithmetic. Initially adults and more experienced students guide Math Recovery activities until beginning students can complete activities on their own.

Math Recovery and Cognitively Guided Instruction group activities can be examined with genetic analysis because both programs work in cycles of implementation, observation, evaluation, and development of modifications. Student participation impacts the next cycle of shared activity and the subsequent customized joint activity impacts students' psychological tools. Math Recovery's Learning Framework in Number and the Cognitively Guided Instruction problem types map student progression in numeracy development and attune the teacher to how students are thinking. These frameworks also help the teacher find the appropriate mathematical concepts that can be facilitated in the zone of proximal development. From a sociocultural perspective Math Recovery and Cognitively Guided

Instruction classrooms are sites where learning is transformative knowledge co-construction. Both methods do not account for historical and cultural aspects of Native students learning mathematics in public schools. I will continue this analysis in Chapter 5 and Chapter 6.

Native and Indigenous Education Issues

Native and Indigenous epistemologies. According to sociocultural theory, most learning develops in social contexts. Social contexts are shaped by culture and history. To gain insight on the phenomenon of Native student learning mathematics in a public school, some Indigenous scholars recommend learning about Native cultures. It is beyond the scope of this work to thoroughly cover Native and Indigenous epistemologies. However, a brief overview serves to reveal the ideological foundations common within Native ways of knowing and being.

In 2006, there were 4.5 million American Indians and Alaska Natives representing 175 languages and more than 550 federally recognized tribes (DeVoe & Darling-Churchill, 2008). All Native communities may have different customs, languages, religions, values and cultures. As a result, a singular definition or interpretation of Indigenous epistemology does not exist. I am including some similarities and consistent themes among Native cultures to inform this study however, I strongly caution against using this information to essentialize Native peoples.

The concept of community is central to Native epistemologies. Cajete (Cajete, 1999)(1999) writes “Mitakuye Oyasin, ‘we are all related’,” personifies what Indian people often perceive as *Community* (p.165). *Community* is an inclusive term that includes people, other living things, and the natural world. Relationships between community members are a foundation of tribal identity (Cajete, 1999). Community is based on the belief that individuals must act in certain ways for society to function as a whole and individuals owe these behaviors to the other members of the community. Traditional Native education functions to produce the whole person within a community. It is not about transmitting and receiving information for the singular goal of improving oneself. Native education "affirmed(s) the basic principle that human personality was derived from accepting the responsibility to be a contributing member of society (Deloria & Wildcat, 2001, p. 44). Relationality and interconnectedness is the sense of being part of and obligated to the whole. Native people seek harmony. Cajete (1994) writes, "We are, one and all, social beings living *in relation* to one another. Our physical and biological survival is intimately interwoven with the communities that we create and create us" (p.167). Deloria (2001) describes personality as a product of power and place. Power is the essential living force of the universe and place is the relationship to all things. Native people must anticipate their actions and consider the implications of their actions.

Native knowledge is developed retrospectively and through observation (Cajete, 1994, 1999; Deloria & Wildcat, 2001). Native people learn what to know and how to be by interacting with, listening, and observing elders (Deloria & Wildcat, 2001). Native knowledge systems require "a prodigious memory" (Deloria & Wildcat, 2001, p. 22). Storytelling is a prominent feature in traditional Native education. Elders report about their own experiences or the experiences of their elders (Deloria & Wildcat, 2001). Storytelling can convey practices, concepts, ethics, codes of conduct, and meanings at a variety of levels (Cajete, 1999). Storytelling is the embodiment of epistemologies and a vehicle for education. I used storytelling as a vehicle in Cognitively Guided Instruction mathematics word problems in the study.

Native and Indigenous education research. There are two major areas in Native and Indigenous education research that impact this study: Native learning styles and culturally aligned asset pedagogies. Asset approaches are the dominant body of research in Native and Indigenous education and will be discussed in the section titled *Native and Indigenous Mathematics Education*. Native and Indigenous learning styles inform asset approaches.

Native and Indigenous learning styles. Research on Native and Indigenous learning styles, social norms, and practice preferences reflect Native cultural epistemologies and reveal Native and Indigenous ways of knowing and being. Trumbull, Nelson-Barber, and Mitchells' (2002) article *Enchancing Mathematics Instruction for Indigenous American Students* highlights potential elements of conflict between reform mathematics and Indigenous pedagogy. The researchers identify verbal exchange as the area with several elements of potential conflict for Indigenous students. The majority of learning and interaction in reform mathematics classrooms is based on verbal exchange (Trumbull et al., 2002). Classrooms dominated by verbal exchanges are likely to disenfranchise many Indigenous students from participation (Trumbull et al., 2002). For example, direct questioning in classroom discourse puts students on the spot and American Indian students often cannot or will not respond to explicit probes (Delpit, 2006; Trumbull et al., 2002). Delpit writes "When asked inappropriate questions or called on to talk before the entire class, many Native American children will refuse to answer, or will answer in as few words as possible" (2006, p. 171).

Reform mathematics promotes discourse as an important and essential classroom practice that should be central in math classrooms (Franke et al., 2007). Student verbal explanations are considered evidence of competence and understanding. This is in contrast to Indigenous ways of knowing where the ability to perform a task is evidence of competence (Delpit, 2006; Quattromani & Austin-Manygoats, 2002). Reform oriented mathematics classrooms usually privilege verbal competence over performance competence in student practice. Performance competence is privileged in testing contexts.

Math Recovery interview assessments also privilege verbal competence over performance competence. In Math Recovery interview assessments, students are expected to verbally explain how they solved problems. Student demonstrations are accepted as evidence of competence only when students can also verbally describe what they did. If a student solves a problem by creating three groups of five objects and then tells the teacher the answer is 15, this answer would be considered incomplete. The Math Recovery teacher would require the students to verbally describe what they just performed. A complete correct answer would be if the student did the demonstration and said "I made three groups of five objects and then counted by fives 'five, ten, fifteen'". The performance demonstration of competence must be accompanied by a verbal explanation to be considered correct.

Participation roles of discourse in many Indigenous cultures differ from expectations in sociomathematical norms. Delpit (2006) observed that in Athabaskan communities individuals with a higher status, like a teacher, are expected to speak the most. Subordinates, like students, are expected to watch, listen, and learn, much like a spectator. Indigenous children are often taught to respect elders by listening and not questioning (Trumbull et al., 2002). Reform mathematics classrooms expect students to actively participate asking questions, challenging others including adults, and interrogating for meaning (Franke et al., 2007). Expectations of participation differ greatly in this comparison and are likely to disproportionately affect learning and achievement among Native students. Native students are accustomed to learning through observation (John-Steiner & Osterreich, 1975; Rogoff, 1990a; Trumbull et al., 2002). Cleary and Peacock (1998) found American Indian students preferred to learn through observation and preferred to perform new skills only when they were fairly confident they could execute a skill correctly. In fact, "American Indian children have traditionally been expected to act competently or not act at all" (Cleary & Peacock, 1998, p. 34). American Indian children do not like to be put on the spot and are more likely to see public demonstrations of mistakes as failures, instead of seeing mistakes as opportunities for everyone to learn, as promoted in reform mathematics discourse norms (Cleary & Peacock, 1998). Cleary and Peacock also found that while Native students would not present their own work before the whole class, they were very comfortable presenting someone else's work (1998). This was done in the spirit of trading and mutual assistance.

Most Native students have strong connections to family and community and prefer cooperative and non-competitive learning and peer-peer learning (Cleary & Peacock, 1998; Swisher, 1990). In addition, American Indian families value non-interference of others and adults will go to great lengths to respect the choices of other people without interference (Cleary & Peacock, 1998). This includes the children's decisions. Delpit found Alaska Native families believed "children were not to be coerced with authority, but were to be treated with the respect that provided them with rationales, stated or unstated, to guide them to make decisions based on their own good sense" (2006, p. 100).

Field-dependence and field-independence refer to how students learn with field-dependence as holistic and global in learner orientation and field-independence as analytical, logical, and temporal (Pewewardy, 2002). Field-dependent learners see themselves as part of the environment and establish meaning in relation to the whole. Pewewardy (2002) notes this holistic orientation makes it hard for this type of learner to pick out important details from the overall context. Field-dependent learners are “highly visual, spatial, integrative, relational, intuitive, and contextually focused” (Pewewardy, 2002, p. 28). Field-dependence is often seen in cultures that are collective and family oriented (Nuby, Ehle, & Thrower, 2001). Field-independent learners prefer to compete to gain individual recognition and are generally task-oriented (Pewewardy, 2002). This type of learner can categorize, prioritize, and isolate information from the whole. Field-independence is often seen in cultures that privilege personal autonomy and individualism and is common in White culture (Light & Martin, 1986)

A word of caution is necessary because research has shown Native students have commonalities and tendencies; research has also demonstrated individual and tribal variation. As a result, over generalizations can lead to stereotyping and essentialism and this type of absolute conclusion should be avoided (Cleary & Peacock, 1998).

Native and Indigenous mathematics education. Mathematics education research with Native and Indigenous students and communities is rare. Of the studies that do exist, most utilize asset approaches. Asset pedagogies examined the intersection of language, literacy, and culture and shed light on the systemic inequities faced by students of color. Asset pedagogies sought to counter the deficit approaches of the 1960’s and 70’s (Paris, 2012). Deficit ideologies view the languages and cultural ways of knowing and being as deficiencies or obstacles that students of color have to overcome, in order to be successfully educated in dominant society’s cultural ways of schooling (Paris, 2012).

Ladson-Billings's (2014) culturally relevant pedagogy focuses on students as active learners. She reveals that "by focusing on student learning and academic achievement versus classroom and behavior management, cultural competence versus cultural assimilation or eradication, and sociopolitical consciousness rather than school-based tasks that have no beyond-school applications" (p.75). Ladson-Billings comments the secret behind culturally relevant pedagogies "The real power of CRP is the ability to link principles of learning with deep understanding of (and the appreciation for) culture" (p.75).

Culturally responsive, relevant, congruent, approaches to teaching, pedagogy and education are terms found in the literature. One theme in Native and Indigenous mathematics education is in developing curriculums contextualized within Native and Indigenous student culture (Howard, Ferier, Lowe, Ziems, & Anterdson, 2004). For example, Thompson, Chappell, and Austin (2002), Illustik (2002), Berken (2002) wrote lesson plans that use Native oral history, Native games, as well as art and craftwork to present mathematics concepts like symmetry, patterns, and geometry. Examples can also be found in the work of Lipka, Hogan, Webster, Yanez, Adams, and Clark (2005) *Math in Cultural Context* (MCC). Math in Cultural Context program features lesson plans for building structures for drying salmon, composing Yup'ik songs and drum compositions, designing beading patterns, and border designs for traditional clothing (Lipka et al., 2005). This type of curriculum presents mathematics in culturally familiar contexts that incorporate familiar activities to Native students. Mary Brenner's (1998) work is centered in Native knowledge. Her approach involves observations in and out of school and assessments to determine strengths and patterns of learning. A unique feature of her work involves using the local dialect as a tool to scaffold mathematics concepts and vocabulary.

Contextualized mathematics education curriculum has been developed with a strategy called a third space. Third space is a place where educators and researchers collaborate with Native and Indigenous families, elders, and communities for mutual sharing and learning. These active partnerships work to develop rigorous mathematics curriculum that is culturally relevant. Partnerships also serve as professional development for teachers and educators to increase awareness of Native and Indigenous culture and community goals and needs. The mathematics education programs of Jerry Lipka (Lipka et al., 2005; 1999) and Judith Hankes (1998) utilized third spaces.

Lipka's (2005) work in Math in Cultural Contexts involved teacher study groups, which provided a social space to dialogue, investigate, and design programs. The groups included teachers, community elders, and mathematics researchers. Emphasis was placed on the unique value each member brought to the process. This strategy served a number of purposes. It enhanced teacher commitment and deepened understanding of goals to improve fidelity. Elder participation aligned activities and pedagogy with Native culture; ensured authenticity of the Native epistemologies used, and promoted tribal self-determination in education. Mathematics researcher input ensured rigorous and purposeful development of important mathematical concepts.

Howard et al. (2004) recommend explicit attention is needed on the challenges of forming effective partnerships. He recognizes that effective partnerships are:

> Resource-intensive and complex…establishing, maintaining and continuing effective partnerships require a commitment of time, energy, and money. There are organis(z)tional and budgetary constraints, including dealing with hierarchies and finding the way through (or around) bureaucracies… (listening is essential) to inform

thinking, decision-making and actions of partners. Moving beyond one's own perspective is a key to ensuring the continuation of effective educational partnerships.

These are a few examples of the work being done in Indigenous mathematics education. The research on Native education focuses on schools in general and teachers, students, and curriculums specifically and in Bureau of Indian Education or tribal and Indigenous schools.

Chapter 3

Qualitative Methodology and Case Study Mode of Inquiry

In this chapter I discuss how I conducted a study to collect data on how public school Native first graders experience collaborative mathematics activities when culturally modified with Indigenous ways of knowing and being?

I conducted a qualitative study utilizing a case study methodology. Creswell states "case study research is a qualitative approach in which the investigator explores a bounded system (a case)…over time, through detailed data collection involving multiple sources" (2007, p. 97). This case study featured the examination of embedded cases within the case study unit. An ethnically diverse class served as the case unit and Native students within the class as the embedded cases. "Case study researchers typically observe the characteristics of an individual unit (in order to)… probe deeply and to analyze intensively the multifarious phenomena that constitute the life cycle of the unit" (Cohen & Manion, 1980, pp. 106-107). The single case for my study was Native first grade students engaged in collaborative mathematics activities modified with Indigenous ways of knowing and being. The embedded cases were the Native students in the class. The data collected provided an in-depth, and detailed accounting of the joint activity of students learning and doing mathematics nested in a larger joint activity of a community classroom. Case study methodology was best suited for this study because I sought to understand a phenomenon and understanding the phenomenon required focused inquiry (Merriam, 1988; Yin, 2003).

This study also fit the characteristics of qualitative case studies outlined by Stake (1995). I sought a holistic understanding of student experiences and in context. The study was of one case and did not use a comparison group. Embedded cases were analyzed for patterns and themes but students were not directly compared with one another. This study was "empirical and field oriented with emphasis on observables and participant observations in a naturalist setting" (Stake, 1995, p. 48). Case study is the appropriate mode of inquiry because I studied *how* students were experiencing the intervention and how the modified intervention impacted them. *How* questions are inherently exploratory and lend themselves to the use of case study research strategies (Yin, 2003). Case study was also the appropriate approach because I examined contemporary events that could be directly observed and participants could be directly studied and interviewed (Creswell, 2007; Yin, 2003). Case study design allows for an intensive examination of contextual conditions because the context is highly pertinent to the phenomenon of the study (Yin, 2003). Case study's focus on the context aligns with sociocultural theory's attention to the social context of joint activity.

Observations played a major role in the study due to the age of the students. "Observation studies are superior to experiments and surveys when data are being collected on non-verbal behavior" or from young participants. (Cohen & Manion, 1980, p. 107). Observations of student behavior were compared with Native education research literature to understand possible cultural interpretations student behaviors. This topic is discussed in the findings section in Chapter 5, Native Learning Styles. First grade students typically provide limited information in interviews or surveys. Case study was best suited for this study because focused inquiry is required to understand complex phenomenon (Merriam, 1988; Yin, 2003).

The study was qualitative, but it also included some quasi-statistical data to measure mathematics achievement and activity attempts counts (Maxwell, 2005). Yin (2003) calls this type of data *tabular materials*. "Any claim that a particular phenomenon is typical, rare, or prevalent in the setting or population studied is an inherently quantitative claim" (Maxwell, 2005, p. 113). The quantitative analysis contributes data to give detail and depth to describing the phenomenon. This is not a mixed method study because the quantitative data did not significantly impact the research methodology. The tabular materials inform and contribute to the intensive, in depth and detailed description of the case.

I considered an experimental or evaluation case study design for this study. While this study could be considered a social experiment, I decided not to use an experimental case study because my research question required a holistic interpretation of many variables. The large number of variables in this study prevented the degree of control needed for an experimental case study (Yin, 2003). Large numbers of variables are needed to develop an intensive, holistic, and contextual understanding. I also decided that an evaluation case study did not suit my research question. I did not want to study effectiveness like achievement gains of the modified intervention. Both experimental and evaluation case study require comparisons of treatment and non-treatment groups. I did not have the resources to support a study with multiple sites or even multiple groups within a single school.

Action Research Design

The case study was employed with an action research design. Action research is flexible and adaptable. Somekh (2006) writes, "Action research is not value neutral; action researchers aim to act morally and promote social justice through research that is politically informed and personally engaged" (p. 7). Action research was appropriate because "action research is a small-scale intervention in the functioning of the real world, and a close examination of the effects of such intervention" (Halsey, 1972, p. 186). I designed the study with an action research method to best serve implementation and examination of the case unit.

> Action research is situational…it is concerned with diagnosing a problem in a specific context and attempting to solve it in that context; it is usually (though not inevitably) collaborative…it is participatory (with) members themselves taking part directly or indirectly in implementing the research; it is self-evaluative – modifications are continuously evaluated within the ongoing situation, the ultimate objective being to improve practice in some way or other". (Cohen & Manion, 1980, p. 19)

The teacher in this classroom and I as the researcher, collaborated in the study. I taught modified lessons for the embedded case students and the teacher taught standard Add+Vantage Math Recovery lessons. We collaborated in iterative cycles of implementation, observations, consultation, evaluation, and cultural modifications to support Indigenous ways of knowing and being. This cycle of mutual learning is a feature of sociocultural theory. This study examined the experiences of Native students in a public school to inform instruction and practice to improve education. Cohen states, "the principal justification for the use of action research in the context of the school is improvement of practice" (Cohen & Manion, 1980, p. 192).

Researcher Positionality

The participants of this study were first grade Native students in a public elementary school. I am neither a Native nor a child. While childhood is a common experience of all adults, the reality is, we are no longer children. As adults, we view childhood from our own set of memories, ideas and personal reflections. In contrast, children are experiencing childhood for the first time (Oakley, 1994). It is important to acknowledge the differences between the researcher and research participant perspectives. It is also important to be aware of power dynamics between adults and children. I employed strategies to support and enhance each child's capacity to express their feelings and experiences in ways that are true to them and not in responses that children interpret I want from them (Smith, 2011).

I am not a Native student or teacher and as such, I am not a cultural insider. I do, however, share some common experiences with Native students by being a non-dominate society student in U.S. public schools. I know what it feels like to be expected to perform according to school norms that were strange and unfamiliar to me. I remember being disorientated, in my early years of school and eventually realized my cultural ways of knowing and being were not recognized in school. I believe this perspective helps me to relate to and understand Native student experiences as non-dominant society learners in public schools. My personal student experiences influenced and motivated me to research racial disparities in education.

I have contextual insider experience in teaching young Native students in a public elementary school. I lived in an Indian reservation community for 15 years and I taught in that community for 6 years. I observed while teaching and living in the community the pressures Native students encounter in U.S. public schools. I frequently heard school staff express deficit views of Native students and their families. As a teacher, I reluctantly implemented and witnessed educational policies and practices that privileged dominant society students and excluded non-dominant society students.

I also have contextual insider knowledge in early childhood education. At the time of this study, I had over six years of teaching experience as a head start and first grade teacher. I have a bachelor's degree in early childhood education. I am also a certified Montessori

Instructor for primary aged children (3-6 years old) and a certified Math Recovery Intervention Specialist. My teaching experiences support intuitive insights and interpretations in the research process.

Researchers seeking to work with children as participants, instead of studying them as research subjects, must dedicate time to establish research relationships with children (Harcourt & Conroy, 2011). At the time of the study, I had been at this school for three school years as a Math Recovery Intervention Specialist. The staff was already familiar with me and we had, and continue to maintain, a good working relationship. After initial observations to collect data on the classroom context and culture, I visited the classroom for ten days to get to know the students. After that, I conducted a small group discussion with the participants about the nature of research, the role of the researcher, the role of the participants, and the goals of the study (Harcourt & Conroy, 2011).

As the researcher, I hold certain epistemological perspectives on learning mathematics and Native students. I support National Council of Teachers of Mathematics principles that all students are capable of learning mathematics and all students need high expectations and opportunities to learn in order to acquire mathematics knowledge and skill (NCTM, 2000a). In addition, I believe that student learners are heterogeneous and require accommodations to meet their diverse learning needs. *One size fits all* approaches ignore the differential realities students face in their classrooms and schools by concealing taken-for granted rules and ways of operating that privilege some and disadvantage others (Gutierrez, 2010). Equal access to self-professed neutral or universal mathematics education systems "without the expectation that the system will be affected by new participants" will "likely benefit neither Indigenous students nor others from non-dominant groups" (Trumbull et al., 2002).

Site of Study

The study site was a first grade classroom in an urban public elementary school in the southwest. New Mexico covers 121,356 square miles, with a 2013, estimated total population of 2,085,287 people. Thirty three percent of the total population live in rural communities (Rural Assistance Center, 2014). Roughly 75% of all communities in New Mexico have 500 or fewer residents (New Mexico Community Foundation, 2013). One third of the total state population live in cities located in close proximity to each other in the center of the state: Albuquerque, Santa Fe, and Rio Rancho (Brinkhoff, 2013). Native people have lived in New Mexico for approximately 12,000 years. Pueblo tribes have lived along the Rio Grande since the 1200's and the Navajo tribes have lived in New Mexico since the 1500's. Native people have survived European contact and colonization since the late 1500's (Office of the State Historian State Records Center & Archives, n.d.).

In the 2011-12 academic school year, this school had a majority minority student population with 19% White students (2011-12). Nine percent of the student population was Native and 77% of students were from low socio-economic status homes, as measured by free and reduced lunch eligibility statistics (2011-12) [3]. The study class had 18 total students, and six were Native. These students were identified from information provided by their parents or guardians at school registration. The teacher provided this information to me after parent permission was granted through signed consent forms. No other verification such as tribal enrollment verification was used.

[3] This information came from an official state website but I am unable to cite the source(s) because of confidentiality necessary to the study.

A major consideration in site selection was gaining access. I spent almost three years developing a relationship with district and school staff. In pre-proposal preparations I conducted my Math Recovery Intervention Specialist practicum at the research site school. The year-long training provided me opportunities to develop relationships with the principal, instructional coach, and classroom teacher Ms. Walker. I am using Ms. Walker as a pseudonym to maintain confidentiality. It is especially important for childhood researchers to develop strong relationships within a community network to gain access to researching young children (Smith, 2011). Initially, the principal showed great concern over allowing me to conduct my certification practicum at her school. As she got to know me and see what I was doing her attitude completely changed. I also faced concern from the classroom teacher. In our first conversation she wanted to know if I had ever been a classroom teacher. After that conversation, she allowed me to visit the classroom. Fortunately, after the first visit she decided to allow me to conduct my Math Recovery Intervention Specialist practicum hours with her students. Ms. Walker explained that she could tell in the first ten minutes I was in the classroom; I had experience working with children. She told me that she was concerned I would be disruptive if I was inexperienced. In Ms. Walker's experience the university researchers she encountered had no experience with children at all. They were awkward, disruptive, and ineffective with children. During my practicum we got to know each other. She got to see me teach and interact with students. We developed a strong relationship as colleagues. It was the strength of our relationship that made conducting research in her classroom a pleasure.

I also faced challenges at the district level. It is common knowledge in my academic community that the study district was wary of research and researchers. I had heard that gaining permission at the district level was difficult and time consuming. Unfortunately, this was my experience as well. I spent another year volunteering Math Recovery Intervention Specialist services while navigating institutional research permissions from the university and school district. The Math Recovery Intervention Specialist work helped me develop a network of supportive people positioned to help me gain access to the school and classroom. This investment proved to be essential to gaining research permission. I had the support of the district coordinator for Math Recovery, the principal, the school mathematics instructional coach, and the classroom teacher by the time I sought school district and university institutional review board permissions. I would not have gained access without their endorsements.

In addition, the district required I hold a current teaching license for the age group I wanted to conduct research with; fortunately, I have that type of teaching license. In total, gaining research access was a long, resource intensive process. I was fortunate to have university funding to pay for my time at the school, for the practicum, training classes, and research activity. I also was able to get grant and scholarship funding to pay for my Math Recovery training tuition and research materials. Gaining research access was a combination of hard work and being the right person asking the right people at the right time. I don't know of many other graduate students with these kinds of opportunities. This was a complicated process and I feel fortunate to have gained access. However, I fear these issues may have negative outcomes for both researchers and the district. Obstacles to research impede research. If research is not conducted in this school district the distinct qualities and issues of the students in this district will not be represented or examined in the academic body of knowledge. This district like most urban school districts has many problematic issues to solve. On a more optimistic note, I hope my study will encourage the district to be more open to research and researchers.

Mathematics Intervention Modifications

For this study, I modified a first grade mathematics intervention to incorporate Indigenous ways of knowing and being. As a classroom teacher, I have in the past included Native cultural activities but I did not culturally modify classroom practice norms. There were three types of cultural modifications for the study teacher instruction, student practice, and assessment.

Teacher instruction modifications. Typical Add+Vantage Math Recovery teacher instruction is verbally dominant with extensive use of direct questioning. (See Appendix 3.A or Example of Typical AVMR Instruction). In the Add+Vantage Math Recovery intervention talking about what you know is the dominant form of evidence confirming competence and knowledge. Direct questioning is the dominant strategy for eliciting verbal responses. Classrooms dominated by verbal exchange pose barriers for Indigenous student participation (Trumbull et al., 2002). As a result, the modifications I made to Add + Vantage Math Recovery were designed to increase opportunities for non-verbal communication and non-verbal ways of showing competence. I sought to find methods of teacher instruction that avoided direct questioning of students and also included teacher demonstrations with visual demonstrations. To incorporate these ideas I modified teacher instruction with a strategy I called teacher *self-talk*. *Self-talk* is an explicit metacognitive discussion carried out by the teacher for a student audience. I hoped this strategy would function like the sociomathematical norm of *revoicing* (Franke et al., 2007). Like *revoicing*, teacher *self-talk* is a demonstration of organizing and aligning ideas to significant mathematical concepts.

The teacher monologue describes what the teacher is thinking and doing. I intended to present multiple demonstrations over an extended period of time to support Indigenous ways of learning, where students prefer to learn through observation (Cleary & Peacock, 1998; Trumbull et al., 2002).

I incorporated self-questioning instead of direct questioning of students because Native students have shown resistance to this type of challenging discourse (Delpit, 2006). I hoped this method would mirror Indigenous participation roles where high status participants dominate conversations and subordinate participants take on a spectator role (Delpit, 2006). Teacher demonstrations with *self-talk* also supports Indigenous ways of knowing by positioning teachers as models and facilitators and avoids confrontational questioning of students (Trumbull et al., 2002). Implementation of *self-talk* was problematic and resulted in unintended consequences. I erroneously assumed homogeneity in student participation preferences and didn't anticipate some students would really want to talk. I discontinued this practice and sought other means of promoting students' mathematical thinking. I discuss this topic in greater details in Chapter 5, Findings-Mathematical Thinking and Learning and Chapter 6 Implications.

Student mathematical practice modifications. I modified Add+Vantage Math Recovery activities and student participation practices to align with Native learning styles and participation preferences. The Add+Vantage Math Recovery intervention routinely uses competitive games. The games are designed to give students practice and rehearse new skills to gain fluency. The intervention assumes that students are motivated by competition. Competitive games are played between students and between students and teachers. Research reports Native students prefer cooperative activities and dislike competitive games especially when they perceive the game is unfair (Cleary & Peacock, 1998). Friendly competition has its place in Native societies but not in learning environments or in contexts that can be perceived as unfair (Garrett & Garrett, 1984; Swisher & Deyhle, 1989). I witnessed negative reactions to competitive Math Recovery Intervention Specialist activities while tutoring Native students. Last year, I observed some Native students cry or refuse to play when they were losing in a competitive game with me. One of the students who cried told me he didn't want to play anymore. When I asked why, he said the game was unfair because they couldn't beat a teacher. Study modifications included changing Add + Vantage Math Recovery activities to be cooperative and non-competitive (See Appendix 3.B for examples of modified Add + Vantage Math Recovery games).

Many Native societies respect children's autonomy (Cleary & Peacock, 1998; Delpit, 2006). I modified student classroom participation to give students opportunities to be self-directed and support student autonomy. Students worked on learning activities in extended time periods called *work blocks.* A typical mathematics *work block* for study participants started with a series of routine warm up activities, followed by a researcher lesson with student participation. After that students were free to choose from a range of activities prepared for their level of knowledge and skill. Activities included games, dominos, manipulatives, flash cards, and a mathematics iPad app called Native Number. Each student also had a binder with worksheets. The binders were filled after the students were assessed and contained materials specifically selected for their developmental level. An additional selection of worksheets of varying difficultly was also available to students. After the first six weeks of the intervention I introduced the cultural activity of beading looms.

During the work block students could also choose to work alone, with a friend, in small groups or with the teacher. Native students often prefer cooperative and peer-peer learning (Cleary & Peacock, 1998; Urmston Phillips, 1983) which is more consistent with collective cultural learning and social activities. In many tribes Native children are encouraged to be self-directed and adults refrain from coercing them. Adults prefer influencing children's decisions over exerting authority over them (Cleary & Peacock, 1998). I influenced students by providing a range of activities and periodically assigning activities as needed. I hoped that a modification allowing students to be self-directed would support Indigenous ways of being autonomous and non-interference of children (Cleary & Peacock, 1998). In general, study students were engaged and focused when they were allowed to be self-directed in activity choice. Sometimes, I interfered with student self-direction for behavioral management issues or when students consistently chose non-challenging or too difficult work. Details can be found in Chapter 5 Findings-Mathematical Thinking and Learning and Chapter 6 Implications

Assessment modifications. The research site resident Math Recovery Intervention Specialist conducted standard Math Recovery interview assessments for study participants before and after the research treatment. The assessments provide summative information on student mathematical knowledge and skills. Student scores are measured in the Learning Framework in Early Number. Math Recovery interview assessments are given one-on-one to students. The interview is dominated by direct questioning of students by the intervention specialist.

Modified assessment took the form of a portfolio of student work samples and observation notes. I used the portfolio to capture data on student achievement in the context of learning instead of the context of testing. Collecting assessment data in learning contexts takes place over time with multiple data points. Math Recovery interview assessments collect data from only two assessment events. Student test performance can be negatively impacted by children's emotional states (National Institute For Early Education Research, 2004). If testing occurred on a day when a student was emotional or stressed, then that would negatively impact assessment results. Early childhood research literature recommends educators consider test scores as part of a broader assessment that may include observations and portfolios (NIEER, 2004). In Chapter 5, Findings section on student mathematical thinking I discuss observations between performance skills and testing results.

I planned to also assess students in individual performance assessments. My intention was to support Native ways of knowing by giving them opportunities to show competence as *doing*. Native cultures often value performance competence over verbal competence (Quattromani & Austin-Manygoats, 2002). I did not conduct these assessments because other research activities took the time available. All my time with students was spent working with students in learning activities. In lieu of individual performance assessments, I was able to observe student performance competence as they performed daily activities during the mathematics *work block.* I compared interview assessment scores with observation data. I did not compare the data to determine statistical significance or effectiveness measures. I used comparisons to see if there were similarities or differences between the two types of assessment.

I planned on scoring the portfolios with the Learning Framework in Number but was not able to do so because I did not implement performance assessments. As a result, I did not document enough samples and observations to completely score portfolios with the Learning

Framework in Number. Despite this, portfolios were still useful collections of artifacts and information.

I used student portfolios with a learning story approach taken from the field of early childhood assessment. Learning stories created from a selection of observations collect meaningful elements which influence a child's learning process (Goodsir & Rowell, 2010). Carr used learning stories to assess student's learning dispositions. I used portfolio data to assess student mathematical learning dispositions, content knowledge and skill levels, and to describe the experiences of study participants. The teacher and I, as researcher, collected learning story information through video recordings, observations, and field notes. We shared this information daily during recess and lunch. We documented these conversations in reflection journals. During consultations we paid special attention to insights on cultural aspects of student behavior in the classroom. This was especially important because neither the teacher nor I are Native.

Sampling Site

Sampling selection was based on purposeful or criterion sampling. Purposeful sampling assumes that one must seek a sample that can best provide insight in answering the research question (Merriam, 1988). Criterion sampling establishes standards that contain aspects of the specific case to be studied. Participants are selected based on how they match study criteria (Creswell, 2007; Merriam, 1988). Criterion sampling was used to select the site and the participants. The classroom, students, and teacher met specific requirements of the study criteria. The site inclusion criteria were as follows:

- A public school.
- A classroom that was using the Add+Vantage Math Recovery intervention.

- A first grade classroom because Add+Vantage Math Recovery is designed for first grade.
- A class with Native students.
- A teacher who agreed to give me access.
- A teacher who agreed to and was allowed to implement the modified Add+Vantage Math Recovery intervention.

Participants – Students. Student inclusion criteria were as follows:

- First grade students
- Students who are identified by their parents as Native
- Students who are English language speakers
- Students in the case study classroom
- Student who receive regular education services (Math Recovery is a response to intervention model and is not designed to address learning disabilities and special education services) (Swanson, Busch, MacCarty, & Wright, 2010).

Families gave demographic information to the school when they enrolled their children. The classroom teacher has access to this information. As per my agreements with the institutional review board, I provided the criteria and parent permission forms to the classroom teacher. She sent home the recruitment letter and permission forms to the children that met the study criteria. I did not have access to any student information until after parent permission was given. Then and only then, did I learn which students were eligible for the study. Student Native status was self-reported by their parents. I did not use any other criteria for determining Native status. After parent permission was documented, I obtained student assent.

Six students were eligible out of a class of 18 total students. Six students participated in the study. There were two males and four were females. Institutional review board restrictions allowed me information on Native and non-Native demographic only. Student participants volunteered tribal affiliation information during informal conversations. For example, they discussed visiting the Pueblo to see their relatives. Students also talked about being of a certain tribe. The six students represented Navajo and Pueblo tribes; as well as White, Black, Latino, and Asian Indian. All students used English as their primary language.

The study student exposure to Native culture varied. Some students regularly traveled to the reservation to visit relatives (two to three times a month). Some students only visited the Pueblos for feast days and ceremonial dances (a few times a year). Some students never reported visiting or talked about Native communities. Some students participated in pan-tribal activities like pow-wows. The information collected on student cultural participation was from informal student conversations and information from the classroom teacher. Interviewing families was not designed into this study. This information could have informed the cultural aspects of this study however, I did not have the resources to obtain research permission to interview families. I also did not have the resources to conduct and analyze additional interviews. This was a self-funded dissertation study and I made several concessions so I could complete the study with the available resources.

Participant – Adult. The classroom teacher was a key informer for the study (Yin, 2003). This person was well suited to be a key informer because she was the classroom teacher, and she was willing participate and give me access to her classroom. The study teacher also completed the Add+Vantage Math Recovery professional development training and was experienced in using the original intervention. The teacher had an educational and teaching background in early childhood education. She possessed a PhD in Language, Literacy, and Sociocultural Studies. The teacher had experience conducting research. In addition, her background in early childhood education and sociocultural studies gave us a mutual reservoir of knowledge that made our consultations productive, insightful and enjoyable.

The classroom teacher felt she had considerable skill and expertise as an elementary school teacher. Her particular interest was in literacy and language arts. She confided in me that she felt less skilled in teaching mathematics and this increased her interest in the study because she hoped to learn from me.

Data Collection

Data was collected with interviews, interview assessments, observations, field notes, collection of artifacts, video recordings of instruction and student practice, and a researcher reflective journal that included notes from teacher consultations.

I interviewed the teacher formally at the start of the study. (See Appendix 3.C for interview questions). The teacher interview focused on two topics: her professional and personal background, and her beliefs on classroom culture. We consulted in informal conversations throughout the implementation phase of the study. We met daily during recess and teacher preparation time. We discussed implementation issues, scheduling, intended, and unintended outcomes. We shared observations of student behavior, student comments, and events impacting study student's emotional and physical state as it related to being ready to learn. I documented our informal conversations in a researcher reflection journal.

The teacher and I both collected observation notes of student behaviors, conversations, student work samples, and student made mathematical drawings. Our shared insights informed adjustments to research implementation and interpretations of study data. Information supplied by the teacher confirmed my observations and alert me to additional aspects to consider. I also met with the classroom teacher after data analysis to discuss study findings.

Mathematics assessments. Two types of mathematics assessments were used in the study. Math Recovery interview assessments and Native Number app assessments. Math Recovery interview assessments were used to measure student mathematical knowledge pre and post study treatment[4]. Math Recovery interview assessments were conducted, videoed, and scored by the school Math Recovery Intervention Specialist. I also viewed and independently scored the video assessments. Our scores were very similar but when they differed I used the school specialist scores instead of mine. Math Recovery Interview assessment scores are reported and discussed in Chapter 5: Findings-Mathematical Thinking and Learning. Students used a mathematics app called Native Number. Each student logged in and the software collected information on student progress, areas of challenge, number of mistakes, fluency speed, and topics covered. Unfortunately, the app data did not reveal new information on student achievement and there were student user problems. A complete discussion is located in Chapter 5 Findings-Mathematical Thinking and Learning.

Video recording. Film and video are traditional data collection methods for research with children in real life contexts (Walsh, Bakir, Lee, Chung, & Chung, 2007). Studying children's classroom activity is a complex process where events can happen quickly. Video is well suited to record these types of events because video can be viewed repeatedly, slowed

[4] I cannot provide copies of the assessments because they are copyrighted. I have permission to use them in assessment because I am a certified interventionist but that credential does not include permission to publish the assessments.

down, and even paused. In addition, video can capture events in subtle detail that is difficult to capture in written observations (Walsh et al., 2007). I video recorded both study participants and myself with special focus on interactions and conversations. I collected data with video recordings for two reasons. First, I was studying children in real life and real life is very complex. Second, I gave direct instruction and I could not conduct detailed observations while teaching. Video can capture detailed information on the semiotic mediation and the use of tools in the joint activities. Video recording classroom activities collected valuable information. Video contained detailed information for analysis (Walsh et al., 2007). I was able to view video repeatedly to observe all the details, and provide me opportunities to see beyond initial impressions (Walsh et al., 2007). Repeated viewing also allowed for "coding in separate passes" where each viewing is focused on one theme or pattern at a time (Walsh et al., 2007, p. 46).

Videoing in the room was fairly unproblematic. Initially students *mugged* for the camera but this behavior was short lived. Students quickly got used to the equipment and did not disturb it. The external microphone captured participant voices clearly and prevented other voices from being recorded. The teacher arranged the classroom with a table in the back of the room for study activity. For the most part the classroom respected the space, and there were very few incidents of non-study participants in video recordings. Video captured great details of interactions that I would not have collected if I simply reflected in field notes. I also set up the recording equipment to record students working in small groups without adults and captured very interesting behaviors.

I used a single camera mounted on a tripod for unmanned video recordings. I used an external microphone to focus sound and reduce ambient noise. Study activity took place in the classroom, and I took special precautions to video record only study participants. This was accomplished by holding group lessons and student practice in a corner and the back of the room. The camera was positioned away from the rest of the class. I used a microphone to direct recordings and avoid recording non-participants. Occasionally the camera would capture a non-participant voice or image, and in these occasions I erased the footage.

Artifact collection. The classroom teacher and I collected student work samples in the study. Items were selected to highlight student mathematical thinking and learning strategies. Of special interest were drawings of mathematical solutions for word problems. I recorded student comments and behaviors in the researcher journal. I used the drawings, field notes, and video transcripts to document students solving word problems. The combined data sources served to give a detailed record of what students did and how they were thinking. This discussion is detailed in Chapter 4 Storytelling Illustrations.

Researcher journal. I kept a journal of the research experience (Creswell, 2007). This document contains reflective insights on data interpretation, study modifications, research events, and comments from participants. This document serves as a chain of evidence (Yin, 2003). Initially I kept separate field notes, consultation notes and the researchers reflection journal. I soon discovered that it was more efficient to write my field notes and then create sections for reflections and comments. The combined journal helped me see the data in a more holistic sense. The combined journal was most helpful in comparing student behavior with research literature. For example, I observed students using avoidance behaviors. This behavior is not mentioned in Native learning style literature. After close examination and rereading Native learning style literature, I feel this behavior could be related to Native cultural preferences for child autonomy and parental non-interference. This is discussed in Chapter 6 Implications.

I found it useful to have a variety of data collection methods. The variety of methods produced similarities and differences in the data. The similarities confirmed information across collection methods and the differences alerted me to areas for further data collection. Video data was very interesting but I had to use it sparingly. The extensive time required to process video data is a concern as well as needing to destroy all video after transcription and analysis. The journal served multiple purposes; cultural reflection journal, record of events, and produced consultation topics. Journal records also facilitated theme development in analysis. In the end, the research journal was effective, easy to use, and had the least restrictions.

Research Protocol

Adult consent was obtained for the classroom teacher. Parent permission, and child assent were obtained for six Native students. Initial study observations were conducted using field notes to develop a sense of the classroom and how it functioned. I used these observations to develop a description of the context (Stake, 1995). I completed these observations in the first two weeks of the study. I continued to make field notes about the classroom context and culture throughout the study, and recorded my reflections in a research journal. I collected data during the fall semester, starting three weeks after school started and ended at the winter break. I delayed coming into the classroom at the request of the teacher. She requested time at the beginning of the year to get her students accustomed to their new environment.

Research activities took place during the mathematics *work block* (90 minutes). A typical research day started with a five minute warm up with finger patterns partitions of five and ten (3 and 2; 4 and 1; 5 and 5: 8 and 2). The warm up was followed with a skill building activity like *a count around* for learning the number word sequences. (See description of a *count around* in Chapter 5 Findings Mathematical Thinking and Learning). Next, I would teach an Add + Vantage Math Recovery lesson. After the group work students would be released to choose activities. I circulated through the room assisting, redirecting, and observing students. The last two weeks of the study the school Math Recovery Intervention Specialist conducted the post-test Math Recovery interview assessments. The duration of the study proved long enough to collect relevant information, witness regular cycles of student activity and discover patterns in the data (Bogdan & Biklen, 2007; Lincoln & Guba, 1985). Working in the classroom was very interesting and rewarding. I was honored to spend this time with the students and the classroom teacher.

Data Analysis

I did not utilize a sociocultural theoretical framework until the data analysis phase of the study. I proposed the study with a combination of several theories and each theory applied to only some aspects of the study. I really struggled with this dilemma. Social constructivism explained student mathematical thinking, but it didn't take into account the influence of culture in the classroom. I observed study students confirming and challenging Native learning style research. I needed a unifying theory that explained the experience of heterogeneous Native learners in a multicultural public elementary school. I was confused and my research proposal was scattered and overly complex. In the study I carefully observed the students. I analyzed the data with an open mind so I could see the story the data would tell. It was the work of Vera John-Steiner that led me to sociocultural theory. John-Steiner and Osterreich (1975) studied Pueblo kindergarteners and analyzed Native learning styles with sociocultural theory. Their research served as an example of how I could use sociocultural theory to analyze my study data. Sociocultural theory assisted me in identifying and organizing data findings. Data analysis revealed information on how case study students responded to cultural modifications and classroom culture. See discussion of findings in Chapter 4 and Chapter 5.

I started the study with priori codes (Marshall & Rossman, 1999). The priori codes came from Math Recovery practice and process norms. I anticipated the priori codes would be useful in analysis but as it turned out the emergent codes proved to be the better codes. I believe this happened because I selected the priori codes based on social constructivism but emergent codes developed out of sociocultural theory. This change in theoretical perspective made the emergent codes more useful than the priori codes.

Standards of Quality

To attend to quality and credibility I used the recommendations of Yin (2003) and Creswell (2007). Yin (2003) writes high quality case studies are based on three principles. The first principle is that high quality case study uses multiple sources of evidence. Second, high quality case studies have a case study database. The database is separate from the case study report. It contains *raw* data like case study notes, documents, researcher narratives, and tabular materials (Yin, 2003). All the video and any identifiers were destroyed after coding from my database. I was required to do this as per my institutional review board agreements. Yin stresses databases need to be highly organized to allow future reference. I used the qualitative software Atlas TI to hold and organize the data in a searchable database.

Using this software was very challenging and proved more difficult than useful. In the end repeated readings and notations on hard copies of transcripts, observations, field notes, and journal entries proved to be the most useful. High quality case study researcher also maintains a chain of evidence of the research process. I recorded the chain of evidence in the researcher journal. This record proved useful in analysis and during the study. The record of chain of evidence helped me plan next steps by keeping track of what I did.

Creswell (2007) writes of eight validation strategies. Three of these strategies were used in the study triangulation, thick description and regular member checks. Triangulation makes use of multiple different sources, methods and theories to provide collaborating evidence (Creswell, 2007; Stake, 1995). Thick descriptions allow readers to make decisions about transferability (Lincoln & Guba, 1985; Merriam, 1988). Member checking involves taking researcher collected data, analyses, interpretations and conclusions back to research participants so they can determine accuracy and credibility (Stake, 1995). I met with the teacher regularly and shared my observations and thoughts on the students and checked in with her on emerging themes and initial analysis intuitions. The teacher was a wealth of information about her practice and her students. I also *member checked* with students as events occurred. For example, when students cried or looked emotional I would ask, you look happy, sad, angry etc? Then I would ask them what was going on? The students explained their feelings clearly and bluntly.

Credibility was also attended to in my research positionality discussion in Chapter 2. Eliminating researcher beliefs and values is neither possible nor desirable. I explain my positionality in detail to inform readers of my assumptions and values. Explicit discussions of the researcher biases support research credibility and validity (Maxwell, 2005). I also discuss my personal background in relationship to concepts relevant to the study findings: cultural fluidity, heterogeneous cultural experiences, and things to consider when studying cultural aspects of learning in multicultural contexts. See the beginning of Chapter 6.

Ethics

Case study research has basic ethical considerations and research with young children and Native students has additional unique considerations. In this section, I address all three topics in this regard. Research ethics require informants to participate voluntarily and without coercion (Bogdan & Biklen, 2007; Creswell, 2007). Informants must understand the nature of the study including the dangers and obligations involved (Bogdan & Biklen, 2007). Bogdan and Biklen (2007) write, “informants are not exposed to risks that are greater than the gains they might derive” (p. 48). Anonymity of informants is protected by use of pseudonyms for the site city, school name, and all informants. Informants and gatekeepers were informed about the purpose and goals of the study (Creswell, 2007; Merriam, 1988). The people being observed knew they were being observed, and I was careful to avoid appearances of *spying* on the children or recording private behavior (Merriam, 1988). Since I was participating in the classroom I needed to remain aware of the degree in which presence was changing what was being observed (Merriam, 1988, p. 181). My presence in the classroom was impactful, but I worked very hard to align my practice and presence to be consistent with the classroom teacher. For example, I followed the same classroom rules during mathematics activities. I also incorporated classroom norms like giving student jobs, opportunities for student self-direction, and problem solving mediation. Fortunately, we had similar teaching and behavior management styles, and similar beliefs about students and their families. This strategy proved complimentary and not disruptive.

Case study research involves intensive, specific, and detailed descriptions; as result, it is very difficult to maintain anonymity. Publication of a case study can hold repercussions for participants. As the researcher, I disclosed research findings with participants and their families at a dinner presentation. I presented only general findings and themes and did not use any names in examples. I emphasized my appreciation for their participation and let them know it was an honor and pleasure to work with their children.

Special considerations must be taken when children are research participants. In this study, I sought the perspective of children and assumed they could be competent participants. Ethical participation of children requires supports and structures to ensure their personal safety (Harcourt & Conroy, 2011). Research involving children require both parent consent and child assent (Grey & Winter, 2011). Adults inherently have power over children. Ethical research with children requires their informed voluntary participation. For this reason, adult consent must be equally considered and adult consent must not supersede child assent (Grey & Winter, 2011).

Assent should not be considered an initial or one-off issue (Grey & Winter, 2011; Smith, 2011). Despite initial parent consent and child assent, researchers need to honor and be sensitive to occasions when children do not want to be questioned or observed. Children may not have the social maturity or verbal skills to articulate reluctance to participate (Grey & Winter, 2011). Researchers must be "mindful that children can express dissent through non-verbal cues" like body language, facial expressions, failing to respond, ignoring or hiding from the researcher (Grey & Winter, 2011). Children must understand they can and be allowed to withdraw or resume participation at any time (Fuson, Smith, & Cicero, 1997).

Participants were informed they could opt out of research activities at any time. There were times when students elected to not participate in a particular activity. These occasions were rare and had more to do with children not wanting do academic work or avoiding conflict than about participating in research. Incidents of non-participation are described in Chapter 5 Findings-Mathematical Thinking and Learning.

Caution must be exercised when conducting research with Indigenous people. The research community has a history of exploitive, deceptive, and unscrupulous research arrangements with Indigenous communities (Norton & Manson, 1996). Indigenous scholar Linda Tuhiwai Smith (1991) describes research experiences of indigenous peoples.

> 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….The ways in which scientific research is implicated in the worse excesses of colonialism remains a powerful remembered history for many of the word's colonized people. It is a history that still offends the deepest sense of our humanity. (p. 1)

Ethical research with Indigenous students challenges assimilation and works to remedy the detrimental forces of colonization (Kincheloe & Steinberg, 2008). Researchers must respect Native culture and values (Ellis & Earley, 2006). The incorporation of Indigenous perspectives is done out of respect for Indigenous culture and values. American Indian best interests must be a priority for the researcher and study (Stiffman, Brown, Striley, Ostmann, & Chowa, 2005).

Research with Native peoples reveals themes and tendencies but also demonstrates variation and diversity (Cleary & Peacock, 1998). Caution must be used in conclusions and assumptions about commonalities in research findings to avoid essentialism (Kincheloe & Steinberg, 2008). Au (1993) argues, "while becoming informed about cultural differences, we should be careful to avoid stereotypes that suggest that certain groups of students cannot benefit from…activities that require their active, constructive involvement" (p. 119). Essentialism has also been used against Indigenous students to justify remedial, nonacademic, and non-challenging curricula (McCarty & Watahomigie, 2004).

Limitations of Study

Case study by design has a very small sample size and this creates issues for transference and generalizations but certain types of generalization are possible (Bryman, 2010; Yin, 2003). Maxwell (2005) discusses two types of generalizations in qualitative research, internal and external. Internal generalizability "refers to the generalizability of a conclusion within the setting or a group studies, while external generalizability refers to its generalizability beyond that setting or group" (Maxwell, 2005, p. 115). Case study research can be used for internal and moderate generalizations (Bryman, 2010).

This study was limited to a single case due to resource and access limitations. I initially planned for a phenomenological or multi-case study, but I was not able to arrange additional sites or cases. The goal was to design a study with greater generalization potential; however, considering the lack of research in mathematics education for American Indians, this study will still serve to inform this under researched area of education.

Chapter 4

Findings

"Children need to have voice about who they are. They need to know that what they are is good. It does not matter what is happening in their lives, somewhere in all children is something good." Ms. Walker

Findings: The Context

Findings of the study are reported in two chapters. Chapter 4 reports on the context of learning and the importance of culture in the education of Native students. Chapter 5 reports findings of mathematical thinking and learning. I divided the findings into two chapters in order to highlight the importance of culture in the overall learning context. Classrooms are culturally shaped spaces where learning occurs (Gay, 2009). Mathematics is widely viewed as a *pure science*, free of language and cultural issues (Moschkovich & Nelson-Barber, 2009). In reality, mathematics is an intrinsically social activity and carried out by people in community to solve problems (Schoenfeld, 1992). Ernest describes mathematics as a "socially constructed human invention" (Ernest, 2009, p. 51). In this chapter, I discuss the cultural aspects of the study findings and connect them to learning mathematics. Data was collected in a case study action research project studying the following question: How do public school Native first graders experience collaborative mathematics activities when culturally modified with Indigenous ways of knowing and being. Pseudonyms are being used to report the findings and protect participant anonymity. I used the following pseudonyms for study participants: Ms. Walker for the classroom teacher: Ben, Emily, Hazel, Isabella, Jacob and Jennifer for the study students.

Culture

Culture matters when examining school experiences because issues of power are enacted in classrooms through the *culture of power* (Delpit, 2006). In addition, cultural capitol impacts student participation in schools (Lamont & Lareau, 1988; Lareau, 2003). Changing power relations in schools requires dominant society and non-dominant society people to engage in examining how culture impacts education (Bishop & Glynn, 1999). Developing understanding over time of the cultures of the students they work with, the dominant society culture of schools, and their own cultures is critical for teachers as they facilitate student learning. They need to develop critical awareness of how they represent and enact dominant culture in classrooms (Bishop & Glynn, 1999). Cultural conflict in schools is particularly relevant for Native students due to the U.S. Federal American Indian education policy history of cultural genocide (Curcio, 2006-2007). Ignoring culture, and claiming culture doesn't play a role in teaching and learning denies the reality of Native students in public schools. National mathematical practice standards do not currently consider or acknowledge cultural bias in the norms. Mathematics reform classrooms pressure students of color to adopt dispositions and values of dominant society in order to be recognized as competent in mathematics (Martin, 2012). For example, to be considered competent in mathematical discourse students are asked to question and interrogate their fellow classmates and teachers, what happens to these students when this type of behavior is a cultural taboo? Improving educational achievement for Native students requires understanding the role of culture in teaching and learning as well as changing power relations in schools (Castagno & Brayboy, 2008). The findings of this chapter focus on the cultural aspects observed in the study context.

Classroom Culture

Classroom culture and teacher beliefs. The typical Add + Math Recovery intervention is practiced without considering contextual factors like the overall classroom culture. Classroom culture was a finding of interest to this study because the intervention occurred in the classroom, and the classroom culture influenced the intervention. The classroom culture impacted how students felt about participating in joint activities. It was the positive affective factors developed in the classroom culture that supported the challenging work of learning mathematics. In this section I describe the classroom culture and how Ms. Walker developed it.

The focus of this study is on the experiences of students in the classroom. I did not directly collect data on their lives outside of school. What I did learn about students' lives I learned from the teacher. I did not describe the details of study students' lives because all children experience stress outside of school. The details of individual lives is not as important as knowing most low-income families of color struggle under a variety of social pressures. The study students had complicated lives outside of school, and the students needed nurturing classrooms and schools. Ms. Walker designed a classroom that was nurturing. Ms. Walker is a veteran teacher who has been working with children for over 30 years. She is a highly educated teacher with a PhD in Language, Literacy, and Sociocultural Studies. Ms. Walker is a White lesbian woman who was raised in foster care and is raising an adopted a child of color. Ms. Walker is not a person of color but her life experiences support her understanding of being outside dominant culture. Ms. Walker engaged in a holistic approach to teaching that was grounded in her education, professional training, and most importantly, her well defined identity and strong sense of self. Ms. Walker explained that, “I teach from the center of myself, I teach from who I am. I teach from my experience of being in the experience of schooling. I have lived this experience. I have studied this experience. I am an anthropologist who teaches.” Ms. Walker studied the human experience of the classroom. She sought to understand the context, history, social forces, learning, and personalities of her students.

Ms. Walker was very candid in the interview and in our daily consultations. The information in this section was developed from a combination of her interview responses, our conversations, and in class observations. Ms. Walker described having a global view on the purpose of education. Ms. Walker teaches children, not curriculum. To describe Ms. Walker’s teaching as learner centered is an oversimplification that negates fundamental aspects of her work. Ms. Walker’s teaching pedagogy is centered on the concept of humanity. “I educate for humanity and not content. It is the difference between understanding that we are working with human beings and not curriculum. I teach the child.” She teaches children how to learn and not just what to learn. Ms. Walker’s students learn to be students, problem solvers, and researchers but, more importantly, her students learn to be people in community with others. Content is included, but it is not the singular goal. Ms. Walker teaches her students with a carefully, and intentional designed classroom community. There are three main themes in her teaching approach. First, she attended to the children’s basic needs. Second, she taught children to be students, learners, and community members. Third, she got to *know* her students and their families by building relationships through genuine communication. The aspects of her classroom are developed simultaneously. The themes intersect, overlap, and reinforce each other. Ms. Walker utilizes her wealth of experiences to implement several strategies to achieve her goals.

Ms. Walker believes in teaching the whole child by relating to student life both inside and outside of school. She likes her students and gets to know their families. Ms. Walker holds non-deficit views about students and families. “I found that (humanity) in myself, and I work to help students and families find that in (themselves and) their children. We all struggle in our lives, and I teach the whole person with respect and compassion.” Ms. Walker communicates with families and is honest about how family stress affects their children. She has high expectations for students. Ms. Walker is firm but caring, and she insists upon great efforts from her students. These ideals are also tempered with a realistic understanding of the limitations of a public school classroom. Ms. Walker refers students for further evaluation and special education placements when necessary. She reports abuse and neglect to authorities. Ms. Walker’s professional disposition supports the Native students in her class. This is vital for a traditionally underserved student population, like Native peoples.

Ms. Walker had a positive relationship with Jacob. He is a bright student who could be challenging for adults. He is one of the first students to volunteer answers; he is very competitive and critical of himself and other students. He is impatient and didn’t like to wait for other students. Jacob’s teacher from kindergarten reported that she was afraid of him and his family because they could get very angry. There was an incident where Jacob got in trouble at school and his father stormed into the school and was very angry. However, during the study, he was quite charming and caring. He volunteered to help with class jobs and chores. He would hop up to help me carry in my research activities into the classroom. He did have moments of anger and aloofness, but I did not witness any yelling, fits, or angry outbursts. Ms. Walker was able to understand Jacob and value his strengths. She helped him utilize his strengths in constructive ways that supported his self-esteem and relationships with others. I feel Ms. Walker's relationship with Jacob helped him be successful in class and during mathematics activities with me.

Another student, Ben, had attended a variety of different schools before arriving in Ms. Walker's class. His former teachers also reported that he was hard to deal with. Thankfully, Ms. Walker really connected with him. She said, "I really get this kid". Ben was an enthusiastic learner. He was a global thinker with original thoughts. Ben often expounded on his expansive thinking making multiple associations and connections. For example, Ben was asked what he liked about mathematics. He answered "the abacus, the time, division, square rooting and multiplying by zero, the sum to one to one hundred, and dynamic multiplication…it is hard but super easy for me." He talked about the levels of mathematical ability and related it to a Bell curve. He also talked about how mathematics in school started easy and got harder as you got older. It was hardest in *grad* school. Ms. Walker recognized his intellect and encouraged his explorations. She engaged him in conversations. She directed him to resources where he could explore his ideas.

Attending to students' basic needs. Ms. Walker attended to the basic needs of her students. As in Maslow's hierarchy of needs, students must have their physiological needs met before they can attend to higher order needs (Maslow, 1999). Ms. Walker said, "I cannot teach a child who is sick, tired, hungry, or otherwise preoccupied and stressed." Students could go get a drink of water and use the bathroom most any time. During lunch, the teacher collects wrapped non-perishable food that was not eaten from her class's school lunch and saves them for redistribution as an afternoon snack. After lunch recess, the teacher reads to the class. The lights are turned off and students are encouraged to relax, with most students choosing to lie on the floor. At other times, the teacher leads the students in relaxation exercises. These activities include, but are not limited to, breathing, stretching, and posture checks. I saw Ms. Walker initiate this when the students were especially loud and moving around the room off task. She said, "We are taking a brain break. Take a big breath 5,4,3,2,1 shhh. Take a big stretch." She would periodically direct students to, "stack your blocks, sit up straight, now take a big breath," in reference to previous yoga activities taught by the school physical education teacher. Basic needs must be met before students can be ready to learn. This is especially true for underserved students where they may be experiencing poverty, insecure housing, and racism.

Another aspect of attending to student basic needs is maintaining safety. She did this for both physical and emotional safety. Students showed their trust in her by routinely bringing their concerns to her. She spent time everyday helping students express their concerns and they would problem solve together. Ms. Walker worked as a moderator to help students resolve their conflicts and face and manage their emotions. I have even seen her bring students from other classes into the room to resolve playground conflicts. By facilitating resolution of conflict and release or management of emotions, Ms. Walker assists students to resolve issues and process feelings that would otherwise distract from learning.

Ms. Walker uses something called *refocus time* as part of behavior management. This is a school wide program initiated after a student receives multiple interventions but continues to be disruptive or off task. The student is told they need *refocus time*. Sometimes students are given a choice of refocus activities. Choices include going for a short run outside or sitting in another classroom for a few minutes. *Refocus time* is also used for students to write notes of apology, think of better ways to handle situations or conflicts, and finish schoolwork. Ms. Walker comments, "*Refocus time* is about moving students to a different space, physically and mentally. It is time for students to pull themselves together. It's better for a student to do pushups against the wall instead of throwing a desk." Ms. Walker used refocus time in conjunction with her fellow first grade teachers, and students from other classes would periodically appear to do *refocus time* in her room. Ms. Walker would like to see an art space available for *refocus time*. "Working clay and painting changes what is happening in the brain." It is an outlet that moves children out of anger, frustration and into a creative space. *Refocus time* helps a student stop unwanted behavior and then gives them the space to accept responsibility. Ms. Walker says, "It is all about getting back to the cognitive work."

During my teaching and observation time in the classroom students generally complied with *refocus time*. Some students complained, but they still complied. Some students even asked for refocus time. This was true for a student who every now and then needed a short run outside to release extra energy. He often did this when frustrated. The exercise helped him to settle down and be focused. I also saw Ms. Walker use *refocus time* to allow a younger sibling to visit an older sibling in the same school. The younger sibling was highly anxious and needed a hug from his older sister to help him get through the day. *Refocus time* was flexible, and Ms. Walker observed her students and used *refocus time* to best suit student needs.

Understanding child development. Ms. Walker teaches children to be learners, students, and community members which influences learning in all subject areas including mathematics. She has a birth to third grade endorsement with an emphasis on early childhood development. "I think understanding human development is essential to good teaching. I believe all educators should have grounding in development at all ages and stages. It is from this knowledge that "I can be passionately forgiving, appropriately understanding." "I can look at my kids (first grade students) and understand why they are barking like dogs, and I know how to move them to do math. My early childhood development training has helped me to read my students."

Ms. Walker believes first grade children need to be taught how to be learners. Ms. Walker employs theme-based units of study with explicit lessons on how to ask questions, research information, and develop answers. Here is an example of a graphic organizer the class created when they started learning about the solar system. Ms. Walker gave the prompt "What is a solar system?"

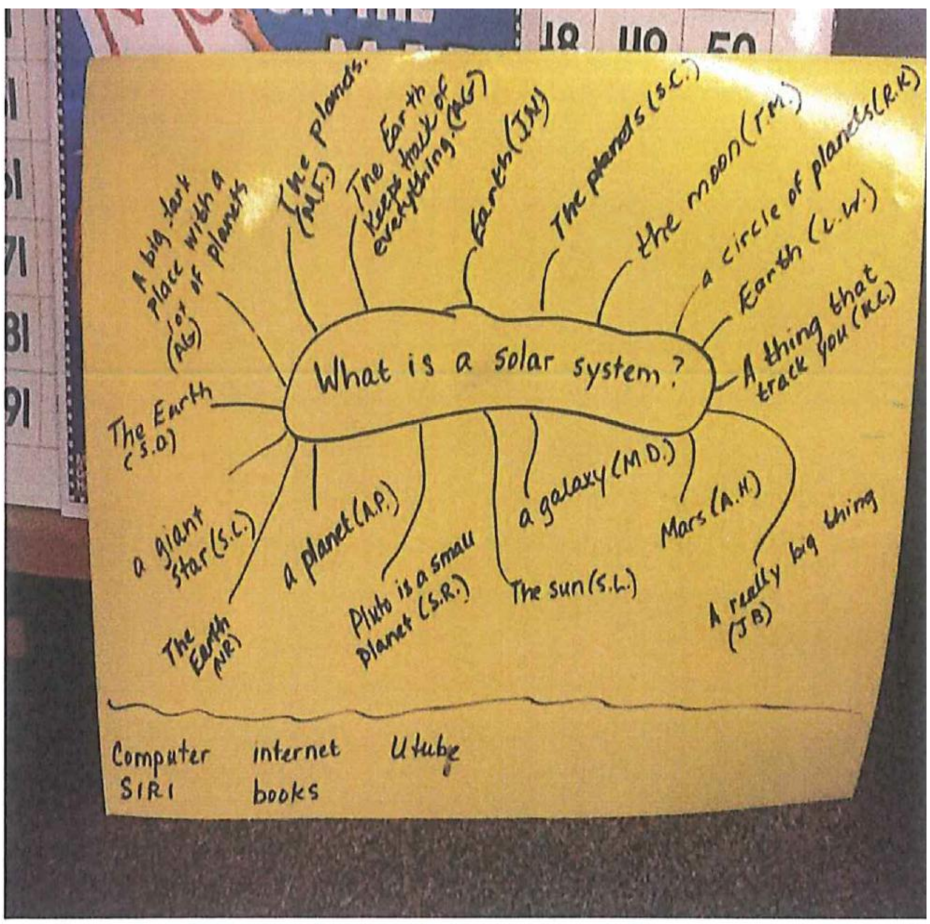


Figure 4.1 Graphic Organizer

Student answers are written on the chart with their initials to show authorship. On the bottom of the chart are student ideas for resources to investigate to find answers. Students did research in books, online, and questioned adults. Students wrote out essays by hand and retyped them into a word processor. Ms. Walker explained to the children that typing essays was practice with computer skills and made their work more accessible to readers. Ms. Walker assigned students to tables in small groups of three to five scattered around the room. Occasionally, students would sit in a lone desk for a period of time until they were reintroduced to a group. Ms. Walker continuously observed and assessed placements and moved students as needed. She carefully placed students at the tables to promote social harmony and peer learning.

A community of learners. Ms. Walker also teaches children to be learners as individuals within a larger classroom community. She works to instill a sense of student ownership and belonging. She explained to students that "this learning is yours" or "the learning belongs to you." Ms. Walker noted if students were disruptive, off task, or destructive, she interrupted this as the students were messing it up for themselves and their fellow classmates. Student learning is about and for students. "The learning is yours, so if it is good, you learn a lot. If you don't try, don't pay attention, it will be bad for you because you won't learn." She would often explain to her students, "the classroom belongs to you and you belong to this class." During parent teacher conferences, families reported that their children talked about being responsible for their own learning. Families also commented that their child often said, "The learning belongs to me."

Ms. Walker develops the community by having students get to know one another. First, she helped them learn to spell each other's names by incorporating their first names into the weekly spelling list. If students asked how to spell a name, Ms. Walker would direct questions to the student named. This child would orally spell their name, and check other student spellings. Students would use this knowledge in attendance record keeping. Ms. Walker also developed the classroom community by holding daily group discussions. This was a time for students to bring up questions, concerns, and share stories. Ms. Walker also used this time to review previous lessons and preview new lessons. Group discussions happened at least once a day and sometimes more often. Sometimes she used group discussion to problem solve a student conflict. Sometimes she gathered the students together to discuss an event that happened at the school like a fire drill or special visitor. It just depended on what was going on. She also developed the class community by giving students opportunities to contribute to their class community through service. Students performed daily routines in the form of jobs and duties like maintaining the calendar; helping with attendance, escorting their peers to the nurse, and delivering the lunch count to the cafeteria. Ms. Walker encouraged students to help each other. Cooperation and helping skills developed in the classroom supported collaborative mathematics activities. Once developed these skills helped students to take turns, listen to each other, and work together in mathematics learning.

Ms. Walker has high expectations for her students and held realistic but positive views of families and students. She did not ascribe to deficit views. The class had a set of agreements and rules between the students and teacher, in the form of a class constitution. Students were actively involved in writing the document. Ms. Walker required that all the agreements and rules be about being fair, safe, and caring. She explained to students that they needed to think about what we needed to do, to be awesome first graders. She says to them “We are going to be together for 180 days so how are we going to do it well?” The constitution had statements like “I agree to do my best.” “We will help each other,” and “we will use our minds well”. All students were asked to sign the constitution, and the finished document was posted on the classroom door. During the initial brainstorming work, Ms. Walker noticed children would suggest negative rules. “I think it’s interesting that students always start with negative statements.” Negative statements included: “we won’t lie, cheat, yell, hit…”etc.” Ms. Walker asserts that first graders are just learning how to be learners and members of a classroom. When children give these types of answers, she would ask them, “How do we say that in a way that is about what we want, instead of what we don’t want?” She explained “it is very hard for anyone to know what to do in a new situation when the only thing they know is what not to do. It is important for educators to teach young children *what* to do.” Ms. Walker referred back to the constitution when helping students with conflicts or unwanted behavior. She asked students to reflect on if their actions were safe, fair, and caring. She reminded them that they signed the constitution and promised to uphold it. Ms. Walker believed students could and would uphold the classroom constitution. I suggest the high expectations of the classroom constitution agreements may have helped students persevere in challenging mathematics activities. I observed Jacob and Emily complete an 800 numeral dot-to-dot worksheet over the course of three days. They worked together, used their minds well, and persisted, despite the difficultly of the activity.

Ms. Walker *knew* her students well. She believed that in order to really know children, you have to get to know their families. She was skilled and committed to developing relationships with students and families through genuine communication. Ms. Walker conducted parent-teacher conferences; phone calls, emails, home visits, and attended student family events both inside and outside of school. She was in frequent contact with parents and student families. In our consultation meetings, I noticed she knew details about student lives both past and present. She talked to students and more importantly she listened to students. The children trusted her and turned to her for support. Families also communicated and shared with her. Ms. Walker had a depth of knowledge, compassion, and respect for her students and their families. She has been developing these relationships for many years. Families request her, and she often has siblings and relatives of former students in her class. Former students regularly come visit her. Ms. Walker established positive relationships with most students and families, but there were exceptions. Some families didn't like what she said about their children. Some families would not communicate with her. Some families complained when she made special education referrals, and some families complained when she did not. Ms Walker shared her insights and information with me during our daily meetings. She helped me *know* the students. I used this information to shape instruction, behavioral management approaches, and curricular themes. Knowing students better offers insights into how they learn, what motivates the, and what might be distracting them.

Ms. Walker had a history of being able to have a positive relationship with families labeled as s*cary* or u*nmanageable* by other teachers and school staff. She was successful working with most families because she communicated with them with respect. She told families "You are the expert on your children, help me get to know your child so I be a better teacher". Ms. Walker worked with families from children's strengths and positive qualities. She established relationships with families and was able to also communicate student challenges. Ms. Walker was able to establish positive relationships because she sought to connect with the humanity in all people. She also sought to help children develop a sense of self that was valid and real. She said that, “children need to have voice about who they are. They need to know that what they are is good. It does not matter what is happening in their lives, somewhere in all children is something good.” Students had opportunities to have *voice* in the family journals (see next section) and during group discussions. Students had voice in storytelling for mathematical word problems (see storytelling illustrations in Chapter 5).

Ms. Walker was invested in getting to know her students as individuals, and she helped students get to know each other. She developed student relationships with daily group discussions focused on their families, neighborhoods, previous experiences in school (kindergarten, pre-school), and events outside of school. Students are encouraged to share and tell stories in class. Ms. Walker routinely points out connections between students and herself. Ms. Walker also connects student assignments to their personal experience. For example, the students studied constellations. After researching and reading multi-cultural constellation stories, the students created their own constellation art and wrote their own accompanying constellation stories. Students wrote to their families asking them to tell them how the moon got into the sky. These stories could be traditional legends or made up stories. The completed art and narrative was compiled into a class book. Storytelling was integrated into mathematics activities. Student stories were used for mathematical word problems (see storytelling illustrations in Chapter 5). Students told the story of how they solved a mathematical problem with their illustrations and their explanations of those drawings.

Family journals. Another strategy employed by Ms. Walker was *family journals*. *Family Journals* are notebooks that were sent home each week. Students write letters to someone in their family and that person writes back. Students got to choose whom they would write to. At first, Ms. Walker wrote out letters for students to copy. Next, students dictated their letters to Ms. Walker, who wrote it out for them to copy. Eventually, students were able to write on their own. Student journal entries included illustrations and art. Occasionally, families did not write and/or did not return the notebooks. Family members get three chances to write back, and if they do not, then Ms. Walker found another person to correspond in the journal. Missing journals or journals without family responses help Ms. Walker know that further communication efforts are needed and this gave her an opportunity to contact families.

The family journals served many important functions. First, they were an opportunity for students to have meaningful opportunities to write. Second, when family members wrote back, it provided meaningful opportunities to read. Third, it provided practice for developing penmanship and creativity. Ms. Walker explained, “Who better than your family for children to write, read and communicate with? These are the people they love.” Ms. Walker instructs families to interpret student writing as best they could and not correct grammar and invented spelling. The goal is to get the student writing and communicating; “it is about preserving children’s voices.” The family journals also served as a communication device between the school and home. Homework, school notices, and letters to parents were sent home with the family journal. “This is how I bring the families into the class.” Communication was established as the class norm where student voice was sought and respected, family input was valued, and classroom work was shared. These relationships informed families and teachers of student successes and struggles. It also informed my mathematics instructional practices.

Not all families embraced family journals. Ms. Walker reported that some families felt the journals invaded their privacy. There were also families who complained that the journals were a way for the teacher to get parents to do their work. In addition, some families never returned the journals or did not respond at all.

Ms. Walker asks families to participate in whatever ways they can. They can write in other languages, draw pictures, or have someone be their scribe. "They can write in any language they want. It is my job to get it read." Ms. Walker used a variety of writing prompts such as "how did you choose my name?" and "how do you celebrate holidays?" Ms. Walker reads all the journals out loud to the whole class. She explained that "first graders can't read and this is how they all get to know each other. It is a way to create community that includes families." The students have approached the parents of fellow students and asked about their journal entries. Students also had favorite stories, art, and jokes from *family journal* responses. At the end of the year, all the students take their *family journals* home. The journals were a great keepsake capturing their first grade year. Families of former students told Ms. Walker they continued to use *family journals* for many years.

Ms. Walker reported that other teachers and academics have not had the same success with *family journals*. She has been told that the journals "didn't go anywhere" and participation dropped off. Ms. Walker explained her success:

> You have to allow the social interaction of the child and families. You cannot dictate the interactions. Journal entries get messy because human relationships are messy. Other people have failed with family journals because they can't *go* there. Basically teachers censure content. I encourage students to *go* where they *need* to go.

Some students could be very blunt and direct in their journal entries. Ms. Walker remembers reading of sad or troubling information about families. For example, "I have had students write, 'I am sad because I don't like the way you hit me. It scared me." I asked Ms. Walker what she did when students reported abuse. Ms. Walker replied she complied with all children abuse and neglect laws and regulations but could not give details of specific incidents. Student journal entries span a wide range of topics, tones, and content. "I've seen beautiful entries with touching exchanges between families and children." Ms. Walker has also observed children writing to their absentee biological parents. Not every child in this circumstance did this, but the phenomenon happened consistently year-to-year. "I have often thought about what this means for these children. Why are they doing this? What purpose does it serve? I don't know the answers but, more importantly, I don't stop them." Ms. Walker could imagine adults discouraging children from writing to people they don't see or know. She could understand parents being offended that their children wrote to absentee parents. Family journals are about giving children voice, and she believed children got something out of writing to these people. Ms. Walker does not take over student work and she does not let parents take over the process. Ms. Walker believes *family journals* work in her class because she gives students ownership of their writing. Ms. Walker describes *family journals* as "the most powerful piece of literacy I have ever come across."

In future work I can see using *family journals* to explore family funds of knowledge (Gonzalez, Moll, & Amanti, 2005)for mathematical topics. Journal questions to families could ask how do you use mathematics at home, at work, or in the community? Students could also write examples of storytelling illustrations for word problems in the *family journals*.

Nested Joint Activity

In the study classroom, the teacher taught all content areas for the same students in the same classroom. The mathematics lessons took place inside the classroom and I am calling this structure *nested joint activity*. I am using *nested joint activity* as a sociocultural term that describes the activity of learning mathematics embedded in the larger activity of creating the classroom culture. This term assumes the synergy of semiotic mediation occurs within joint activities and between joint activities. I am suggesting the model influences mathematics learning, where mathematics learning is enhanced by a nurturing, high expectation, culturally responsive classroom culture. Semiotic mediation in the first activity, building classroom culture, transforms into new psychological tools that influence semiotic mediation in the embedded second activity, mathematics instruction and learning. In the

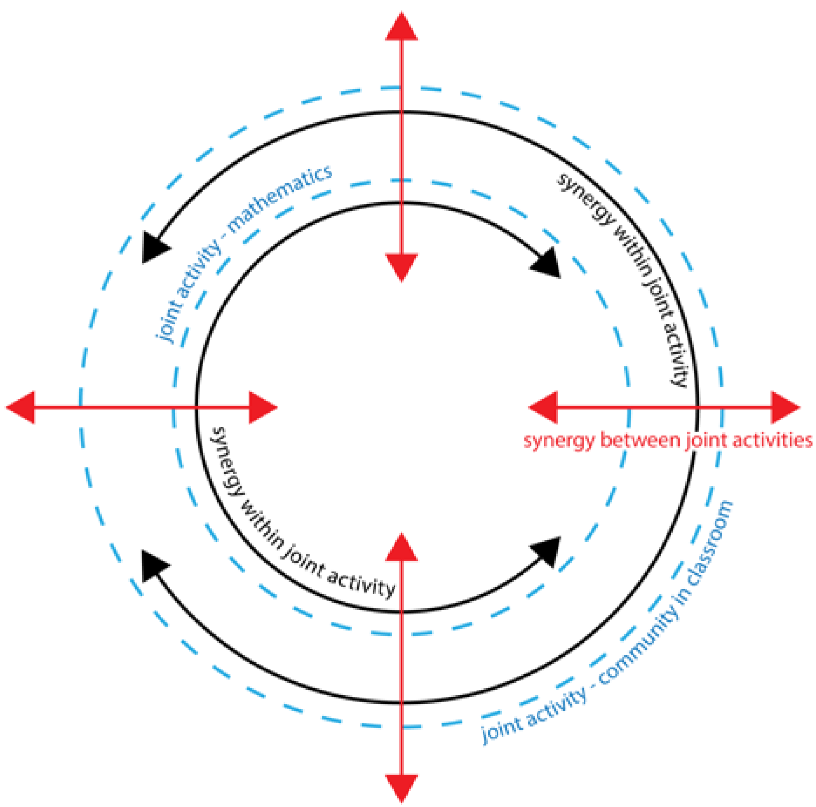


Figure 4.2 Nested Joint Activity Diagram

classroom culture activity students learned how to work collaboratively and feel connected to school. The classroom culture also gave students the opportunity to connect school learning to their lives. Students were encouraged to value who they were, and where they came from as a resource for learning. Students engaged in reading, writing, and speaking about these connections. Learners used these tools in the semiotic mediation of learning mathematics. For example, students asked for word problems based on their families and lived experiences. Students were accustomed to connecting their lives with the learning in school, because they did this in the activity of building the classroom culture through journal writing. Students, families, and the teacher used the journals to share family stories, ask questions, and report classroom news. Information gained during the mutual communication informed the teacher about family traditions and cultures, and served as resource for incorporating diverse and culturally relevant semiotic means for cognitive pluralism.

Chapter 5

Findings: Mathematical Thinking and Learning

Data was collected in a case study action research project studying the following question: How do public school Native first graders experience collaborative mathematics activities when culturally modified with Indigenous ways of knowing and being. The focus of this chapter is on findings related directly to mathematics teaching and learning. Three themes developed from analysis: student mathematical thinking, Native learning styles, and collaborative learning. Student mathematical thinking section includes discussions on storytelling illustrations for word problems, the Math Recovery intervention, Native Number mathematics app, and student presence. The section for the theme of Native learning styles includes a discussion on culturally relevant mathematics activities. The section for the theme of collaborative learning includes discussions on student avoidance and copying.

Student Mathematical Thinking

I used a wide range of activities and approaches in the study. I did this to support cognitive pluralism and create diversity of opportunities so students could engage in mathematics learning. This chapter includes discussions on each approach. I start this chapter with storytelling illustrations because it is the most interesting mathematics finding of the study. My research plan included a form of alternative instruction that involved researcher demonstrated lessons, a concept I called teacher *self-talk.* The idea was to present mathematics lessons with manipulatives or other visual aids with a teacher monologue to reveal alternative strategies, underlying concepts, and common errors. I wanted teacher *self-talk* to replace mathematical dialogue that offers challenge, interrogates for meaning, and is otherwise confrontational. I believed this approach would reduce verbal dominance, challenging discourse, and allow students to learn through observation.

I implemented teacher *self-talk* as direct instruction for the study students. From the beginning, this method was very problematic. Instead of engaging students and revealing mathematical thinking, teacher *self-talk* created behavior management issues. Students were completely unfamiliar with this type of instruction and were confused. Ben, Jacob, and Isabella really wanted to talk and question, but in order to instruct in a monologue, I had to stop them from talking. Suppressing student conversation was an undesired and an unintended consequence. After students realized they were not to talk, they started talking to each other (Ben, Jacob, Isabella) or lost interest (Jennifer). Only Hazel and Emily watched quietly. After having similar results in multiple attempts, I discontinued the practice. After the unsuccessful launch of teacher *self-talk,* I started looking for other ways to support student mathematical thinking, encourage mathematical dialogue, while reducing the pressures of challenging discourse and verbal dominance. Fortunately, I discovered the power of storytelling with illustrations as a vehicle for mathematical discourse.

Storytelling illustrations. Students were working on word problems in the mathematics curriculum. I noticed that the students were having a very hard time solving word problems. To support student learning, I started a series of lessons based in Cognitively Guided Instruction. Cognitively Guided Instruction uses a series of problem types to develop student problem solving skills in mathematics. (See Appendix 4.A chart for problem types and examples). After introducing these problems, I noticed most students could solve the word problems, but they couldn't <u>show</u> their work. After talking to them, I realized they didn't understand how to relate the mathematics word problem to a visual representation that explained their thinking. To help them I explained, “The drawing had to tell the story of what happened in the word problem and how you solved it”. Ben said, “oh like pictures in stories?” I said, “Yes, you need to draw a picture that tells the story of your word problem.”

After this discussion, I discovered that most study students were very enthusiastic about drawing illustrations for story problems. Their interest in drawing the story motivated them to think mathematically. Drawing illustrations got them thinking about and discussing mathematical processes and strategies. This activity got them looking at each other’s work with a critical eye. They asked each other questions, talked about aspects of the problem, and analyzed solution strategies in ways I could never get them to do before. I used storytelling illustrations with the study participants. Ms. Walker was really impressed with the work and used this method with the whole class. The story problem illustrations inspired students to engage in socio-mathematical discourse. Unlike the sociomathematical practice norms promoted by reform mathematics researchers; students did not challenge nor interrogate each other for meaning (Franke, et al., 2007). The conversations were friendly and inquisitive, and they wanted to understand and communicate mathematical meaning of the story through drawings.

I started with problems at the initial or beginning level of complexity in the progression of problem types. Beginning problems can be directly modeled for addition and subtraction. The students were to solve the problem and draw an illustration to explain how they solved the problem. For example, I asked students to solve a problem and draw a picture to explain their answer.

Researcher: “There is an apple tree. It has five apples. A deer comes and eats two of the apples. How many are left? “

(Ben drew an apple tree and a deer. The tree had two dots in area above the trunk.)

Researcher: “Ben, tell me about your picture”.

Ben: (*pointing to the dots*) “The tree has three apples in it because the deer ate two of them. Five take away two is three”.

Researcher: “Yes, that is correct, but your picture needs to tell the story of how you solved it. Right now your picture only shows the answer as three apples. I don’t know how you got that answer. I want the picture to tell the story of what happened”.

Ben: (*sat still for a moment staring into space, then he smiled), “*I got it”.

Figure 4.3 Storytelling Illustration 5-2=3, Ben

He drew tight circles over the dots filling in the treetop. Above the tree, he drew five dots with short lines attached to each apple. He connected two of the dots with long lines down to the deer. Then he pointed to the dots above the tree and said:

> There are five apples (*He pointed to the dots with short lines*) these are the stems, (and) every apple has a stem. (*Then, he pointed to the two dots connected with lines to the deer*) These are the two apples the deer ate *(He then pointed to the three remaining dots).* These are the ones left over. See, there are three left.

I told him now I could see how he solved the story problem. I asked him to write an equation that fit the story, and he wrote 5-2=3. Emily was listening and watching Ben work. After we were done, she drew this picture.

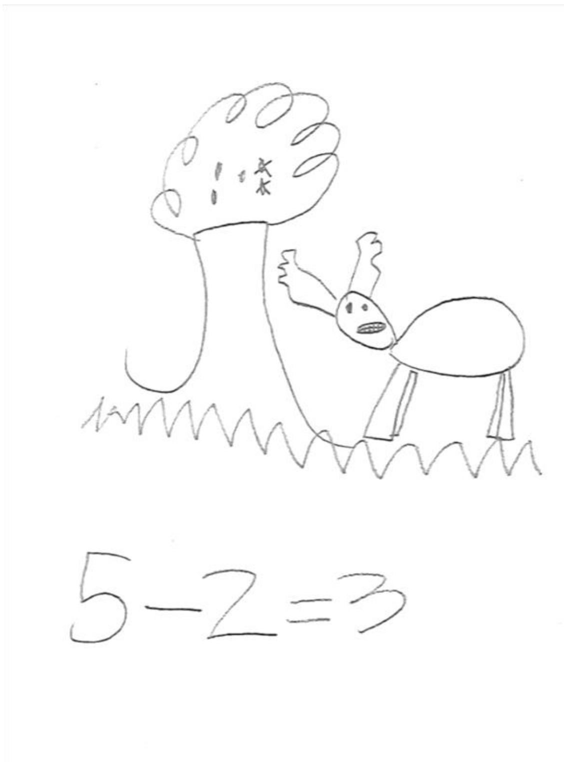


Figure 4.4 Storytelling Illustration 5-2=3, Emily

I asked Emily to explain her story illustration.

> Well you see there is this deer that was hungry. He's got horns so you know he's a boy. There is this apple tree with five apples on it and he eats two of them. See his teeth? I crossed out the apples he ate. Now there are three apples left.

Emily drew the dots in the regular dot pattern for five. She used information from Math Recovery activities in her story problem illustrations.

Initially, I wrote problems with random names and contexts, but one day I didn't have prepared story problems when the students asked to work on story problems. I started making up stories, and the students volunteered information.

Ben: "I want the story to be about a hot air balloon. We saw some yesterday. I wish I could go on a balloon ride."

Researcher: "Ok, Ben, you are going on a balloon ride."

Ben: "I want my family to go with me."

Researcher: "Ok, Ben you are going on a balloon ride with your family."

Ben: "Yeah, me and my big brother, my little brother, my mom, my dad, my step dad, that makes six."

Researcher: "Ben is going on a balloon ride with his family, and there are six of them. The balloon can carry ten people. Can everyone in Ben's family fit? Is there room for more people? If so, how many more?"

Ben drew this picture.

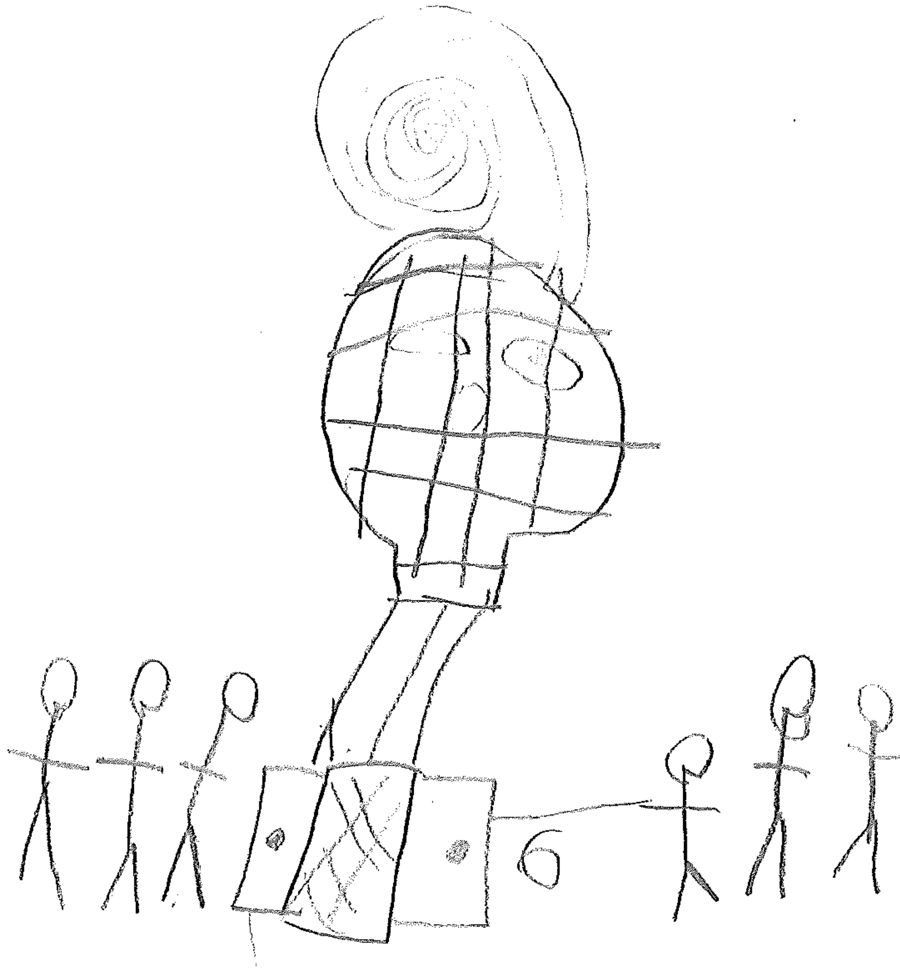


Figure 4.5 Storytelling Illustration Hot Air Balloon, Ben

Researcher: "I see six people at the balloon, but I don't know if they will all fit?"

Ben: "Well, here is the door, and they are all going to get in."

Researcher: "Are there any extra spaces? Remember the balloon can hold ten people."

Ben: "Hmmm I know it is four, but I don't know how to draw that."

Emily: "Here, look at my picture."

Figure 4.6 Storytelling Illustration Hot Air Balloon, Emily

Emily: "See? I am using the ten frame (be)cause I know there are ten spots. It is like the bus ten frame, but it is a balloon with ten seats. This is Ben's family (*She points to the smiley faces*). There are four empty boxes, so four more people can go".

Story problem illustrations were opportunities for students to think and talk about mathematics. Sharing the illustrations got students working together. They analyzed each other's images, and considered the mathematics of the story problem. Student attention was on the mathematics and on consulting each other.

On another occasion, Hazel asked for a story problem with her family in it. She explained her brother's birthday was coming up, and he would be ten.

Researcher: "Hazel's brother is having a birthday; he is ten years old. You have a cake and some candles. You only have five candles. How many more candles do you need?"

Hazel: "You got to get more candles (be)cause he won't like it if there is only five."

Isabella drew this picture (see Figure 4.7).

Figure 4.7 Storytelling Illustration Birthday Cake, Isabella

Hazel: "Hey that's not right. There are only four candles on the cake."

Isabella: "Well, there are five more see (*pointing to the tally marks*)."

Hazel: "That is only nine candles, and my brother is ten. You need one more here." *(She points to the cake*).

Hazel analyzed Isabella's work with precision and a concern for accuracy. The story problem mattered to Hazel because it was about her brother. The students were more engaged and invested in the story problems when they volunteered information for the subject and context. Student volunteered information made the story problems relevant.

I did not always use student input for story problems, but students were still engaged with story problems if I used familiar contexts and situations.

Researcher: "You have 15 stickers, and you have five friends. You give each person some stickers. How many stickers can you give each person so that they all get an equal amount of stickers?"

Hazel initially drew a picture with fifteen faces. She drew fifteen dots and drew a line from each dot to each face.

Researcher: "What story does your picture tell us about how to solve this problem?"

Hazel: "You have 15 stickers, and you give each person a sticker."

Ben: "You have five friends. You drew too many people."

Hazel: "Oh, and everybody gets the same amount."

Ben: "Yeah, so it's fair."

Hazel erased all the faces and redrew five more. She drew one dot across from each face "one, two, three, four, five." Then, she started at the top face and drew a second dot next to the first dot “six.” She repeats drawing the dots until each face has two dots. She has counted to ten. She goes back to the top face and draws a third dot “eleven.” She finishes with three dots across from each face. Then she drew a circle around the dots to create a set of three dots and then she drew another line from the set to each face.

Hazel: “Ok, each person gets three stickers.”

Ben: “Yeah, that’s right!”

Please note the Figure 4.8 is of Hazel’s final solution. You can still see the erased remnants of the first drawing under her final solution.

Figure 4.8 Storytelling Illustrations Partitive Division, Hazel

Story problems with familiar contexts and subjects encouraged students to create illustrations with detail. Emily drew this illustration for the problem: “You are going to the movies with five friends. You have four tickets. Do you have enough tickets? If not, how many more tickets do you need?”

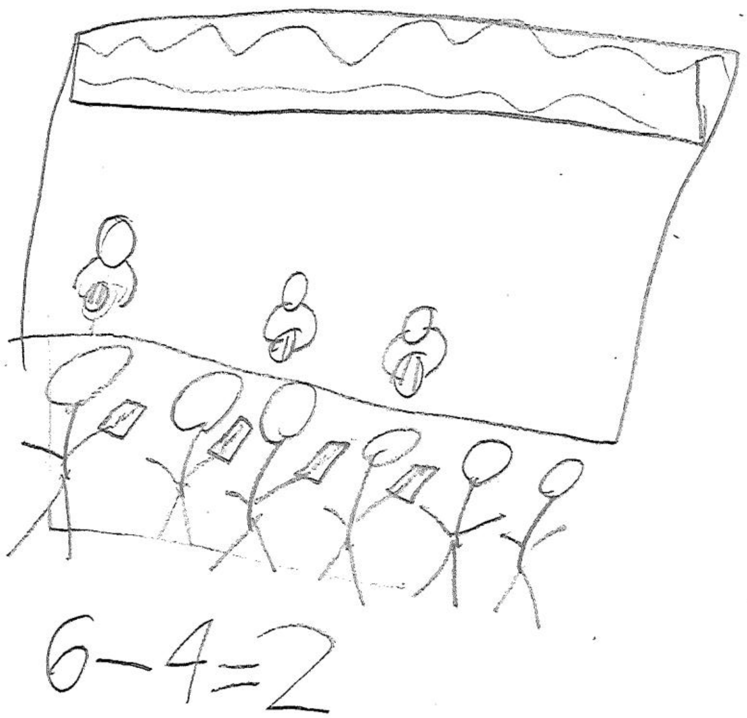


Figure 4.9 Storytelling Illustration Movie Theater, Emily

> **Emily:** “This is the place you buy tickets. These are the people who sell them. I drew six people, and four of them have tickets. You can see I need two more”.

If I didn’t include student input into the story problem, the students would add it themselves. Isabella drew an illustration for the problem: “Four people are going to the movies. Tickets cost five dollars each. How much will it cost for four people to go to the movies?”

> **Isabella:** This is me and (*she names three girls*). We are going to the movies. Each of us has a ticket. They are five dollars each…five, ten, fifteen, twenty. It costs twenty dollars, but we will need more money (be)cause, (you) see I got a pop, (name) has popcorn, and (name) has candy.

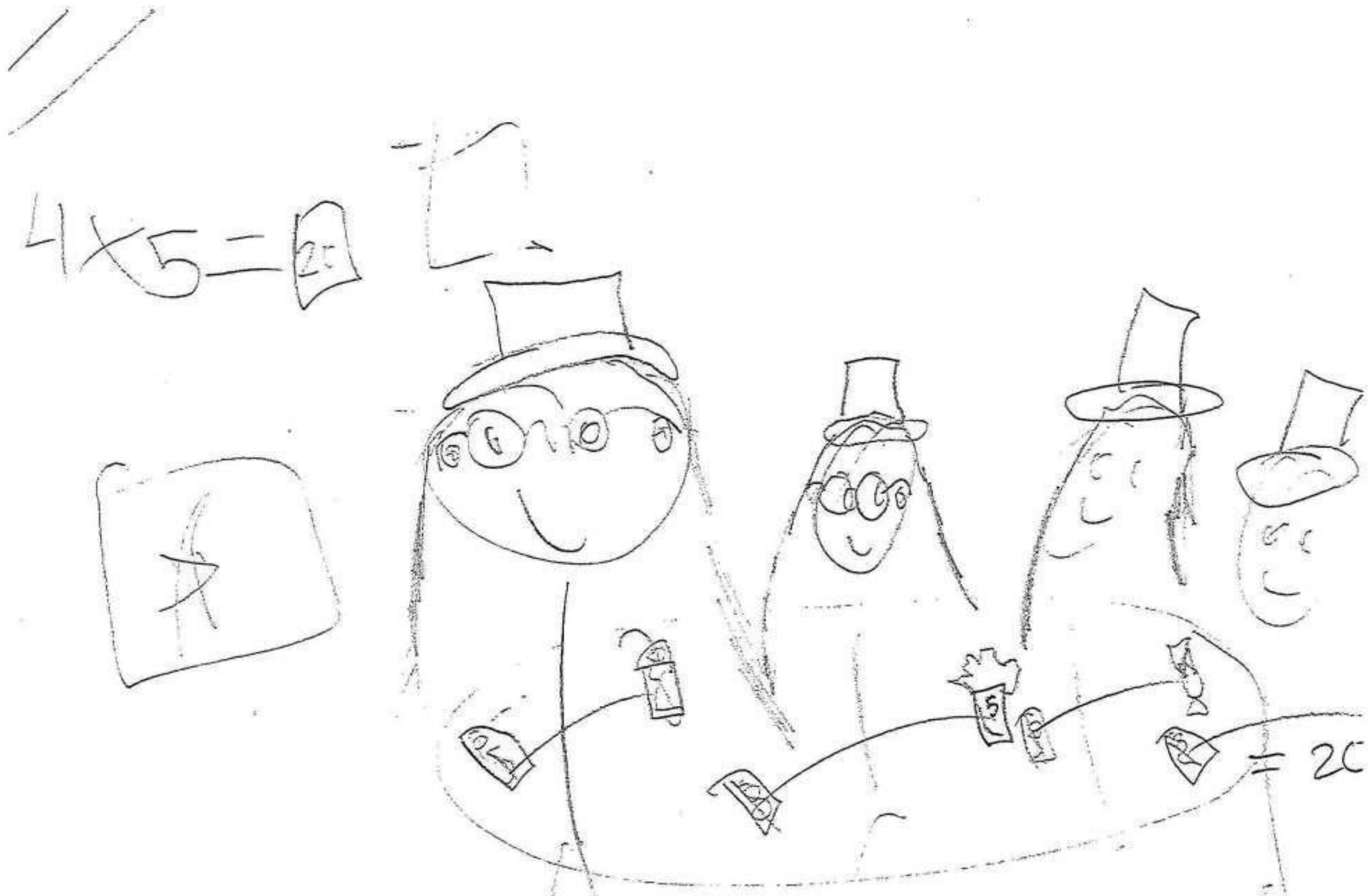


Figure 4.10 Storytelling Illustration Movie Theater, Isabella

Some students did not want to participate in the story problem illustrations. Jacob could answer all the initial addition and subtraction story problems mentally. He complained about having to draw a picture: “This is stupid” and “Ahhh I don’t want to.” Sometimes he would just write the equation for the story problem but then refuse to draw the picture. I would ask him to draw a picture that told the story of how he solved the problem. He said, “This is how I solved the problem.” In an effort to get him involved with the story problem illustrations, I challenged him with harder, more advanced problems. I thought if he had work with manipulatives or mathematical tools he might be more likely to draw an illustration of what he did.

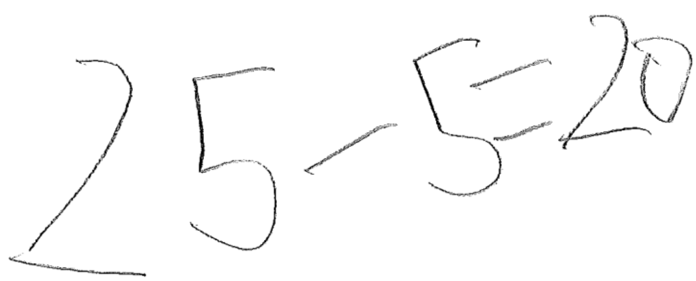


Figure 4.11 Storytelling Illustration 25-5=20, Jacob

I watched him solve this problem by counting back from 25, five times on a numeral roll, but he still would only write the equation. I suggested he draw the numeral roll and show counting back as an illustration telling the story of the problem. He just shook his head no. The only illustrations I could get him to draw were for multiplication. When asked to explain his work, he said, “This is four groups of five and that makes 20.”

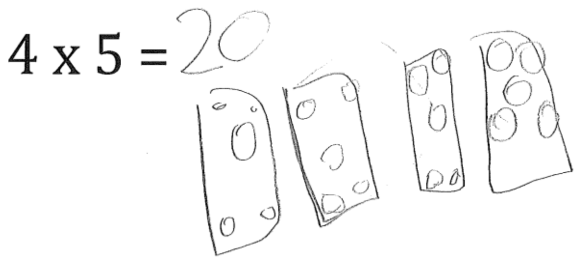


Figure 4.12 Storytelling Illustration 4 x 5 = 20, Jacob

Jacob could explain his mathematical thinking.

> **Researcher:** “What are double eights?”
>
> **Jacob:** “Sixteen”
>
> **Researcher:** “Why?” (*Jacob sat still and looked across the table.)*
>
> **Jacob:** “Can I use that”(*he pointed to a bead frame. He picked up the frame and created this pattern).*

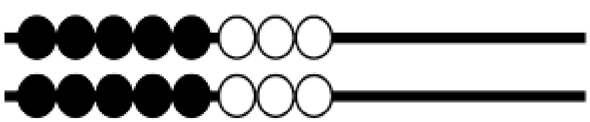


Figure 4.13 Double Eights Beadframe, Jacob

> **Jacob:** “This is sixteen because this is ten *(pointing to the five black beads on top and the five black beads on the bottom),* and this is six, (*pointing to the three white beads on top and the three white beads on the bottom),* and ten and six is sixteen”.

In a separate activity Jacob showed he could explain how he solved addition equations with manipulatives in this example.

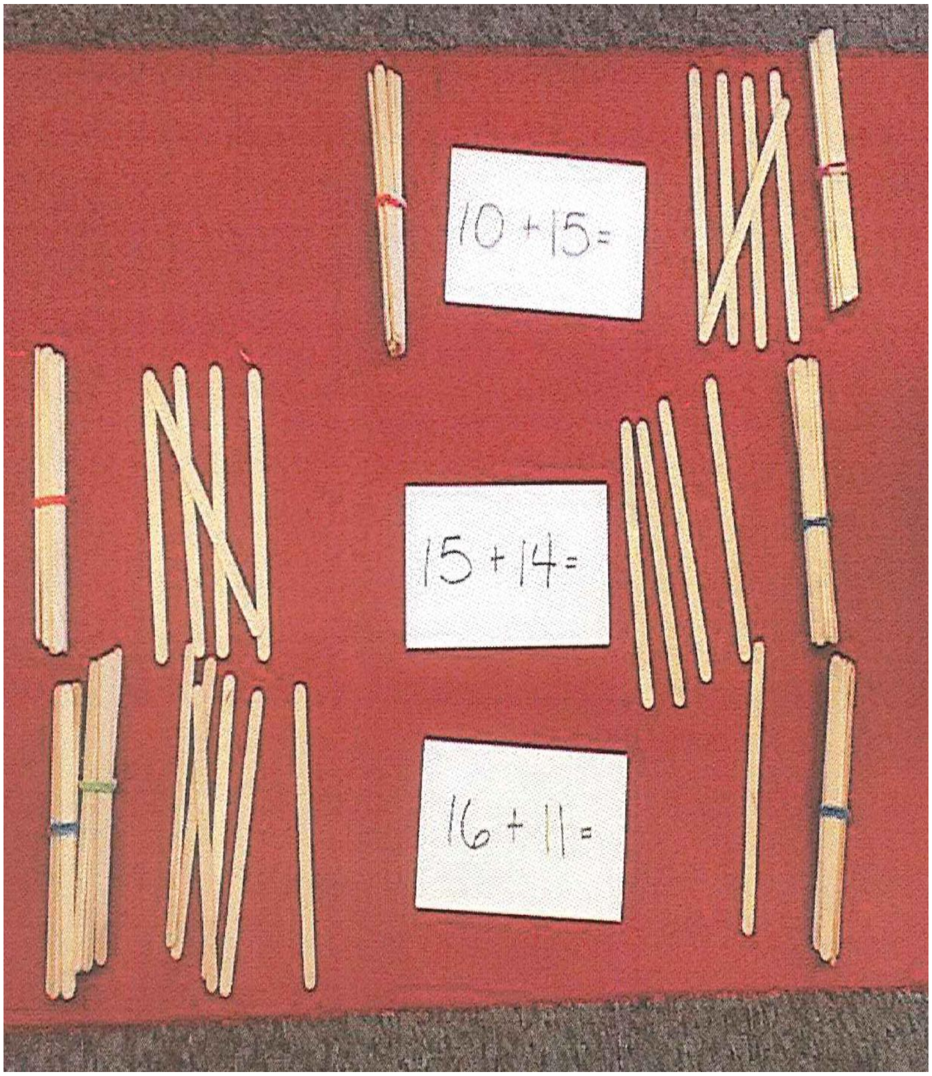


Figure 4.14 Tens and Ones Addition, Jacob

Jacob moved the two bundles of ten together on the left side: "This is ten, twenty." He pointed to the five single sticks arranged as a tally mark set of five. "Five more is twenty five. Ten and fifteen is twenty five." When he finished he moved the bundles back to their original locations.

He then moved on to the next problem. He moved the two bundles of ten together on the left side: "ten, twenty." He pointed to the tally mark set of five on the left side: "five more is twenty-five". Then he pointed to the singles: "Twenty-six, twenty-seven, twenty-eight, twenty-nine. Fifteen and fourteen are twenty-nine." He moved the sticks back to their original locations making sure the set of single sticks in the tally mark set of five were correctly aligned.

As seen in these two examples, Jacob would explain his thinking when solving problems in certain situations. I wondered if Jacob just didn't like drawing. When I asked Jacob if he liked drawing he said "yes". I then asked him why he didn't want to draw mathematics drawings. He said "(be)cause it is stupid. I don't need to draw when I can do the problem anyway". I asked his teacher, and she informed me that Jacob was an excellent artist and would spend lots of time drawing for other class activities. I had to conclude that Jacob just didn't want to draw illustrations of mathematics solutions. I suspect he didn't see storytelling illustrations as useful for solving mathematical problems. It should also be noted, that Jacob did these more challenging activities alone. Jacob was very critical of himself and others. I suspect that he did not want other students commenting on his drawings. Furthermore, I did notice Jacob resisted activities he thought pointless. He often complained about memorization or skill building activities. He said they were "boring." Hazel, Ben, Emily, and Isabella were very involved with the story problems. Emily and Isabella drew detailed illustrations about the mathematics and included additional contextual details. Ben and Hazel were interested in using relevant stories for mathematics word problems. Jacob resisted drawing illustrations for storytelling word problem solutions. Hazel and Emily watched attentively during teacher *self-talk,* and perhaps they were learning. Patterns in learning style preference for the storytelling illustration work was observed, where all but one student actively participated. Jacob was the exception and could be considered an outlier. However, it should be noted the study sample was very small (6), and reliable conclusions cannot be made from such a small sample size.

Math Recovery. All study participants were assessed with the Math Recovery Intervention interview assessments before the study activities began. Initial assessments revealed the participants had a range of scores. Assessment information is used to understand their mathematical thinking and design individualized instruction and activities to stimulate new learning and extend student knowledge. Caution must be exercised to avoid overwhelming and discouraging the learner (US Math Recovery Council, 2010a). The intervention was modified with Indigenous ways of knowing and being in the following cultural modifications, replacement of competitive games with non-competitive and cooperative activities, the addition of opportunities for non-verbal participation, opportunities for student self-direction and choice, and peer-learning opportunities like expert novice pairing. Cultural activities such as storytelling and beading were also included so students could participate in Native culture based activities.

Table 4.1 Initial Math Recovery Interview Assessment Scores

Student	FNWS	BNWS	Numeral ID	add & sub. strategies	Structuring #'s 1-20
Jacob	5	5	3	2	1
Emily	5	4	1	3	1
Ben	5	3	3	1	2
Isabella	4	3	2	1	1
Hazel	1	3	1	1	0
Jennifer	1	2	0	0	0

Math Recovery is implemented in two formats: individual pull out sessions with a Math Recovery Intervention Specialist and the Add+Vantage Math Recovery classroom version. I chose Add + Vantage Math Recovery for several reasons. First, it is structured for groups of students and avoided activities where students compete against adults. The collective aspect of Add + Vantage Math Recovery also allowed me to reduce the amount of adult direct questioning of students. Another reason I chose Add+Vantage Math Recovery instead of the Math Recovery Intervention Specialist program is that the specialist program is very resource intensive, requiring 20 hours of one on one tutoring per student. The resource intensive nature of the pull out program makes it impractical and less likely to be implemented in schools.

All study participants made gains as measured by Math Recovery interview assessments.

Table 4.2 Post Math Recovery Intervention Interview Assessment scores

Student	FNWS	BNWS	Numeral ID	add & sub. strategies	Structuring #'s 1-20	10's & 1's
Successful Discontinuation Recommendation Scores	5	5	4	3	2	1
Isabella	5	5	4	4	3	2
Jacob	5	5	4	4	3	2
Emily	5	5	4	4	3	2
Ben	5	5	4	4	3	2
Hazel	4	3	1	2	2	1b
Jennifer	3	3	1	1	1	1a

Isabella, Jacob, Emily, and Ben scored in the Math Recovery "successful discontinuation recommendation" range (USMRC 2010a, p. 78). While Hazel and Jennifer improved, they did not score high enough to be considered for successful discontinuation. Hazel scored low in the Math Recovery interview assessment for numeral identification. She said incorrect names for several numerals in the interview assessment (e.g., for the numerals 13, 17, 99). At times she would say the single digit names for each digit in a two-digit number. For example, she might say "3, 5" for thirty-five. This is in contrast to her ability displayed in performance of classroom activities. Hazel was able to sort two digit numerals into *number families* (see Figure 4.15). She sorted all two-digit numbers in the correct category based on decade. For example, 24 is in the twenty *number family*. Hazel was also able to name all the numerals correctly. She could also explain why she sorted the two digit numbers into certain categories. For example, Hazel held a card with 27 on it and said "this goes in the twenty family. The first number tells you what family. This is a two. It is in the twenty family, so it will say twenty. This is twenty-seven."

1 ones	**10** teen	**20** twenty	**30** thirty	**40** forty	**50** fifty	**60** sixty	**70** seventy	**80** eighty	**90** ninety
3	14	21	39	41	57	68	73	84	95
5	19	26	30	49	52	65	76	81	97
8	17	23	33	44	58	62	77	88	92

Figure 4.15 Number Families Activity

Hazel could also organize numerals in the correct sequence for any number 1 to 100. She could correctly sort and name all numeral cards in the teens/not teens activity (see Figure 4.16). In this activity, the student sorts through numeral cards finding numerals 10 to 19. In the lesson, the researcher explains:

> Two digit numbers that start with one are in the *teens family* and sometimes say teen in their name, like fourteen and seventeen. Teen numbers are tricky because they do not always say *teen* in their name. For example, 11 looks like it should be said "oneteen" but it says eleven.

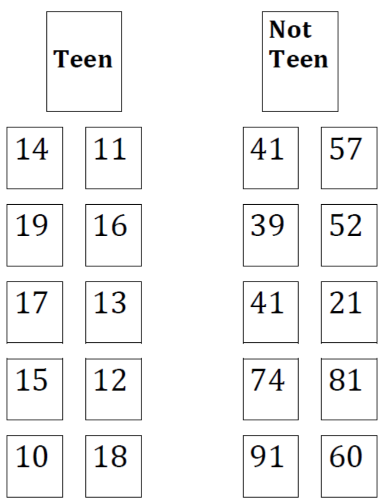


Figure 4.16 Teens/Not Teens Activity

Hazel could accurately sort teen numbers from the other numbers and correctly identify teen numbers. Hazel could also point to any numeral when asked in the range of 1 to 100. She could also tell you what any two-digit number looked like. For example, "Hazel what does 47 look like?" She would reply "a 4 and a 7. The four is in front and then seven." Despite being able to correctly complete these activities, she missed 13, 17, and 99 in the interview assessment. I don't know why Hazel missed the numeral identification questions on the interview, but she definitely showed she could identify numerals from 1 to 100 in classroom activities. These observations make me question whether single event assessments accurately capture student knowledge and skill.

Jennifer's assessment score also did not qualify for successful discontinuation. She had very low mathematical knowledge and skill when the study started. She made gains in the Math Recovery post-assessment, but she still scored low. Jennifer worked for weeks on numeral identification for numerals 1 to 10. She practiced identifying and creating quantities in a variety of activities. Yet, she was still not able to accurately identify numerals 1 to 10 by the end of the semester. The classroom teacher also noticed that Jennifer's lack of academic progress occurred in all content areas, and she has been referred for further evaluation. Ms. Walker reported that in parent teacher conferences the mother conveyed a high degree of tension and disappointment with Jennifer. An older sibling was gifted academically, and they believed Jennifer was just not trying hard enough. Ms. Walker assured her that she was trying but something was impeding Jennifer's learning. She stressed the need for more information about what is happening with Jennifer's learning before any conclusions can be made.

Native Number. Native Number (Native Brain, 2014) is an iPad app I made available to study students to further diversify cognitive pluralism. The name of the product is meant to imply mathematical learning is innate in all people and thus native (Native Brain, 2014). The product name is not meant to imply any connection to Native Americans. Native Number is designed to develop number sense in young children approximately kindergarten age. Their website describes the program as an adaptive, mastery-based Number Sense curriculum delivered in the form of an iPad app. It is designed for individual users and each user gets an account. Native Number adapts to the users enabling learners to move quickly through material they already understand and to spend as much time as they need to develop emerging concepts and skills. The app is self-correcting and is designed to increase in difficulty as the learner progresses. If a student gives incorrect responses the app is designed to decrease in difficulty. The app has short visual demonstrations of how to solve tasks. Native Number assesses student fluency and keeps track of how long it takes students to solve a task. A progress bar grows longer for fast and correct answers. The bar shortens for slow or incorrect answers. The app uses bright colors, images of animals, and this design is intended to be intrinsically motivating. The app includes both audio and visual instructions. Students respond by touching and dragging images across the screen.

Native Number is mastery-based which means that a learner has to demonstrate a minimum level of competency on each concept or skill before being exposed to more complex activities that depend upon that understanding (See Appendix 4.B Student Subskills Summary Matrix). The curriculum contains twenty-five activities that are organized into five subskills. These subskills are based on the number sense research from the Common Core State Standards and National Council of Teachers of Mathematics Standards. The subskills are:

- Number Concepts: Connect number words and numerals to the quantities they represent
- Number Relations: Develop a sense of whole numbers and their relations, across different representations
- Number Ordering: Understand relative position and magnitude of whole numbers
- Counting: Understand ordinal and cardinal numbers and their connections

- Count with understanding and recognize “how many” in sets of objects (Native Brain, 2013 para. 2)

A key feature of the app is the dashboard. This feature allows a teacher to keep track of each student. The dashboard keeps track of student attempts, successes and wrong answers. The app keeps track of time elapsed from last use for each student but not overall total time of use by each student. I had one iPad per study participant. Students could choose and sometimes were assigned the iPad app during the mathematics time block. Initial interest in the technology was quite high but waned as the time passed. Jacob was very interested in the app and completed the entire program first. By the end of the semester four students finished the entire program and two students did not. Hazel and Jennifer did not complete the program during data collection (one semester), and were also the same two students that did not meet the successful termination scores for Math Recovery. Students with high Math Recovery assessments scores completed the Native Number program. The higher the Math Recovery scores the fewer attempts were needed to complete Native Number tasks. The two students who did not complete the program had the lowest Math Recovery scores. In addition, these students made many more attempts with fewer completed topics. See Tables 4.3 and 4.4 for a detailed summary of attempts by category.

Table 4.3 Native Number Summary

Student	Attempts	Topics completed
Jacob	1240	25
Ben	1500	25
Emily	1980	25
Isabella	2410	25
Hazel	3510	11
Jennifer	2210	9

Table 4.4 Math Recovery Scores

Student	**Math Recovery Initial total score**	**Math Recovery post-MR intervention total score**
Jacob	16	23
Emily	14	23
Ben	14	23
Isabella	11	23
Hazel	6	13
Jennifer	3	10

Observations of the students using Native Number revealed that some students could not work independently on the tasks. They were not successful with certain tasks even with direct researcher support. The greatest challenges centered around decontextualized academic language. Some students didn't recognize greater, longer, lighter when looking only at a numeral or number set. On one occasion Hazel was really struggling with one of these tasks. I asked her what "greater" meant? She said "better". She went on to explain that she did not know which was *better,* a card with five birds on it or a card with seven fish. We talked about how in this problem the term *greater* meant *more*. I rephrased the question as "Which card had more?" We discussed some other examples, but she continued to miss this type of question.

Students also struggled with tasks with multiple layers of abstraction. For example, the app showed a numeral seven on a card and a card with nine bears. The app would say "longer". Students were to touch the card that was longer. Emily said, "I don't know. They are both the same size". In order to solve this task, the student must understand that the question assumes that the numerals represented quantities as measurements; seven means seven equal measurement units set end to end to represent a total length. Assuming the same equal measurement units are used for both cards, then nine units set end to end are longer than seven of the units. Similar confusion occurred when asked which is lighter; students were shown two cards, one with a numeral and one with a set of objects. In both circumstances students needed direct instruction and support from the researcher. The adaptable features of the app, included app generated demonstrations of solutions, but this did not increase student understanding with these tasks for some students. In fact, some students would start poking at any graphic on the screen, attempting to guess at the right answer. Even with direct instruction from the researcher the students repeatedly answered these tasks incorrectly. The study students were able to measure and solve first grade measurement problems with direct modeling, but they still struggled with the app.

Measurement skills and knowledge did not transfer to solving Native Number app tasks and it was not a good use of instructional time to teach students so they could simply be successful with the app.

Students did not have experience with the academic vocabulary and the abstract context. The app used decontextualized academic language and this created situations in which students could not make sense of the task. I communicated with Native Number staff, and they suggested giving direct instruction on the vocabulary. Early childhood learners need hands-on concrete experiences before proceeding to abstract problem solving (Piaget, 1974). Children need to measure objects, see, feel and experience concepts of longer, shorter, heavier, and lighter. They need to understand that measurement involves multiple units of equal size. Young learners must experience aspects of measurement and learn the vocabulary in real contexts before they can make sense of abstract, decontextualized tasks as presented in Native Number. The app does not provide young students concrete experiences in measurement. The app measurement tasks were abstract and I observed some of the study students struggled with this level of abstraction.

Another section asks students to drag numerals, number sets, rods into a sequence from largest to smallest. To respond correctly the student had to line up items from left to right, so the large numbers appeared on the left and small numbers on the right in decreasing order. Ben lined up items from right to left, “I got them largest to smallest but I’m wrong. I don’t get it”. He held his finger over the sequenced items and moved it across from right to left. It could be argued that the left to right sequence is an academic assumption developed from reading text but young children are novice readers in first grade, so it is not reasonable they would know the left to right sequence. The left to right assumption caused Ben to be confused and not able to complete the task even though he was able to correctly sequence numerals. I believe this task measures a student's ability to sequence numerals and not whether they do so left to right. I think this is an unintended complication to the app task.

Student presence: Physically and emotionally ready to learn. All student learning depended on student presence. Students need to be both physically and mentally present. Student absences negatively impacted learning opportunities and retention of skills. Students who were distracted by stress or wellness issues had negatively impacted learning (NIEER, 2004). Ben was having an "off" day. Most days he was an engaged and enthusiastic learner. Ben was very verbal and often talked globally connecting a variety of topics. However, on this day he stared off into space during activities. His conversations were scattered. He had difficulty solving mathematical tasks he had previously mastered. Jacob noticed and said, "Are you ok? You look funny." Ben "I'm fine but my mom got me up too early this morning." The next day Ben started shaking uncontrollably. He had a very high fever and spent a week home from school. After he recovered from this illness, Ben returned and did not display these types of symptoms again for the rest of the school year. On another occasion, Jacob was not able to solve subtraction tasks that he easily solved the day before. He sat with slumped shoulders. He frowned and looked dejected. He angered quickly and just kept saying "I don't get it!" After the lesson I took Jacob aside and asked him if he was ok. Jacob said "yes". I continued "did something happen? You look unhappy". Jacob told me no one came to eat with him at the school family Thanksgiving lunch. I asked him how he felt about that and he dropped his head down with a frown on his face. He did not answer. After this interaction I offered him the beading loom, which he accepted. I wanted to give him the opportunity to engage in a mathematical task he was skilled at and really enjoyed.

Later, I learned from Ms. Walker that his family wanted to come but could not afford to pay. It is clear that his personal stresses were influencing his presence and influencing his learning.

Hazel was often absent and tardy to school. Being frequently absent and tardy impacted Hazel's learning. At the close of the study, she had missed over 20 days of school. Ms. Walker communicated with the family, and they reported the mother had been ill. Hazel had to stay home to care for her younger siblings. Hazel's father was working out of state and their extended family lived hours away on the reservation. The family did not have any other resources to care for Hazel's younger siblings. Day care transportation issues caused Hazel to be tardy and after a couple weeks the problem was identified and remedied. Unfortunately, these events reduced her opportunities to participate and learn. High rates of absenteeism are common challenges reported in Native education literature and in study district reports (Chapman et al., 2011) [5]. Day–to–day family and tribal responsibilities of even very young Native students pose challenges that educators and educational systems must acknowledge and strategize to facilitate learning among Native students. Ms. Walker communicated regularly with families, and this relationship helped inform her about what was happening Hazel. Ms. Walker worked to help the family strategize and find resources to cope with these issues like alternative transportation, tutoring, and summer school. This observation leads me to ask, how do we as educators facilitate ongoing, enduring learning within the parameters of Indigenous life and responsibilities?

Emotional stress can affect students' ability to be present and ready to learn. Isabella, Hazel, and Iris experienced disruptions to their family life with frequent cycles of leaving

[5] The school district American Indian study cannot be cited due to confidentiality necessary to the study.

and returning family members. They also experienced changes in residence and custody. During these events students were often emotional, tired and easily frustrated. Stressful events outside of school negatively impacted academic skill and the ability to persist in cognitively challenging work. This is why I recommend nurturing classroom cultures where students get their emotional and physical needs addressed.

Native Learning Styles

I incorporated Native learning styles into the collaborative mathematics activities. I provided opportunities for students to be self-directed in activity choice and whether they wanted to work alone, in pairs, small groups, or with myself. I included storytelling illustrations to support field-dependent learners. I implemented strategies to reduce verbal dominance and challenging discourse. I expected the study participants would behave in ways consistent with Native learning styles. What I observed was behavior that confirmed as well as challenged Native learning style research. Study participants were given both verbal and non-verbal opportunities to respond to questioning. Hazel consistently chose non-verbal responses over a verbal response. For example, when asked, "what two numbers go together to make five?" Hazel would hold up two fingers on one hand and three on the other. She would often silently show answers with manipulatives. For example, Hazel would answer 10 minus five by creating a collection of ten and taking five away. She would say the answer was five but you had to ask her "so ten minus five is that?...what is that?" Hazel would say "five". Hazel did talk but was usually watchful and quiet during group activities.

In contrast, Jacob consistently responded verbally. He dominated conversations and would even respond quickly to questions poised to other students. For example, three students were working on ten plus activities with the researcher. The group was shown a numeral on a card and they were to solve what ten plus that number was. Each student had a 100's chart and two opaque bingo counters. Students placed the first counter on the starting number, then figure out what number was ten more, and place the second counter on the total of ten plus that number. Jacob completed the task first and shouted out the answer. He did this several times. I responded in a variety of ways including acknowledging his response, trying to call on other students first, and asking him to give others a chance to respond. These strategies did not stop Jacob from blurting out answers. Jacob was competitive and impatient. He would often sigh, frown, drop his face into his hands, and said, "Come on!" when waiting for other students to solve tasks. Jacob did like to work with a partner but only with students he perceived as intellectual peers. Jacob explained, "I want to work with Emily (be)cause she is smart." Jacob also complained that he didn't want to work with different students because he perceived them as "not smart" or not able to complete the task. Jacob did not volunteer to help academically struggling students and would complain if asked to do so. Jacob also complained when he thought other students were copying his work. Jacob displayed behaviors that were field-independent. He was task oriented, competitive, and wanted recognition for his own achievements. He was motivated by competition and avoided being seen as not knowing.

Field-independent learners are analytical and like sequencing activities (Pewewardy, 2002). Jacob was actively engaged in analyzing and sequencing activities. He was working on an activity making rods with two colors of linking cubes. The completed rods represented two quantities that add up to ten. He had three rods composed of five blue cubes and five white cubes, then 6 (blue) and 4 (white), and 3 (blue) and 7 (white).

Researcher: "I see you are making the tens. (That) looks good. Push them together and tell me what you see?"

Jacob: "(*pushes all the rods together side by side. He stares at it).* 'oh…hey'. (*He moves the six and four next to the five and five. Then he puts 7 and 3 next to four and six).* 'look, it is like going up"

Researcher: yes, it looks like stairs?

Jacob: yeah!

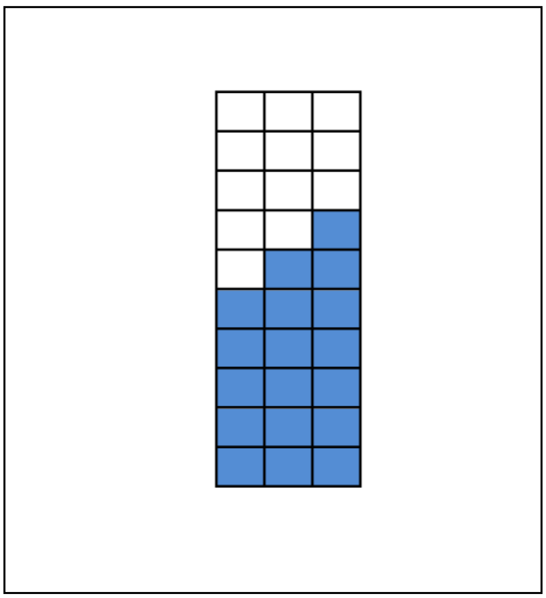


Figure 4.17 Partitions of Ten with Linking Cubes Activity Example One

Jacob complained about activities designed for memorization or fluency development, but he showed greater interest to memorization when he understood how the skill could be used for practical applications.

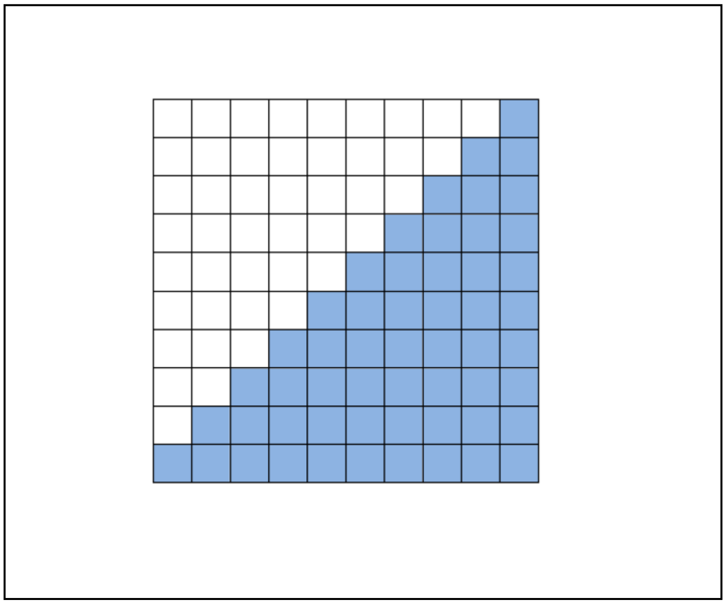


Figure 4.18 Partitions of Ten with Linking Cubes Example Two

Researcher: "What do all the rods remind you of?"

(Jacob shrugs)

Researcher: "Think what are you working on that has row of tens in it?'

(Jacob looks to the shelf). "The beads?"

Researcher: "Go get it"

(Jacob gets his bead loom. It had an alternating pattern of colors five black and five white).

Researcher: "Which rod is like your pattern?"

(Jacob picks up the five and five rod).

Researcher: "Yes, now if you flip it over, it matches the second row of beads."

Jacob: "Cool"

(Researcher points to the rods): "See how you made the pattern go up? You can make that with your beads".

Jacob: “Hmmm I don’t want to do that yet. I want to finish this.” (*Pointing to his bead loom).*

Researcher: “That’s fine I am just letting you know that you can use the cubes to design your bead patterns”.

Jacob was also interested in connecting skills with mathematical practice. I was introducing multiplication and explaining its relationship to skip counting. (See Figure 4.19.)

Researcher: (*I wrote 3 x 5 =)* “The first number tells you how many groups you have and the second number tells you how many are in each group”.

Researcher arranged counters on paper plates

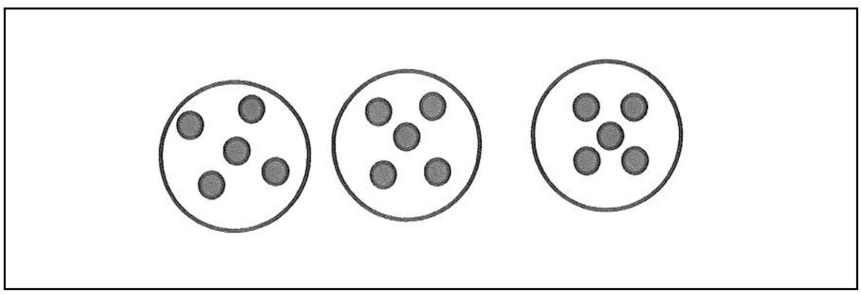


Figure 4.19 Three Groups of Five, Multiplication

Researcher: “There are three groups and there are five counters in each group. So that is five, ten, fifteen; so three times five is fifteen”.

Jacob: *He stands up. His eyes are open wide.* “oh!!! That’s why you have been making us skip count. I thought all that counting was dumb.”

Hazel liked mentoring other students. She was patient with struggling students. She volunteered to work with students on topics she had mastered, like sorting numerals by *number families*. She did not like to work with students she viewed as “bossy.” Hazel and

Isabella would often argue when working together. Hazel would complain that she didn't want to work with Isabella because she "keeps telling me what to do." Hazel was also discouraged by challenge. She struggled with the mathematics app Native Number. When Hazel got tasks wrong repeatedly, she stopped using the iPad. She would return or continue with the app when directed to do so, but was still unable to make progress. For example, Hazel left the app after a couple of minutes of trying unsuccessfully. I asked her to try again. She returned to the iPad but after a few minutes, she was in tears. I sat down with her and asked what was going on. Hazel said, "It took it away." I asked her to try again, and I told her I would watch to see what was going on. Hazel was answering the questions very slowly and incorrectly; as a result, the fluency progress bar shortened. After several wrong answers, some of the progress stars disappeared from the screen. At this point, she dropped her head, frowned, rubbed her eyes, and began to cry. "See! It took it away," I sat with Hazel and tried to help her while she did the app tasks but as she made repeated mistakes, she frowned, slumped over, and looked dejected. She made sounds like "ahhh," "tsss," and "nooooo!" It was obvious she was getting frustrated. The more mistakes she made, the more frustrated she became. This scene repeated itself over the next few days. Hazel's behavior demonstrates how affective factors impact learning. The more upset she was the worse she did. I also discuss Native cultural views on the role of punishment in learning contexts.

The Native Numbers app diversified cognitive pluralism. I could not tell if and how much students benefitted from its use because the students who were most successful had the greatest degree of skills. I suspect Jacob, Ben, Emily, Isabella would have been successful without the app. Hazel and Jennifer were not very successful with the app and their mathematics skills were definitely lower than the other study student. The main issue with

Native Number is that the app does not accurately target student's zone of proximal development. The app does not take into account the knowledge and cultural means students bring with them to the activity. While the app has a self-correction feature, it does not respond to student issues with decontexualized academic language and multiple layers of assumptions. The tasks are field independent and did not supply enough context or familiar vocabulary for some of the study students to be successful.

Students appeared to enjoy using the Native Number iPad app. It did provide an alternative opportunity to develop and practice mathematical skills. The app is designed for kindergarteners and the study participants were first graders. I was disappointed with the results of Native Number because the students who needed the most support in the development of number sense got stuck and could not progress. They also could not use the app independently. These students did not understand some of the tasks and, despite repeated attempts, could not complete the tasks even with teacher assistance. As a result, they did not finish the program and were not exposed to the full range of number sense activities. The app itself is fairly inexpensive, and the data collection system comes with the app software. However, Native Number can only be used on an iPad and purchasing that equipment can be expensive.

Culturally relevant activities. Culturally relevant activities are not part of the Math Recovery intervention. I added these activities because culturally relevant activities increase Native student engagement and support Native student learning (Lipka et al., 2005; Nelson-Barber & Trumbull, 1995). I provided three types of culturally relevant activities; two were introduced by design and one happened spontaneously. The culturally relevant activity that happened spontaneously was discussed in earlier in this chapter in the section titled, *Storytelling Illustrations*. The two culturally relevant planned activities were *hand talk* and Native American loom beading.

Creating objects with beads is an art form used by numerous Native American cultures. Beadwork is used to decorate clothing and ceremonial objects, and even record history (Klinkenborg, 1992). I made simple looms out of boxes and string. I started by showing the students how to weave and sew the beads onto the loom. The first goal was to get the students to correctly weave the beads onto the loom. The second goal was to have students correctly count out and sew on the correct number of beads. The third goal was to start students weaving in simple patterns onto the loom. For example, I used alternating rows of five white and five black beads for the first pattern. Lastly, students worked with linking cubes and graph paper to create a design and weave it with beads onto the loom. The design aspect of the activity supported students learning the partitions of numbers. In the activity they were working with partitions of 8, 10, and 12. For example, partitions of eight are (8 and 0), (7 and 1), (6 and 2), (5 and 3), and so on. Whole numbers are partitioned into whole number combinations. This is not to be confused with fractions. Fractions are partitions of a whole number but fractions are not whole numbers. First grade students are learning about whole numbers. Fractions are typically a mathematical topic for older children. It should also be noted that beading is widely practiced in Native societies, but it is most commonly practiced by American Indian tribes from the plains region of the U.S. (Klinkenborg, 1992).

All study participants worked on the looms with greater and lesser degrees of success. The bead loom activity was very popular. Hazel talked about how her relatives beaded. Ben talked about using his beadwork in his pow-wow outfit. Jacob talked about how his family had beaded things, and he wanted to use the bead loom to make presents for them. Initially, all the participants wanted to work on the looms. Interest waned in the looms after a couple of months, but participants still asked to use them every day of the semester long study. Working with the looms was educational because students were working with whole number partitions of ten and designing patterns however, I still had to make sure the students continued to work with a range of mathematics activities.

Jacob had the greatest interest and skill with the bead loom. He completed several projects and also mastered all the learning goals. He was the only student who could consistently bead without getting tangled or have missing or extra beads. He also was able to design patterns and execute them. In his final project that was completed during the study, he spelled his name in the beads. Given the opportunity, Jacob would bead every mathematics period, all period. Eventually, I used the beading loom as a reward. Jacob thought activities that built mathematical fluency or helped memorize mathematics facts were boring, so I made a deal with him. Every day he had to complete a certain amount of other mathematics work before using the loom. This was a very successful strategy in a number of ways. First, the bead loom motivated Jacob to build his mathematical fluency and memorize facts. Second, the beading activity gave him opportunities to be focused and accomplish a difficult task. In addition, beadwork gave Jacob a chance to gain skill in a culturally recognized art form. Most importantly, Jacob took great pride in creating beaded things to give to his family. I ran into his father once, and he commented on how pleased he was with his son’s beadwork. Incorporating a wide variety of learning activities creates diverse opportunities (cognitive pluralism) for different kinds of learners. Variety supports a range of student interests, strengths, cultural and other identities and motivations.

I implemented a system of hand signals in collaborative mathematics activities because it has cultural relevance to Native students. Native people have a history of using sign language. Unlike American Sign Language, this system was designed for inter-tribal communication rather than an alternative form of communication for deaf people (Davis, 2010). Davis (2010) describes Native sign language as *hand talk* and reports this form of communication is still in use. I used hand signals in two different ways. The first aim was for students to indicate if they agreed or disagreed with others including the teacher. For example, if there was a question about an answer or solution, students would hold out their hand with thumb up for agreement, thumbs down for disagreement and thumb horizontally meant "I don't know". The second aim for hand signals was for managing turn taking. If the students were asked a question in a group activity, they could use hand signals to indicate their response. Thumb up meant "I need help" thumb down meant "I don't need help and I will do it myself," and thumb horizontal meant "please wait, I am thinking." The hand signal system supported non-verbal communication, increased wait time, and is a communication system in many indigenous contexts. The study student quickly adopted hand signals. The discussion on hand signals is continued in the next section on collaborative learning.

Collaborative Learning

Indigenous education research reports a preference for cooperative learning among Native students. I implemented numerous opportunities in the study for collaborative learning. All of the study students would work collaboratively when asked but the frequency that the students chose collaborative-learning activities varied. Implementing collaborative learning proved to be very complex. Student preference for this type of learning did not mean students knew how to work together. Initial student attempts at playing games revealed a host of problematic issues. First, some students did not know how to or were unwilling to give and take turns. I observed Hazel and Isabella arguing. Hazel complained that, “she won’t let me go (take a turn)”and Isabella responded: “I am helping her.” Hazel asserted: “I can (do it).” At this point we had a discussion about what it means to help someone at school. I said “to help someone at school I am asking you to give them hints or suggestions so they can do it themselves. I don’t want you to do it for them.”

Add+Vantage Math Recovery frequently uses competitive games. I changed all the games to be non-competitive to be more closely aligned to Native student learning styles. Some students liked and followed the non-competitive rules, and some students reverted to the competitive rules for games which they had previous experience with. For example, I changed the rules for dominos. Instead of individual piles of dominos positioned so only the player could see, students drew new pieces from a face up communal pile. Next, I changed the goal of the game. I redefined the game rules. So instead of having the first person to match all their dominos win, I told students that the game ends only when every domino is matched and then all players would be winners. Students took turns, but they were encouraged to help get all the domino pieces matched. Jennifer, Hazel, Emily, and Ben followed the non-competitive rules. They were focused and matched all the pieces. They also did not have conflicts. This was not the case for Jacob and Isabella. They started with individual draw piles that were hidden from their opponent. I tried to redirect them with the non-competitive rules, but Jacob said, “I don’t get it. How are you supposed to win?” I answered, “You both win when you match all the pieces.” Both students looked at me and frowned. Jacob responded: “that sucks.” This is a example of students demonstrating heterogeneous preferences.

Learning cooperatively was also complex. I employed a number of different strategies to engage student participation and attention. First, I conducted lessons in small sub-groups based on ability. Two or three students with similar skill and conceptual knowledge were selected for a specific lesson that targeted their zone of proximal development. This activity was a form of peer matching. For example, I chose Jacob and Ben for a lesson on addition with ten frames. Both students were familiar with ten frames, five plus quantities, and partitions of ten. The lesson went smoothly with both students actively exploring, constructing solutions, and identifying strategies.

I used hand signals as a culturally based means for students to use in cooperative mathematics activities to reduce verbal communication. I also used hand signals to increase student engagement and manage student participation. I used hand signals to reduce verbal communication, increase student engagement and manage student participation. Study students used hand signals immediately upon introduction. For example, we practiced skip counting in an activity called a *count around*. I would start a counting sequence, and the students would respond one at a time in sequence. A clock-wise rotation was used for forward counting sequences and counter-clockwise for backward counting sequences. To accommodate different ability levels, the instructor would include a variety of sequences. For example, a beginning level sequence would consist of counting by ones forward. A more challenging sequence might be to count backwards by ones. Counting with different types of forward and backward skip counting sequences could be used to further challenge students. The hand signals gave everyone in the group a chance to participate no matter how difficult. If the task was easy, students paid attention to each other to determine if the given response was correct. If the task was too hard, a student could ask for help and would see peers modeling correct answers. If they lost track of the sequence in the count around activity, students often directed questions to me. I then redirected questions to the previous student or to the group. Redirecting questions back to the students encouraged them to pay attention to each other. Student interaction reinforced overall engagement in the activity.

The hand signal system helped Jacob stay engaged. He was more advanced in his skills and conceptual knowledge than the rest of the group. He complained, sighed, and otherwise made it clear he was bored while waiting for struggling students. The hand signal system improved his attention because he had to stay engaged enough to give his agreement, disagreement, or offer a solution.

In addition to hand signals, I asked students to give alternative strategies for solving problems during lessons. After students gave a variety of strategies for solving a task, I reviewed all the given strategies before moving on to the next task. Students often favored particular strategies with which they felt most comfortable. Reviewing alternative strategies helped students see alternative strategies and methods.

Avoidance. Avoidance behavior was observed with some study participants. I observed avoidance in two types of circumstances; to avoid academically challenging activities, and to avoid conflict with others. Hazel and Jennifer would ask to use the bathroom or get a drink of water to avoid academic activities. After Hazel and Jennifer were excused for the bathroom, they would not return to academic activities. Sometimes they would stay in the bathroom, and sometimes they would wander off into another area of the classroom, perhaps hoping to go unnoticed or fly under the radar. The teacher also observed this behavior during different times of the school day. The class used long blocks of time for student directed activities in a variety of formats. Students worked alone, in pairs, and in small groups or with the teacher. The varied activities and student groupings made it difficult to spot a student who was off task. When Isabella was given a choice she selected work that was very easy for her. For example, Isabella would often choose counting by ones and dot-to-dot worksheets. She would quickly complete the worksheet and then take a long period of time coloring it. Dot-to-dot worksheets were available at different levels of difficulty for students. Advanced worksheets consisted of hundreds of numbers or skip counting. Coloring was not part of the activity, but Isabella did this on her own. When Isabella was assigned more challenging work she would complain, “I don’t want to do that cause [sic] it is hard”. Isabella would also complain when I increased the difficulty for group activities. I was able to redirect Isabella by using a combination of free choice and assigned activities. She readily accepted this.

The second type of avoidance behavior occurred during social conflicts. Jacob behaved in this way during conflicts with peers and adults. For example, Ben and Jacob were working together on a number sequence sorting activity. This activity was recorded with an unmanned camera and microphone. At one point, Ben was holding a chart and accidently poked Jacob in the eye. Jacob covered his eye with his hand saying, “ow,” and rubbed his face. Jacob stood up and turned his back to Ben at a nearby table. Ben immediately apologized but Jacob did not turn around. Instead, he leaned over intently looking at another student’s work. Ben called Jacob’s name and tugged at his shorts. Jacob did not turn around. Ben shrugged and grinned at the video camera before returning to sorting. After about 20 seconds Jacob turned around and watched Ben. At this point, I noticed that Jacob was not involved, and I ask, “Whose turn is it?” Jacob kneeled down and took a turn. Ben said to Jacob, “Yeah that’s right.” Nothing else was said between the two students and they went on to complete the activity without further incidents.

Jacob was a very outspoken participant; however, his behavior was completely different when he did not know the answer. Jacob was eager and vocal when he knew the answer. Jacob would blurt out answers as fast as he could or, when he waited, he would bob up and down in his seat with his hand in the air waiting to give the answer. He would cheer, pump his fist, or say things like, “YES!!” when he answered correctly. Jacob behaved very differently when he didn’t know the answer or responded with the wrong answer. Jacob was silent during mathematics discussions he did not understand. On these occasions, he sat very still and looked down or around at the rest of the group. Jacob was the most advanced student in the study, and this did not happen very often. If Jacob gave an incorrect response to a question, he covered his face or dropped his head face down to the table. He groaned and sighed. Jacob did not like getting the wrong answer. On one day, Jacob gave two incorrect responses in a row. After the first incorrect answer, he froze motionless and expressionless. After a second incorrect answer he stood up and walked away from the table. The first time this happened he returned a short time later and rejoined the activity. On the second occasion, he returned again but on the third retreat, the classroom teacher sent him out of the class. Jacob used avoidance as a strategy in social conflicts and to avoid being seen as not knowing the answer or giving the wrong answer. When he felt confident of his mastery, he was eager to demonstrate. He was motivated by challenge but liked to practice and work on difficult tasks alone. The implications of avoidance behaviors are discussed in Chapter 6.

Copying. Mathematics storytelling illustrations for word problems work revealed another aspect of learning in Jennifer's case. Jennifer was the lowest academic achieving student in the study. She was very quiet in all activities, but she watched everything. In the mathematics story work, she copied all her illustrations. The students were given the following word problem.

> **Researcher:** "There is an apple tree. It has five apples. A deer comes and eats two of the apples. How many are left?"

In the first example, I saw Emily finish first and explain her illustration. Jennifer watched her intently and made her illustrations after Emily. Note Jennifer wrote the numeral five backwards.

Figure 4.20 Emily Example Apple Tree

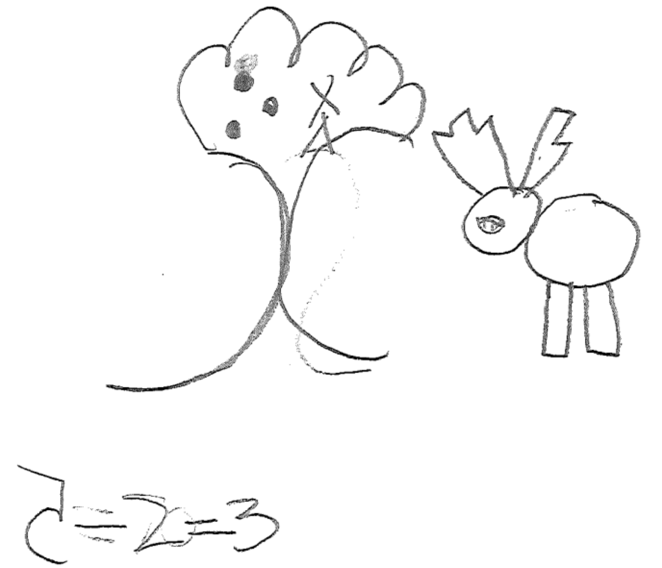


Figure 4.21 Jennifer Copying Apple Tree

Ben told the story for this word problem.

Researcher: “Ben is going on a balloon ride with his family, and there are six of them. The balloon can carry ten people. Can everyone in Ben’s family fit? Is there room for more people? If so, how many more?”

In this example, I didn't see if Emily finished first, but Emily could explain her illustration and Jennifer could not. Also Jennifer did not have the correct number of empty boxes in her picture as shown in Figure 4.23.

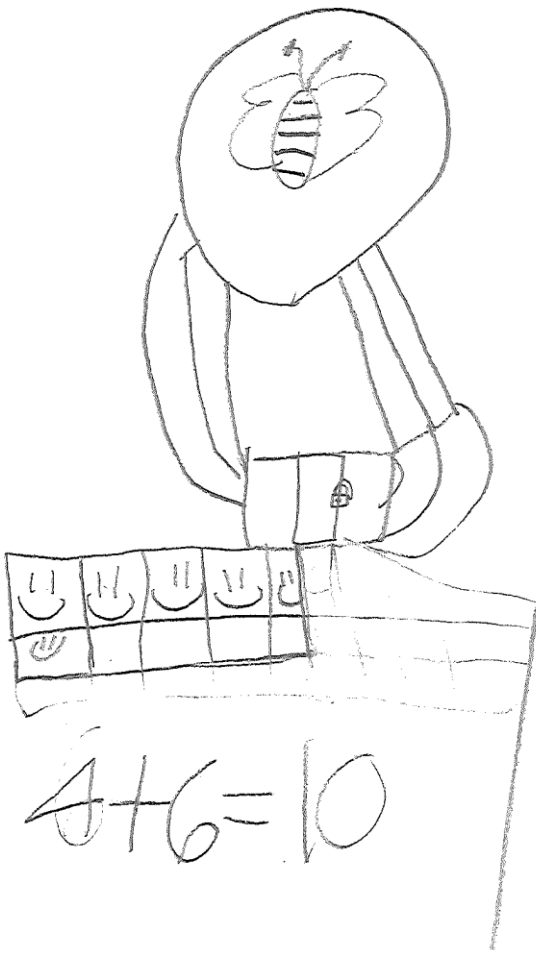


Figure 4.22 Emily Hot Air Balloon Example

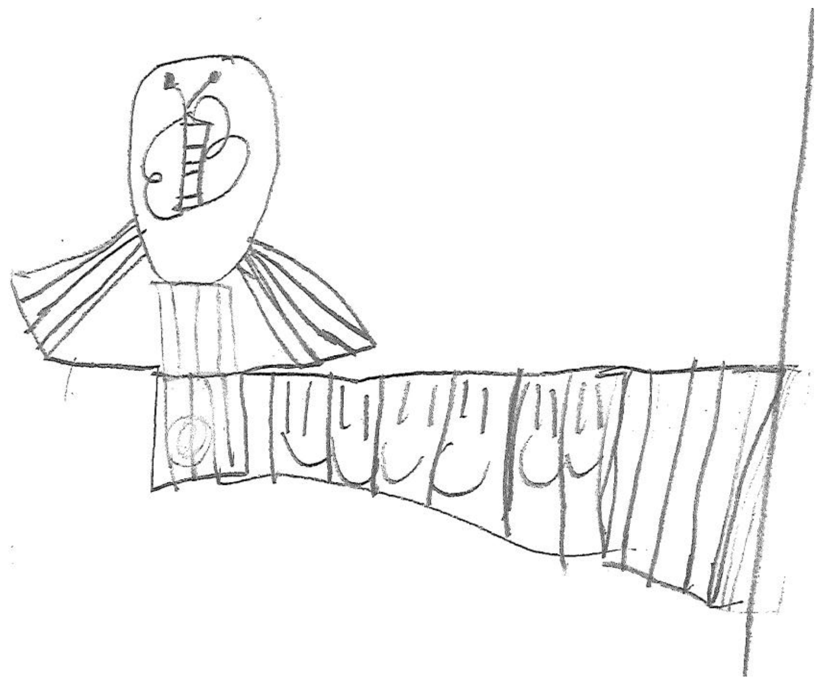


Figure 4.23 Jennifer Copying Hot Air Balloon

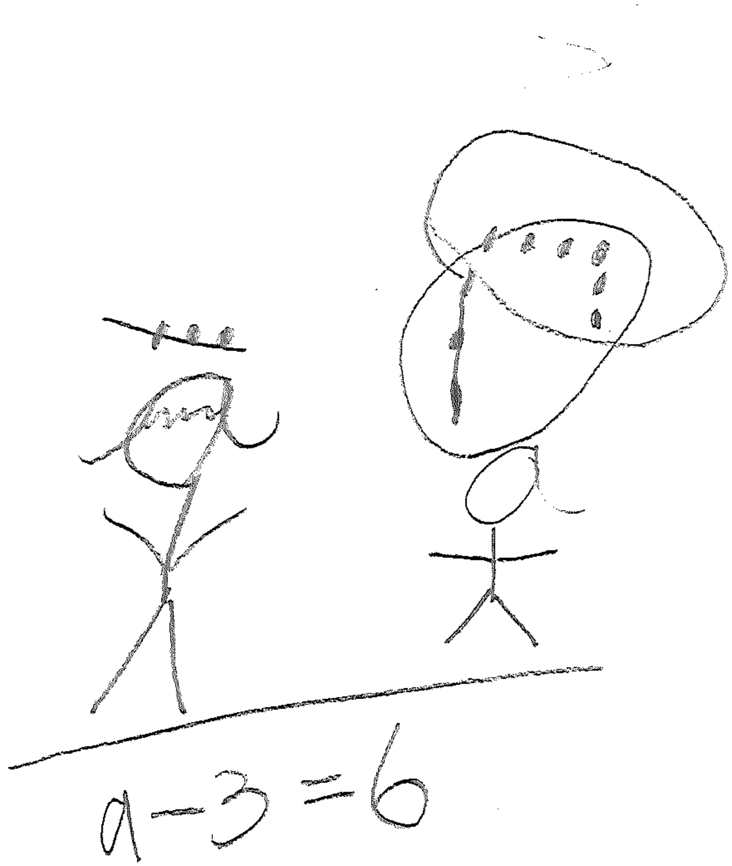


Figure 4.24 Emily Example 9-3=6

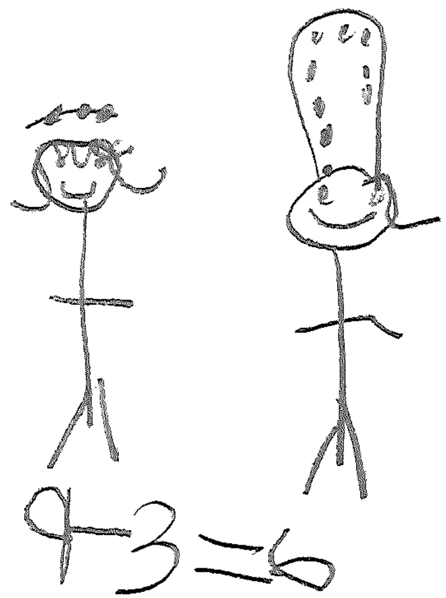


Figure 4.25 Jennifer Copying 9-3=6

Example 4.22 and 4.23 involved the mathematics story problem: “Hazel has three balls and Ben has nine. How many more balls does Ben have than Hazel?” This is a Cognitively Guided Instruction problem for compare difference unknown. Emily explained that, “Hazel and Ben both have three balls.” She crossed out three dots for each figure. “See? Ben has six left.” Emily circled the remaing six dots above Ben’s head. Jennifer on the other hand, could not explain her drawing. When asked, she just smiled, shrugged her shoulders, and said, “like her” looking at Emily. I concluded that Jennifer was copying because she could not explain her illustrations when the other students could. It was also clear that she copied because she did not understand the mathematics and would copy others even if the original author was wrong. (See Figures 4.26 and 4.27.)

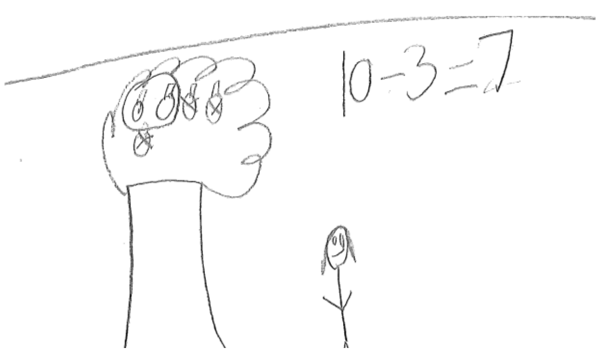


Figure 4.26 Emily Example, 10-3=7

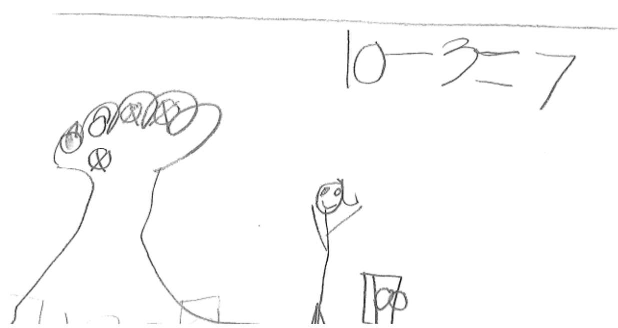


Figure 4.27 Jennifer Copying, 10-3=7

Jennifer mostly copied Emily’s work and may have done this because Emily had clear illustrations and was easier to copy than other students. Regardless of the reason, Jennifer used copying as a way to produce a response for a mathematics activity. I wondered if Jennifer learned while copying. Did she get an educational benefit from copying? In Chapter 6, I discuss if Jennifer is learning vis-à-vis sociocultural theory and suggest reconsidering copying from *cheating* to copying as a *learning strategy*. I also suggest it is important for teachers to develop abilities in discerning copying for learning from copying for cheating.

Chapter 6

Implications

Through this case study action research project I studied how public school Native first graders experienced collaborative mathematics activities when culturally modified with Indigenous ways of knowing and being? Study findings were analyzed in two chapters, one on the study context and one on mathematical thinking and learning. Three themes developed from analysis of the activity of learning mathematics: student mathematical thinking, Native learning styles, and collaborative learning. Both chapters describe the experience of students in the study. In this final chapter, I discuss implications and recommendations of the findings as well as a section on theoretical implications of the study of mathematics education for Native students in multicultural public schools.

Student Mathematical Thinking

In this section on student mathematical thinking, I discuss implications for storytelling illustrations, Math Recovery, and the Native Number mathematics app activities, as well as the implications of providing a wide variety of mathematics activities. In addition, I will also discuss parallels between literacy and numeracy instructional approaches.

Storytelling illustrations. Storytelling illustrations evolved from knowledge I gained while working with students in collaborative mathematics activities. In the study, lessons were conducted in recurrent cycles (John-Steiner & Mahn, 1996). The lessons started with planning followed by implementation, observation, and modification. This cycle repeated itself for each activity. The cycles of joint activity supported mutual co-construction of knowledge where students learned mathematics and I learned about student mathematical thinking (John-Steiner & Mahn, 1996). I modified instruction so I could focus activities for students' zone of proximal development (John-Steiner & Mahn, 1996). Storytelling illustrations were developed as a response to observed student behavior. This activity was not part of the original intervention or study design.

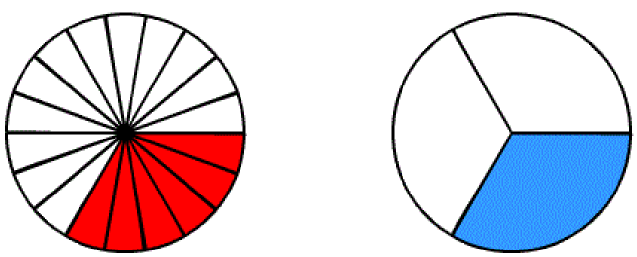
In the theme of student mathematical thinking storytelling illustration produced some of the most interesting findings. The stories for the word problems could be customized for student personal and cultural relevance. It also connected with the Native learning style of field-dependence (Pewewardy, 2002). Drawing illustrations for mathematical solutions allowed students to engage in the context of the problems. Drawings positioned the mathematics work visually and spatially. Storytelling is a culturally valued method of information sharing in Native culture (Cajete, 1994; Deloria & Wildcat, 2001).

Storytelling illustrations got students analyzing each other's work and engaging in mathematical discourse (Lo Cicero, De La Cruz, & Fuson, 1999). Students engaged in what Pirie and Schwarzenberger define mathematical discourse as "purposeful talk on a mathematical subject in which there are genuine student contributions and interactions" (1988, p. 461). I was not able to produce this type of interaction with any other study activity. For example, students in the classroom were encouraged to help each other. In most cases when more experienced students helped novice students they would just do it for them. The novice student would usually watch but there was no analysis, exchange of ideas, and no questions asked. Expert students simply demonstrated how to solve the problem. In contrast, in storytelling illustrations students analyzed each other's work. For example, Ben commented to Hazel she had too many people in her division solution (15 divided by 5). Ben had analyzed her drawing and determined where her error in thinking occurred. In addition, he did not redraw her illustration but allowed her to figure it out herself. Afterward, he checked her new solution drawing and commented that she had done it correctly.

In general, the storytelling illustration activity conversations were friendly, inquisitive, and supportive. For example, Emily offered her solution for the hot air balloon word problem when Ben could not figure out how to draw the solution. Even when students pointed out other student's errors, it was not confrontational. For example, Hazel told Isabella she had the wrong number of candles for a birthday word problem. Hazel did not tell Isabella she was wrong. She simply pointed out the word problem was about her brother, and he would not like to have nine candles on the cake for his tenth birthday. This may seem like a minor distinction, but it is important. Hazel and Isabella often argued. Hazel felt Isabella was bossy. Isabella complained that Hazel was doing things wrong. In this interaction the girls were friendly and Isabella did not take offense to Hazel's correction she simply said "oops".

Storytelling illustration activities demonstrated that even young Native students could engage in mathematical discourse. This is an important point because historically low mathematical achievement encourages deficit views of minority students. I suggest that storytelling illustrations activity can promote problem solving and mathematical discourse among Native students (Turner & Celedon-Pattichis, 2011). The study students engaged in the developmental trajectories of the Math –Talk Learning Communities framework described by Hufferd-Ackles, Fuson, and Gamoran Sherin (2004). The authors framework describes engaged meaningful mathematical discourse as questioning, explaining mathematical thinking, being sources of mathematical ideas, and responsible for learning. They did all this despite not engaging challenging and confrontational sociomathematical norms as outlined by reform mathematics researchers Franke, Kazemi, and Battery (2007). I am suggesting storytelling illustrations engaged most of the study students because it utilized culturally familiar and compatible social norms. It also allowed them to situate the word problems in their personal lives, stories, imaginations, and contexts. It should be noted that one student in the study did not like or actively engage in storytelling illustrations and he will be discussed later in this chapter in the section on Native learning styles.

I assert the storytelling illustrations activity could have additional benefits. For example, storytelling illustrations have the potential to improve student achievement on standardize tests where students are routinely asked to "show your work". Figures 5.1 and 5.2 are examples of how students can use drawings to *show their work* and explain their solutions. These examples also highlight what the equation represents and are aligned with national mathematics standards (NCTM, 2000).

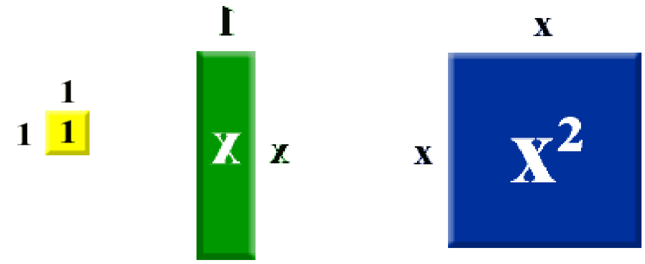


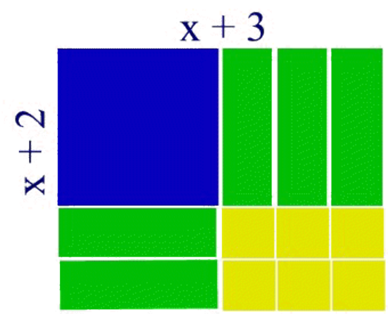
$$\frac{6}{18} \div \frac{6}{6} = \frac{1}{3}$$

Figure 5.1 Diagram for Finding the Least Common Denominator Fractions

Factor $x^2 + 5x + 6$

Key:





$x^2 + 5x + 6 = (x + 3)(x + 2)$

Figure 5.2 Algebra Example

Storytelling illustrations for solving word problems demonstrate student narrative competence in the form of illustrations that depict the important aspects of solving the mathematical word problem (John-Steiner & Panofsky, 1992). The illustrations can document learning development when students use new psychological tools to solve novel and non-routine problems. For example, I propose developing an instrument for measuring evidence of mathematical understanding in student drawing solutions with word problems. The progression of problem types could be used with a scoring metric of their solution drawings. This information could be used as a part of cognitive pluralism to inform teacher practice and help educators to identify activities in the zone of proximal development. John-

Steiner and Osterreich cited the work of Mooney and Smilansky (1973) in their study of Pueblo children. Mooney and Smilansky created an instrument to measure children's drawings. The instrument consisted of two scales, artistic and cognitive. These scales were used to understand language development. I suggest designing a similar scale for analyzing children's mathematical knowledge. This instrument could have the following features:

Possible features for the cognitive scale:

- Did the student start with the correct initial quantity?
- Did the student model the correct operation/change? (+, -)
- Did the student make the correct calculation?
- Did the student represent the problem accurately in the drawing?
- Was the student able to write a correct equation that represented the word problem and drawing?

Possible features of the artistic scale:

- Did the student have details from the word problem context?
- Did students connect the word problem context to their own experience?
- Was it an exact representation or was it abstract?
- Did they use representations, symbols, graphics in their drawing i.e. ten frames, regular dot patterns.

Deciding on an appropriate numeric value for each feature and a scale for total scores would require further research in measurement and assessment and is beyond the scope of this study. However, I recommend the development of this instrument as a direction for further research.

Math Recovery. Math Recovery as an intervention for Native American students in first grade has benefits and limitations. The greatest strength of the program is how it unpacks and organizes the concepts and skills needed for the development of numeracy and number sense. The Learning Framework in Number articulates concepts in early mathematical learning and the relationship between verbal, quantitative, and symbolic mathematics. The program also delineates a sequence of learner phases and articulates the characteristics of each phase. For example, a student learning in a perceptual phase needs to see and touch all objects involved in order to make the correct calculations. In addition, the program suggests activities and exercises to strengthen student perceptual skills while gradually moving them to more abstract thinking. The program also benefits from having its own assessment which are designed as one on one interviews and are modeled on the research of Paul Cobb (1983). The assessments give educators insight into student misconceptions and gaps in knowledge. The program gives teachers a wealth of examples for activities and exercises and also encourages teacher to develop new materials for specific student needs. The Math Recovery progression moves students through hands on concrete experiences to abstract symbolic work.

Math Recovery benefits. Add + Vantage Math Recovery classroom involves various types of joint activity in the form of whole group, small group, pair, and individual lessons and practice. Children use a variety of semiotic means in the form of games, mathematical explorations with manipulatives, and graphic representations of mathematical concepts like number frames. Mathematical development is measured with interview assessments. The study students all made gains as measured by the Math Recovery interview assessment scores. In a sociocultural perspective, increases in scores are evidence that students acquired new psychological tools. The assessments measured the following five areas including forward number word sequence, backward number word sequence, numeral identification, addition and subtraction strategies, and the structure of number. Number word sequence and numeral identification gains demonstrate evidence that students learned systems of counting and numeric symbols like numerals. The structuring of number scores provide evidence of students acquiring knowledge through the use of mnemonic devices like finger patterns and number frames. The addition and subtraction scores provide evidence that students are using increasingly complex strategies, for example the transition from unitary to composite strategies.

The Learning Framework in Number maps mathematical development in children and can inform teachers of what concepts and activities would be in the zone of proximal development. After the baseline assessment instruction is implemented in recurring cycles of instruction, practice in joint activities, and observations that result in new lessons. The cycle of instruction allows the teacher practice to be influenced by the student while the student is being influenced by the shared activity. The semiotic mediation in the mutual learning space transforms information into new psychological tools. It should be noted that individual work is still considered joint activity because the semiotic means are products of history and culture. When students interact with the semiotic means, they are practicing with artifacts of representation, which in turn, are a way of indirectly interacting with other people. I suggest that students need to be familiar with the semiotic means in order for it to be a shared activity. For example, Jacob was familiar with beadwork. His family had examples of the art form. So when he was working independently with the bead loom he was in a shared activity with his family and culture. This would not have been the case if beading was completely foreign to him. It is the cultural relevance that made the individual activity *shared.*

Math Recovery limitations. Math Recovery employs a wide range of games and manipulatives, but it is limited by its reliance on a narrow range of instructional, practice and assessment methods. Math Recovery utilizes educational practices with numerous competitive games, verbally dominant assessments and frequent use of direct questioning by adults. This intervention is also resource intensive. The Math Recovery Intervention requires a certified specialist who provides 40 half hour pull out sessions of one-on-one tutoring over ten weeks. The Add+Vantage Math Recovery intervention is implemented by the teacher in the classroom. Classroom implementation reaches more students than the specialist services, but it puts an additional workload on teachers. Some Math Recovery instructional materials can be purchased, but many must be made by the teacher, especially for activities designed for specific students or student need.

Both interventions require individual interview assessments. The interviews reveal important information and insights into student's skill and mathematical thinking. However, they are very time consuming. The specialist and classroom intervention assessments have four different tests that are to be given at least three times a year. The interview assessments vary in length from 10 minutes to 40 minutes each. Additional time is needed for scoring and evaluation. The assessments reveal information on a student's mathematical thinking, but it is very time consuming. Another obstacle is the fact Math Recovery assessments are supplementary and rarely do they take the place of state or district standardized tests. Teachers work in an era of job intensification and adding a supplementary program, no matter how useful it is, may result in limited use.

For this case study I implemented a culturally modified version of Add+Vantage Math Recovery that involved student choice and self-direction. Students engaged in the range of activities simultaneously. Students were busy, but I was busier still. I suspect that, as students get accustomed to the program they would need less teacher support, and this appeared to be happening toward the end of the semester. Yet, it was hectic to track six students simultaneously working on different activities, needing different assistance, having different levels of achievement, and working toward different goals. Students were working, playing, talking, creating, and learning in the same space. The students reminded me of a bee hive, a buzz of activity. It was energizing, challenging, and inspiring.

If I were a classroom teacher, I would use Math Recovery with students if it were nested in a classroom where I cultivated a strong learning community culture. The most important aspect of the program is the Learning Framework in Number. I would, however, broaden the range of practices in instruction, student practice and assessment for Native students. A multiplicity of semiotic means supports multicultural student populations. The interview assessment provide insights in student mathematical learning however, they consume large amounts of time. I don’t know if I could fit it in.

Cognitive pluralism. In the study I used a wide variety of mathematics programs and instructional materials. This variety can be considered cognitive pluralism. Teachers need a large, diverse, and powerful set of instructional tools to support student mathematical learning (Chapin, 2003). Wertsch describes cognitive pluralism as a kit of tools (1991). Cognitive pluralism is the use of a wide range of activities utilizing a multiplicity of semiotic means and psychological tools in semiotic mediation (John-Steiner, 1995; John-Steiner & Mahn, 1996). I used iterative cycles of joint activity to engage students in the zone of proximal development (Hufferd-Ackles, Fuson, & Garmoran Sherin, 2004; John-Steiner & Mahn, 1996). I also used Math Recovery assessments, the Learning Framework in Number, and the progression of problem types as reference guides for determining sequence and progression of student development and focused teaching to engage each student's zone of proximal development (Carpenter, Fennema, Franke, Levi, & Empson, 1999; John-Steiner & Mahn, 1996; US Math Recovery Council, 2009, 2010a). I contend cognitive pluralism provides opportunities to learn for diverse learners and I support its use for Native students in public schools.

Literacy and numeracy instructional approaches. In Delpit's article *The Silenced Dialogue: Power and Pedagogy in Educating Other People's Children*, she comments on the literacy debate of whole language process oriented instruction versus explicit direct instruction of skills approaches. Delpit contends that the *either or* dichotomy is a disservice to non-dominant society students. She asserts these students need the skills, and practice norms of dominant society in addition to (not instead of) higher order critical thinking skills. She also suggests that dominant society educators need to be open-minded to the alternative perspectives that non-dominant society students bring. From a sociocultural perspective this is similar to acknowledging the cultural, historical, and personal semiotic means and psychological tools all people bring to learning in joint activity (John-Steiner & Mahn, 1996). It is about how our cultural resources enhance and shape co-constructed knowledge.

As I read her work, I noticed similarities between literacy and numeracy education. The National Council of Teachers of Mathematics promotes process oriented mathematics learning, where students can use mathematics in routine and non-routine ways as a new direction for mathematics education (NCTM, 2000). Reform efforts emphasize creativity, exploration, and understanding what mathematics represents. This is a shift from traditional mathematics instruction focused on the memorization and execution of procedures and formulas to *get the right answer* (NCTM, 1989 2000). Math Recovery provides direct instruction on the discrete skills needed to engage in mathematical problem solving. This program has a detailed framework for identifying and understanding these skills called the Learning Framework in Number. Cognitively guided instruction is a more process oriented instructional approach. Cognitively Guided Instruction researchers assume children come to school with informal and intuitive mathematical knowledge and it is from this base children can learn more formal mathematical knowledge. In this program children learn number facts in the process of solving word problems (Carpenter & Fennema, 1996). I am suggesting that non-dominant society students need both direct instruction in skills and process oriented learning for literacy and numeracy development.

In the study I observed some students had limited mathematics skills. I had students who could not tell the difference between 12 and 21. I had a student who could not identify the numerals 5, 6, 7, 8, and 9. I had some students who could not count backwards from 15. Math Recovery instruction helped students with a range of discrete skills like numeral identification and verbal number sequence. This program helped Hazel realize that the numeral 35 was "thirty five and not "3, 5". I don't see how students without these discrete skills could engage in solving word problems in Cognitively Guided Instruction. I don't know if non-dominant society students do not have informal and intuitive mathematical knowledge or if their cultural mathematics knowledge is not recognized in school. I suspect it is the latter, but I do not have data to support that claim. In either case I am suggesting non-dominant society students need both instruction for discrete skills and opportunities for higher order critical thinking. Math Recovery can provide instruction for discrete skills and cognitively guided instruction can provide opportunities for critical thinking.

Consider the hot air balloon word problem described in Chapter 5. Ben was working on the word problem: *Ben and his family are going on a hot air balloon ride and there are six of them. The balloon can carry ten people. Can everyone in Ben's family fit? Is there room for more people? If so, how many?* Ben drew a picture of six people and a hot air balloon. He knew there was space for four more people, but he didn't know how to depict that. Emily drew a hot air balloon with a ten frame as the gondola. She drew six smiley faces in the ten frame with four blank spaces. In this example, she used a representation of ten that she learned in Math Recovery to effectively depict the word problem. Emily used this knowledge to solve a critical thinking activity. This is an example of how instruction of discrete skills and critical thinking can support student numeracy development.

I did not implement Cognitively Guided Instruction as designed. Perhaps if I had the study students might have learned number facts in the process of solving problems (Carpenter & Fennema, 1996). However, what I did observe in the study reminds me of Delpit's contention for direct instruction and process learning for non-dominant society students. I do feel that I was an open-minded teacher who allowed student behavior to inform instruction and incorporate study student cultural resources in collaborative mathematics instruction.

Native Learning Styles

Heterogeneous learners. In this section I discuss implications for variation in Native learners and culturally relevant activities. The study students behaved in ways that confirmed and challenged Native learning style research. While this finding may seem contrary, it is not if you consider it from a sociocultural perspective. Children utilized a wide variety of learning styles and practice preferences in the study. Intra-cultural variation can be explained by heterogeneity of cultural experiences. The students in the study had different lives. Most of the study students had either multiple tribal affiliations or were multi-racial. They had different levels of contact with traditional Native community life and traditions, and they had influences from more than one culture. I suggest variation in experience may have resulted in variation in use of Native learning styles. In the study students behaved in ways that challenged Native learning style research because they had other cultural experiences. The study students live in an urban center outside of any Native reservation or traditional homeland and they lived and went to school in multicultural contexts.

John-Steiner and Osterreich (1975) used a functional systems approach to understand Native learning styles. Functional systems are dynamic psychological systems in which diverse internal and external processes are coordinated and integrated. These systems reveal a variety of characteristics including the use of variable means or mechanisms by individuals to perform particular tasks. In order to succeed when faced with new learning challenges, these individuals reorganize their cognitive strategies (as cited in John-Steiner & Osterreich, 1975, p. 194).

John-Steiner and Osterreich (1975) found that Native learning styles functioned as elements in a dynamic system and not separate strategies. Native learning styles are an adaptation to the challenge of the unfamiliar school context. I argue all learning styles function in this way and because of this, it makes sense to promote the use of a multiplicity of strategies to support learners from non-dominant society cultures and in multicultural contexts. John-Steiner and Osterreich (1975) called this cognitive pluralism.

For example, the authors found that Pueblo communities used different reward and punishment systems than those used in schools. Pueblo communities use observational learning. Observational learning is not tied to a reward system like letter grades. "The adult model on whose behavior the child's learning is based does not punish the child for slowness or failure, what is learned is motivated by the child's need and curiosity" (John-Steiner & Osterreich, 1975, p. 8). Hazel's negative reaction to the Native Number mathematics iPad app was a response based on being punished for being slow. Jennifer experienced negative feedback from her family because they were told she was failing in school. Both students utilized observational learning and I argue their responses could be explained by the difference between cultural and dominant society reward and punishment ideologies. Jacob was interested in beading on a loom for its intrinsic rewards. He was motivated to learn and derived satisfaction from the activity because he was able to duplicate the significant activity of adults (John-Steiner & Osterreich, 1975).

Jacob behaved in ways that were characteristic of a field-independent learning style. He enjoyed individual recognition and was task oriented (Pewewardy, 2002). He was motivated by competition. He did not take interest in the storytelling illustration activity. I was not able to discover why he didn't like this activity, but his behavior demonstrated he didn't want to draw the illustrations. Field-dependence learning style is prevalent in Native culture, but Jacob seemed to be a field-independent learner.

Culturally relevant mathematical activities. I used a number of different culturally relevant activities in the study; beading, storytelling, hand signals. Culturally relevant mathematical activities support student's cultural practices and skill and utilizes this knowledge as an educational resource (Gonzalez et al., 2005; Turner & Celedon-Pattichis,

2011) The use of gestures and everyday experiences draws on student's cultural resources to help them make sense of mathematical ideas (Moschkovich, 1999). Communicating agreement and disagreement is an important part of productive mathematical discourse and the study students were able to engage in this aspect non-verbally (Chapin, 2003). Finding ways to reduce verbal dominance is important for Native students as classrooms dominated by verbal exchange are likely to discourage Native student participation (Delpit, 2006; Trumbull et al., 2002). It should be noted that beading and *hand talk* are more prevalent with American Indian tribes from the U.S. plains region and not as widely used in the southwest (Davis, 2010; Klinkenborg, 1992). Despite this Jacob showed a high degree of interest in the beading activity. He was very proud of his skill and bead creations. He took great pride in making gifts for his family.

In hindsight, I wish I had presented historical and cultural information about the culturally relevant activities with the study students. I could have told the students stories about the activities and shown them examples of beading. I could have had explicit discussions about the use of *hand talk* among Native people. I have to admit I was so focused on the mathematics aspects of teaching I did not think broadly enough to include this in the study. However, I will include historical and cultural information if I continue similar research in the future.

Collaborative Learning

In this section: collaborative learning, I discuss the implications of copying and ask educators to consider the idea of copying as a learning strategy. In addition, I discuss implications of student avoidance behaviors.

Copying as a learning strategy. In findings Chapter 5, I asked a question about whether Jennifer is learning when she copies? I contend that from a sociocultural perspective, she is learning. When Jennifer copies, she is a legitimate peripheral participant (Lave & Wenger, 1991). Copying engages students in semiotic mediation with multiple means and external tools. Copying is a form of observational learning, and observational learning is a Native learning style strategy (Bartolini Bussi, 1998; John-Steiner & Osterreich, 1975). The act of copying engages novice learners with more experienced learners. Repeated participation of the novices in the joint activity could lead to a reduced need for expert support and an increased ability to solve tasks independently. Through the transformation of information in semiotic mediation and the guidance of the teacher toward more complex activities, one might expect Jennifer would someday be able to internalize the means and develop psychological tools.

I am asking educators to reconsider copying as cheating and consider its value as a learning strategy. Instead of punishing students for copying, they could encourage the use of copying as a learning strategy. Teachers could plan activities to incorporate copying. For example, students could work as a group with one student assigned the role of scribe. Teachers could also demonstrate strategies with manipulatives and ask students to replicate them. Ms. Walker was very interested in this finding. When we talked about it she asked me "if I let students copy then how can I assess them?" Students copying all the time in traditional classrooms, it is only in testing situations that copying is considered cheating. My advice to her was to just explain to students when it is and is not appropriate to copy. For example, I would explain it this way, "We are going to take a test. A test finds out what you know. In this class, we spend a lot of time working together and I encourage you to help each other. However, during this one activity I want you to not copy each other."

Avoidance. Some study students displayed avoidance behaviors. I initially was thinking this behavior could be a Native learning style. I see a connection to avoidance behavior with Native social norms for honoring student autonomy and parental interference. Perhaps students used avoidance behaviors in the classroom because they were not used to overt direction or coercion. However, the sample size is too small, and I don't have enough data to draw this conclusion. Student avoidance could also have been influenced by affective factors like avoiding unpleasant or frustrating activities. It might also be when given a choice, some students preferred to color, visit with their friends, or escape the noise and activity of the classroom. It is premature to assume avoidance as a learning style, and I have no data to suggest this behavior is Native specific. I am writing about avoidance behaviors because I thought it was interesting. However, more research is needed to understand this phenomenon.

Nested Joint Activity

Nested joint activity is a term I am using to describe the interaction between the joint activity of building a classroom culture and the joint activity of collaborative mathematics activities. This term also assumes that the synergy of learning takes place in joint activities and between joint activities. In the study, the classroom culture influenced mathematics learning through affective factors. Sociocultural theorists suggest affective factors influence learning because human beings develop in relationship to others (Bartolini Bussi, 1998; Mahn & John-Steiner, 2002). Development is an outcome of social interdependence where human connection and caring support fosters the development of competence (Mahn & John-

Steiner, 2002). Mahn and John-Steiner call this *the gift of confidence*. Student learning is enhanced when students are nurtured and supported at school. In the study, the mathematics learning was supported by the overall classroom culture.

Classroom Culture

The classroom teacher developed a community of learners in her classroom. She was able to collaborate with students to create an environment that was conducive to transformative teaching and learning. She did this by understanding her students' lived experiences, knowledge, and feelings. Thankfully the teacher shared this knowledge with me during the study. Her insights helped to reveal the complexities of students' cognitive and emotional development. Mahn and John-Steiner comment "A teacher's awareness of students' ways of perceiving, processing, and reacting to classroom interactions -- their perezhivanija -- contributes significantly to the teacher's ability to engage the students in meaningful, engaging education" (p. 52). Caring support has the power to instill confidence in students and help them meet difficult challenges, to take risks in creative activity, and to experiment and try new things (Mahn & John-Steiner, 2002).

Emotional support of students needs to be genuine. Supportive efforts need to be based on real knowledge and not stereotypes, or deficit notions of students and their families. Genuine support for students includes high expectations and a diverse range of methods of classrooms with instruction, student practice and assessment. Diverse learners need a teacher who has depth of content knowledge specific to student developmental needs. Diverse learners need teachers who spend time getting to know them as people. Students of color need teachers with minds open to the possibilities and abilities of student learning and able to recognize student strengths and needs. Teachers need to meet diverse needs with a wide array of methods and the ability to develop methods based on what we experience, observe, and learn with students. Mathematics instruction needs to be more inclusive of a range instruction, practice, and assessment practices. Sociocultural theory would call this cognitive pluralism: the multiplicity of means (John-Steiner, 1995; John-Steiner & Mahn, 1996).

The study classroom was a site of semiotic mediation. The participants bring with them tools both external and psychological. These tools are historical artifacts developed from their lived experiences in the communities they reside in and the development of cultural innovations (Bartolini Bussi, 1998; John-Steiner & Mahn, 1996). Joint learning activities within classrooms are influenced by the teacher's own set of semiotic means and psychological tools. Children participate in the shared activity of the classroom, and they also bring their means and tools. Due to the nature of semiotic mediation, participants engage in mutual learning where the teacher learns from students and students learn from teacher (John-Steiner & Mahn, 1996). This shared activity is a synergy of means and tools that transform information into new psychological tools and thus learning develops (John-Steiner & Mahn, 1996). The next section describes the classroom teachers' pedagogy and methods for participating in the joint activity of school.

Community in classrooms. The students in the study had complex lives. Study data was collected during one semester. During that short amount of time numerous significant events happened in the lives of study students including homelessness, parental unemployment, parental disability, reconfiguring of families and family structure, domestic violence, housing insecurity, parents working out of state, and separation from extended family members living far away. The list of significant events is extensive. I am not going to delve into the individual details of student lives. This was not the purpose or focus of the study. I mention stressful events simply to illustrate the complexity of student lives, and to suggest students need a nurturing in school. Students need support to be resilient and manage their stressful lives. I also did not include detailed information about the teacher. I wanted to focus on her pedagogy as a conscience choice. The teacher's experiences and positionality matter, and I did <u>not</u> want to portray her as a savior. I want to emphasize the fact Ms. Walker is an outstanding teacher <u>and</u> her methods are reproducible.

Ms. Walker's pedagogical approach to teaching is distinct, and she was able to articulate her classroom design and intentions. She placed emphasis on creating a community in the classroom based on caring and respectful relationships informed by regular communication with families, observations, and instruction for social and emotional skill development. Ms. Walker's class is closely aligned to the literature on school connectedness and building community in schools. John-Steiner and Osterreich (1975) noted nurturance as an aspect of observational learning, particularly for people raised in Native communities. They wrote:

> In these settings the closeness of family members, the mutual responsibilities shared by members of the community…and the beliefs that Native traditions are important but should not be 'rammed down' children's throats, all contribute to learning by watching and learning by identifying with loved and respected individuals. (1975, p. 11)

To support this finding they cited the work of Bahrick, Bahrick and Wittlinger (1974). The authors found that people out of high school, for more than 30 years, could still recognize 90% of their classmates' photos. They were most likely to remember close friends and people they had romantic relationships with. This research demonstrates that learning can occur outside of instruction. People learned each other's faces because they saw them frequently in shared activity. These findings are an example of observational learning. Important to this study is the fact that emotional investment improved people's learning. I would argue that Ms. Walker's caring community classroom provided nurturance and improved learning. I didn't collect data that measured this, but I inferred this from my observations.

Game of school. Ms. Walker resisted the *game of school* mentality and worked for genuine learning. Her views are closely aligned to the work of Robert Fried (Fried, 2005). Ms. Walker describes this type of resistance as teaching students "how to play the game of school".

> Young children have to find a way to play the dominant (society) game of school. It is not about learning. It is about fitting in and being compliant. Playing school is the icing on the cake, and it is not about the depth of true learning. The act of schooling is about participation and access. As a student, you have voice if you play the game of school. If you act out with anger and unwanted behaviors, you will lose your voice. School punishment is about suspension and expulsion. Behavior is managed by exclusion and is not about learning.

Ms. Walker recalls,

> My first grade teacher put tape on my mouth and put me in a closet because I could read. I disrupted reading lesson by reading out loud. The teacher literally took my voice. She managed my behavior because it was unwanted. This was not about learning.

I have memories of being a cultural outsider in traditional schools, where I was confused, scared, and misunderstood. That experience inspires me to research ways to create true and effective learning environments for non-dominant society student populations.

Family journals. Family journals were instrumental in developing the culture of community in the classroom. Journal communication helped Ms. Walker understand their lived experiences with their families. Journals provided information on values, beliefs, and how students may be making sense of the world. The family journal work is similar to Holbrook Mahn's work with *dialogue journals* (Mahn, 1997). It should be noted that Mahn used dialogue journals with high school students. Ms. Walker used family journals with first grade students and their families. This is important for two reasons. First, Ms. Walker believed that even young children have the ability and right to voice their own experiences. Second, if you want to really understand young children, you need to communicate with their families.

Journals also functioned as a shared activity where semiotic mediation took place, even though the participants were not physically in the same location. In asset pedagogy research for Indigenous mathematics education, co-construction of knowledge takes place in a third space, with researchers, teachers, and community members (Hankes, 1998; Lipka et al., 2005; Lipka & Illutsik, 1999). Ms. Walker's use of journals was a form of third space between families, students and the teacher. The journals significantly contributed to the community culture of the classroom by providing information on the cultural means and tools students bring with them to the classroom. Journal entries bring authentic experiences of the student into the classroom, while also sharing information with families. Family journals reach out to families with the message *you are part of our classroom community*. A significant drawback of the journals is when families don't write back.

Family journals could potentially be a very interesting and valuable research topic. If I pursued this topic, I would collect data from both the students and their families. I think it would be particularly interesting to hear how parents experienced family journals. I also argue that in order to meet the needs of a diverse group of learners, educators must first really know their students. Collecting genuine knowledge requires observation and communication with students and their families. Educators need to learn who their students are as people and learners. Most importantly educators need to use this information to support students in a holistic way.

Observation is a very important part of getting to know students. It is important to <u>watch</u> what they do and <u>listen</u> to what they say. I suggest having explicit conversations with students about how to negotiate school, getting along with others, working together, taking turns, and helping each other. These are all behaviors and social skills we ask of young students. These behaviors are complex. As educators, we need to explicitly teach young students how to do these things. We need to give children opportunities to practice these skills. In addition, we also need to be mindful of our own values and norms. We need to observe ourselves. Educators must understand their own values and culture and the role their culture plays out in the activity of learning. What do we consider normal behavior? What is acceptable? What is the culture of schooling? How is it aligned to or conflicting with the student family culture?

Theoretical Implications

One of my greatest challenges in analyzing the findings was finding an appropriate theory. If I wanted to focus on individual students, I would have chosen constructivism because constructivism explains an individual's mathematical thinking. However, it doesn't explain the social aspects of a classroom. If I focused on the classroom, I could have chosen social constructivism. This theory examines the social aspects of the classroom learning. Yet, as my data indicated, social forces outside the classroom also affected student learning. Theories exist that examine society at large. These theories examine issues that impact the lives of students of color, but reform at this level requires significant change at a societal scale. I have more modest goals. As a teacher and educator, I wanted to research strategies that could be implemented by teachers at the classroom level. I came to graduate school because I witnessed the success and failures of Native students in public schools. I wanted to inform my practice to support these students. So, I designed a study to examine how Native students in an urban public elementary school experience the first grade mathematics intervention, Math Recovery, when it has been modified to acknowledge and support Indigenous ways of knowing and being.

So what theory fits pluralist public school contexts? What theory explains what is happening for students as individuals, impacted by larger historical and cultural forces, but still can explain the phenomena at the student and classroom level? I considered culturally relevant and responsive pedagogies. These theories acknowledge the lived experiences of students of color in dominant society schools. These theories articulate a path for student success. Yet, as Castagno and Brayboy (2008) found in their review of literature after 40 years of culturally relevant pedagogy work, schools and classrooms are failing to meet the needs of Indigenous students. The authors make four recommendations for improvement: a more central and explicit focus on sovereignty and self-determination, racism, and Indigenous epistemologies. Addressing racism and exorcising sovereignty depend on having the power to take action. Teacher attitudes and beliefs matter and racist teachers, whether they are conscious or dysconscious, cannot effectively support the education of students of color (King, 1991). This may be possible in Native controlled education institutions, but I believe it would be much harder in public school settings controlled by non-natives.

Culturally relevant pedagogy implementation is very problematic in multicultural public schools. Developing curriculum for one culture is resource intensive. It would be exponentially more difficult, if not impossible, to implement truly relevant curriculum for all the ethnicities in a school or single classroom. I have had many conversations with my companion about culture. He is Native American, and speaks his tribal language. He was raised as a participant in his traditional culture. He has often said to me "if you can't speak your language, you can't know your culture. Language conveys the essence and true meaning of your culture. Without your heritage language you have no culture." I have seriously contemplated his thoughts for many years but I must admit his comments do not explain my lived experience. I know who I am. I know where I came from. I learned the ways of my family and the culture of my generation, as a sansei (third generation American). It is true my knowledge of contemporary Japanese culture is very limited. As a matter of fact, when I first visited Japan in my twenties, I realized my expectations about Japan were very different from the reality I saw. I learned about Japan from my mother and grandparents. Their stories and experiences represented Japan from decades ago. My mother immigrated in 1955. My paternal grandparents immigrated in the early 1900's and never returned. The Japan they told me about was fundamentally different from the Japan I experienced in 1983. My paternal grandparents remember a pre-WWI nation, and my mother remembers a nation emerging from the devastating effects of WWII. My point is culture is not static; it is constantly evolving and changing. Language is an important part of culture but culture encompasses more than just language.

My companion is right in the fact that I do not know the Japanese language and that fact impedes my ability to understand Japanese culture. Yet, I am more than just Japanese. I am a person of Japanese descent who has lived my entire life in the U.S. I am a member in the culture of Japanese immigrants, and my lived experiences shape my *cultural* identity. My culture is based on pluralist contexts and experiences. My mother emigrated from Japan, my father and I were born in the U.S., and my son is multi-racial. We all identify as Japanese, but our experience and connection to Japan varies. Our lives represent the heterogeneity of cultural experience.

What if, when I was a child, I attended a school that was modeled in culturally relevant pedagogies? What would that be like? In my elementary school, I was one of nine students of color in my grade. There was one Japanese American student (me), one Filipino immigrant student, two Chinese American students, two African American students, and three Mexican American students. Whose culture would our culturally relevant class refer to? Should we have been bused into segregated schools or classrooms by culture? If that were the case, what form of Japanese culture would my education be modeled after? Which era of Japanese culture would be used? This brings me to my next question, "What about children with multiple ethnic identities?" You can see how problematic this line of thinking can be.

The reality is today's classrooms are diverse and will increase in diversity in the future. In 2011, the majority of Native students attend schools in population densities of less than 25% (National Center for Education Statistics, 2012a). In addition, diversity exists within any group of students. In the study, all the student participants were identified as Native, and despite this, the students were heterogeneous learners. Moreover, most of the study students were multi-racial. So, I return to my original dilemma, which theory best explains my research study?

Sociocultural theory explains that learning is developed in social contexts. It acknowledges that all signs, symbols, and means of mediation develop from and are continually shaped by culture. This theory assumes that culture is fluid and is shaped by lived experiences in particular contexts. Sociocultural researchers recommend this theory when examining cross-cultural and multi-cultural contexts (John-Steiner & Mahn, 1996). After careful consideration, sociocultural theory was the conceptual framework I selected. This theory helped me organize and understand the study data. In the end sociocultural theory helped me tell the story of the data.

Sociocultural theory helped me analyze the study data, however, this theory does not articulate specific theoretical guidance for mathematics education. In the study I found that students learned in joint activity within a caring community. Cognitive pluralism afforded opportunities to learn for diverse learners. Connecting student culture and lived experiences to school learning was a resource for learning. Shepard's article *The Role of Assessment in a Learning Culture* proposes "an emergent constructivist paradigm" that incorporates shared principles of curriculum theories (2000, p. 8). Some key aspects of her reformed vision include:

- All students can learn.
- Equal opportunity for diverse learners
- Socialization into the discourse & practices of academic disciplines
- Authenticity in the relationship between learning in and out or school
- Enactment of democratic practices in a caring community
- Intellectual abilities are socially and culturally developed
- Learners construct knowledge and understandings within a social context
- New learning is shaped by prior knowledge and cultural perspective (p.8)

The work of Lorrie Shepard (2000) incorporates the findings of the study and I would look to her theory as a direction for future research.

Conclusion

I conducted a study in order to answer the following research question: How do public school Native first graders experience collaborative mathematics activities when culturally modified with Indigenous ways of knowing and being? I used sociocultural theory to frame my findings and explain the themes that emerged from the data. I discovered that study participants experienced collaborative mathematical learning as legitimate peripheral participants in shared activities. Through the use of cognitive pluralism, information was transformed from the interpersonal to the intrapersonal in the form of new psychological tools. Storytelling illustration drawings served as a form of semiotic means that was part of cognitive pluralism and encouraged student mathematical engagement in ways I could not elicit in any other activity. Students exhibited a variety of learning strategies including Native learning styles that functioned as a dynamic system within the joint activity of learning mathematics. Mathematics learning occurred in and was influenced by the classroom culture. I am calling this phenomenon *nested joint activity*. The classroom as a whole is a form of joint activity that focused on developing children as learners, supported by a community in the classroom. The nurturing culture supported students engaged in challenging mathematics activities. The teacher built the community culture with a variety of strategies with the most interesting and influential being family journals. I contend synergy exists not only within joint activities but also between joint activities. John-Steiner and Osterreich raised “the question of whether a multiplicity of environmental factors might, indeed, affect the nature, functions and styles of language development in children?” (p. 32). The findings of this study would suggest the answer to their question is yes.

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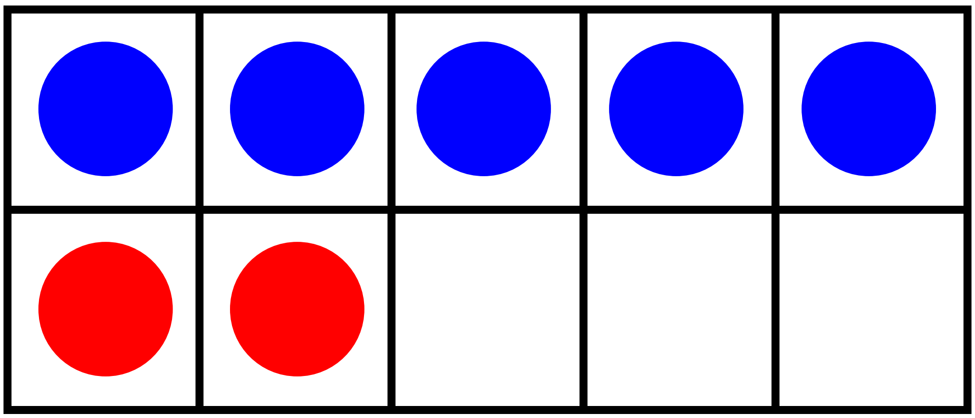
Appendices

Appendix 3.A

Example of Typical AVMR Instruction

The teacher shows students this flash card:



Teacher: What do you see?

Students: Dots

Teacher: How many dots are there? Figure this out without counting by ones.

Students: seven

Teacher: How do you know this?

Students: Cause it is five and two and that makes seven.

Teacher: What is on top?

Students: There five are dots on top.

Teacher: What kind of dots?

Students: Blue dots

Teacher: What is on the bottom?

Students: There are two dots.

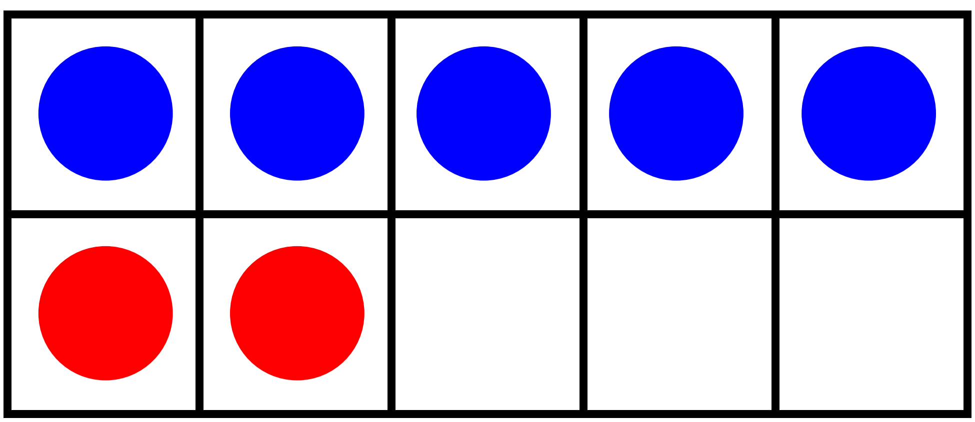
Teacher: What kind of dots?

Students: Red dots.

Teacher: Tell again what you see?

Students: There are seven dots all together. I know this because there are five blue dots on top and two red dots on the bottom. I know that five and two make seven.A modified version of the same lesson.

Teacher shows the students this card.



Teacher:

- "I am looking at this card and I need to figure out how many dots there are.
- Let's see I could count by ones but I want to find ways to figure this out without counting by ones"

Teacher shows this card.

- "So let's look at this card. I see this card has boxes on it. All the boxes are the same size, (point to the boxes).
- I see there are five boxes on top (points) and an equal number of boxes on the bottom (points).
- So if there are five on top then there are five on the bottom"

Teacher lines up the empty box card under the card with the dots so that the blue dots align with the empty box line.

- "There are blue dots in all the boxes on the top. That means there are five blue dots" Teacher moves the empty box card to expose the two red dots.

- "I can see there are two red dots"
- "I know five and two make seven so there are seven dots all together.

Appendix 3.B

AVMR Modified Activity Examples

Treasure Hunt

Description: Treasure Hunt is a game designed to help students develop their verbal sequences. It can be played forward (FNWS) or backward (BNWS). Numerals can be sequenced by ones or by using multiples (For example, for practicing multiples of 3, use 3, 6, 9, …30). The game should be played using approximately 10 numerals. For young children, it can be played with numerals 1-5.

Directions:

- Select an appropriate number range (ie. 1-10, 76-85, etc) based on the needs of the student(s). Use two different-colored sets of numeral cards in that number range. Numeral cards can be printed from Solon Schools' MR webpage: http://solonschools.org/mr/
- Establish two rows using the two different colors. If working on FNWS, place the smallest number on the far left. If working on BNWS, place the largest number on the far right. This number is called the "start number" and should be face up.
- Shuffle the remaining numeral cards. Then, pull out three numeral cards. These will become the draw pile. Add three treasure cards to the remaining numeral cards and re-shuffle. (This ensures that the treasure chests do not end up in the draw pile.)
- Deal cards into two even rows, face down.
- The game begins by Player 1 drawing 1 card from the draw pile. He/she counts forwards or backwards from the "start number" to determine where the card goes. He/she places the card face up in the correct position and removes the card previously in that position. If this card is a "Treasure" card, Player 1 keeps it and Player 2 draws a card from the draw pile. If it is a numeral card, Player 1 gives it to the next player who then places this card face up into the appropriate position.
- Note: It is interesting to watch how children find where to place each new card. Students may find an efficient strategy to find each card's position. (For example, some may use a face up card as a reference number.) These strategies may be used, but should be "checked" by counting forwards or

backwards from the “start number”. This ensures that the students practice the verbal sequence.

- The game ends when all cards have been placed into the correct positions. The winner is the player with the most Treasure cards.

Example: Below is an example of how the game may look if playing backwards in the range of 34-25.

	6			9					4
						1			4

Support: Video clips that show how to play this game with FNWS and BNWS are online.

- Go to **www.solonschools.org/MR/**
- Select **Number Words and Numberals**
- Scroll down and click **More Numer Words and Numerals Videos**
- Click **Treasure Hunt – FNWS** or **Treasure Hunt – BNWS**

Modifications: The game will be played without the treasure cards. The goal of the game is to work cooperatively with a partner to complete the numeral sequence.

Reinforcement Activities for Math

Focus: Number Just After in Range of 1-30

Number Identification in Range of 10-20

Number After Bingo

Child places a counter on the Bingo board if they have the number after the one called out. For example, if 23 is called, child places a counter on 24 on their Bingo board. Bingo is called when 3 in a row are gotten. Use numbers in the range of 1-30 – can use stack of number cards and turn over top card to use as call numbers. (See numeral cards and Bingo cards attached.)

Bingo Cards

11	27	19	12
15	13	20	16
31	10	5	18
15	29	22	25

8	17	29	22
15	13	9	26
21	31	10	19
25	20	12	28

Modifications - The game play continues until all the bingo spaces are filled for all players. Students are encouraged to help each other figure out the number just before and to find it on their

Appendix 3.C

Interview Protocol American Indian Mathematics Education Study

Teacher interview

Beginning time_____________ Ending time_____________

Place:

Interviewer:

Interviewee:

Questions:

1. What is your educational background in mathematics?
2. What is your professional teaching background and experience and/or training in Math Recovery?
3. Please describe the classroom culture you promote in your classroom?
4. What are your expectations for student learning in mathematics?
5. Describe your approach to implementing Math Recovery?
6. Do you have specific teaching strategies or methods specific to working with American Indian students in math?

Appendix 4.A

Problem Types and Examples

MATH STORY PROBLEM TYPES

Joining Problems

Join (Result Unknown) 6 + 3 = __	Join (Change Unknown) 4 + __ = 7	Join (Start Unknown) __ + 4 = 6
Mr. Smith had 6 cookies. Suzy gave him 3 more cookies. How many cookies does Mr. Smith have now?	Mr. Smith had 4 cookies. Suzy gave him some more. Then, Mr. Smith had 7 cookies. How many cookies did Suzy give Mr. Smith?	Mr. Smith had some cookies. Suzy gave him 4 more cookies. Then, he had 6 cookies. How many cookies did Mr. Smith start with?

Separating Problems

Separate (Result Unknown) 7 - 4 = __	Separate (Change Unknown) 5 - __ = 1	Separate (Start Unknown) __ - 4 = 4
Mr. Smith had 7 cookies. He gave 4 of them to Suzy. How many cookies did Mr. Smith have left?	Mr. Smith had 5 cookies. He gave some to Suzy. Then, he had 1 cookie left. How many cookies did Mr. Smith give to Suzy?	Mr. Smith had some cookies. He gave 4 to Suzy. Then, he had 4 cookies left. How many cookies did Mr. Smith have to start with?

Part - Part - Whole Problems

Part - Part - Whole (Whole Unknown) 6 + 3 = __	Part - Part - Whole (Part Unknown) 7 - 4 = __ or 4 + __ = 7
Mr. Smith had 6 white cookies and 3 pink cookies. How many cookies did Mr. Smith have altogether?	Mr. Smith had 7 cookies. 4 were pink and the rest were white. How many white cookies did Mr. Smith have?

Comparing Problems

Compare (Difference Unknown) 5 - 3 = __ or 3 + __ = 5	Compare (Quantity Unknown) 3 + 2 = __	Compare (Referent Unknown) 8 - 5 = __
Mr. Smith had 5 cookies. Suzy had 3 cookies. How many more cookies did Mr. Smith have than Suzy?	Mr. Smith had 3 cookies. Suzy had 2 more cookies than Mr. Smith. How many cookies did Suzy have?	Mr. Smith had 8 cookies. He had 5 more than Suzy. How many cookies did Suzy have?

Multiplying and Dividing Problems

Multiplication 3 x 3 = __	Measurement Division 9 ÷ 3 = __	Partitive Division 12 ÷ 3 = __
Mr. Smith had 3 piles of cookies. There were 3 cookies in each pile. How many cookies did Mr. Smith have?	Mr. Smith had 9 cookies. He put 3 cookies in each box. How many boxes did he need?	Mr. Smith had 12 cookies. He wanted to give them to 3 friends. How many cookies did each friend get?

*WORD PROBLEM CHART BASED ON COGNITIVELY GUIDED INSTRUCTION PROBLEM TYPES

Appendix 4.B

Student Subskills Summary Matrix

Student code	Number Concepts					Number Relations					Number Ordering				
	Rods	Sets	Match Rods	Numerals	Mastery	Rods	Sets	Tallies	Numerals	Mastery	Rods	Sets	Tallies	Numerals	Mastery
Jacob	70	250	30	50	40	40	30	30	100	80	20	20	10	100	80
Ben	140	260	110	110	50	30	60	30	30	30	80	40	50	120	140
Emily	190	150	110	40	50	30	60	150	60	250	20	20	20	30	50
Isabella	530	670	50	210	30	120	60	50	30	70	50	20	20	20	20
Hazel	530	420	10	150	60	310	810	350	640	80	150				
Jennifer	1050	370	80	70	20	120	330	80	90						

Student code	Counting					Demonstrate Mastery					Attempts	Total topics completed		
	one to one	Count up	Count Down	Count on	Mastery	numbers 1	numbers 2	Order	Counting	Counting 2	1240	25		
Jacob	40	10	30	30	50	30	30	10	30	30	1500	25		
Ben	30	10	30	40	20	20	20	10	20	20	1980	25		
Emily	120	60	190	80	60	20	130	30	10	50	2410	25		
Isabella	110	20	20	20	10	30	130	40	20	60	3510	25		
Hazel											2210	11		
Jennifer												9		

Appendix 4.C

2013-14 MR Summaries

Emily						
Date	FNWS	BNWS	Numeral ID	+/- Strategies	Structuring #s	10"s & 1's
9/20/13	5	4	1	3	1	
12/9/14	5	5	4	4	3	2

FNWS: A1 She is facile in the range of numbers to 100 with FNWS and number word after.
BNWS: A1 She can count down from 72 and can give the NWB for numbers to 30. She was slow in answering NWB in general and perhaps this is a less developed skill. **A2** She is facile in the range of numbers 1 to 100 in BNWS. She gave the NWB for all numbers in the assessment, without hesitation or error.
Numeral ID: A1 She identified numerals to 820 but missed 206 "twenty hundred six" and 341 as "314". She also missed 21 as "12". I asked her a second time and she still missed it. **A2** She identified all numerals on the assessment except 206, she said "two hundred sixty"
+/- Strategies: A1 She uses count on strategies to solve addition and missing addend tasks. She also utilizes count down to strategies to solve. Counting down as a skill is slow and not fluent/facile but she does use it correctly. **A2** She uses count on and count down to strategies to solve addition, subtraction, missing addend and missing subtrahend problems in bare number task with no materials. She does keep track of changes on her fingers. She could choose between the two strategies for the more efficient method.
Structuring Numbers: A1 She can create finger patterns to 10 without counting. The student is able to combine and partition numbers in the range of 1 to 10 but at times needs to count to solve. **A2** She utilizes five-wise, pair-wise structures to combine and partition numbers in the range of 1 to 10 in bare number tasks. She knows some doubles but not double 8's, 9's. She applies ten-wise and pair-wise structures in bare number tasks involving addition but not subtraction.
Tens and Ones: A2 She sees ten as a unit of ten ones, can perform addition as bare number tasks but not subtraction. Can perform subtraction with materials
General comments: A1 She can identify numerals 46-55 and correctly sequenced them. She uses pull-off strategies when counting a collection and retains cardinality.

Jacob						
Date	FNWS	BNWS	Numeral ID	+/- Strategies	Structuring #s	10"s & 1's
9/17	5	5	3	2	1	
12/13/13	5	5	4	4	3	2

FNWS: A1 He is fluent in FNWS. He says "one-oh-four" for numbers over 100. **A2** He says numbers over 100 in standard conventions "one hundred four"
BNWS: A1 He is fluent in BNWS. He skipped 30 in 34-27 but self-corrected. **A2** he replied correctly for all assessment tasks
Numeral ID: A1 He correctly identified all but 206 on the assessment. "200 – oh – 6" **A2** He replied correctly for all assessment tasks. Uses standard conventions for numbers over 100.
+/- Strategies: A1 He counts on rather than starts from one in addition. He used count down to 12 to solve 16-12 and was one off with "5". He counted up to 10 to solve missing subtrahend for 10 to 6. I gave him a 2 for SEAL but he is close to a 3. Some more work on counting down to and counting down from will help him develop fluency. **A2** He counts on and down to for addition and subtraction tasks. He can use the more efficient stratedgy. He uses fingers to keep track of changes in bare number tasks.
Structuring Numbers: A1 He was scored a 1 but is close to level 2. He can utilize 5 wise and combinations and partitions of 10 to solve but will occasionally regress to counting. For the most part he does not count things out. When he attains fluency he will be a level 2. **A2** He uses reference numbers involving five-wise, pair-wise and ten plus aspect of teens in addition and subtraction of bare number tasks. However, he does not always uses reference numbers to solve. He still uses count on and count down to solve some written expression assessment tasks.
Tens and Ones: A2 He can add involving tens and ones without using materials or re-presentations but reverts to counting by ones when challenged. Is less fluent in solving subtraction. He can add written expressions but not subtraction.
General comments: He uses a pull-off strategy when counting a collection. He retains cardinality. In general he is confident and eager mathematical learner. Quickly "bored" with skill building tasks. Interested in mathematical investigations. Must be discouraged from bragging or calling other students dumb. Very competitive.

Hazel						
Date	FNWS	BNWS	Numeral ID	+/- Strategies	Structuring #s	10"s & 1's
9/18	1	3	1	1	0	
12/12/13	4	3	1	2	2	1b

FNWS: A1 She can count forward to 112 but she could not give the number word after for 11,19,12. She did not drop back to one to solve NWA. **A2** She can count forward to 112 and correctly gave the NWA for assessment items except 65, "57", "70".
BNWS: A1 She can produce the BNWS through 15 down. She could give the number word before to 10 but not higher. There was no evidence she dropped back to one to solve. **A2** She can say the BNWS 15 down. At 23 she could not name after 21. She could not BNWS through decades for 20's, 30's, 70's. She could not give the NWB for 17,21,50,41
Numeral ID: A1 She can identify numerals to 1-10 but not higher. **A2** She could identify 10,15,47,21,80,12,20,66,100. She could not identify 13, 17,99,123
+/- Strategies: A1 She is a perceptual counter and cannot add concealed collections **A2** She uses perceptual replacements to direct model when adding/subtracting screened collections. Is counting on and counting down to as strategies but has difficulty if the problems involves collections outside of finger modeling range.
Structuring Numbers: A1 She can subitize regular dot patterns to 6 and irregular dot patterns to 5. She relies on counting to solve addition and could not create any two hand finger patterns for 1-5 partitions. **A2** She utilizes partitions of 5 and doubles to 10 without counting but needs to use her fingers to model. Over ten she counts to solve.
Tens and Ones: She can skip count by tens on an off the decade but reverts to counting from one in addition with dot strips. When counting off the decade she says "30..34, 40…44, 50…54" instead of 34,44,54.
General comments: A1 She can sequence random numerals 1-10 correctly. She does not use a pull-off strategy for counting a collection. She does retain cardinality. **A2** She uses a pull-off strategy for counting a collection. She sequenced numerals 46-55. She initially sequenced them 51-46. When asked if that was in the order you count she said "no" and sequenced them 46-51. In general she showed with her fingers the answer instead of speaking the answer. If you could not model the answer it was most times the wrong answer.

Jennifer						
Date	FNWS	BNWS	Numeral ID	+/- Strategies	Structuring #s	10"s & 1's
9/19	1	2	0	0	0	
12/19/13	3	3	1	1	1	1

FNWS: A1 She cannot count past 29 in FNWS. She could not give the NWA from 5 and higher. To do so she had to drop back to one and count up. **A2** She can count up to 100 in FNWS. Can give NWA but drops back to 1 to count and name numbers higher than 10.
BNWS: A1 She can produce 10-1 but cannot start at a higher number. She could find the NWB to 10 but had to drop back to one to count out the answer. **A2** She can count BNWS from 10-1 only. Could not give NWB for 8, 11,13,20. She tried to use counting forward to figure out NWB but was unsuccessful.
Numeral ID: A1 She can identify numbers 1-7 but has to count from one to find the name of the number. She missed identified 5,8,9,10. She could not correctly sequence 1-10. She "read" numerals 1-10 despite being out of order. She did not recognize her mistakes. **A2** She could identify numerals 1-10 without counting. She identified 21by dropping to one and counting but could not identify any other numeral higher than 13. She could not identify nor sequence numerals 46-55
+/- Strategies: A1 She can count visible objects but she skips some items. She uses a pull off strategy but is sloppy and loses track of that she has and has not counted. She does retain cardinality. **A2** She can count a collection of 13 and 18. Uses pull of strategy accurately. Can add two collections that are visable. Touches each item as she counts. Was unable to solve any screened tasks. She has gained some skills but remains a perceptual counter.
Structuring Numbers: A1 She can subtize regular dot patterns to 3 but otherwise she remembers the location of the dots and counts them out one at a time. She says she didn't see any groups. She sequentially raises fingers to create finger patterns on one hand. Could not make partitions of combinations of finger patterns to make 5. **A2** She can subitize regular dot patterns to 6 and irregular patterns to 8 but she missed 4. She was able to solved the domino cards. She pointed in the air for each dot and counted out the quantity by 1's. She could make finger patterns to five but she missed 4. She could not make finger patterns of partitions of five on two hands. Made finger patterns to ten but counted by ones. Did not flash patterns.
General comments: A2 This student spent 4 weeks working daily to recognize numerals 1 to 10. She also worked on recognizing teen numbers and number decade families. She also worked for 8 weeks on finger patterns partitions of five. This student has been referred for special education evaluation.

Ben						
Date	FNWS	BNWS	Numeral ID	+/- Strategies	Structuring #s	10"s & 1's
9/17	5	3	3	1	0	
12/13/13	5	5	4	4	3	2

FNWS: A1 He can count to 109 but said 1,000 was the next number. He answered all the tasks on NWA **A2** He counted to 112 and answered all NWA.
BNWS: A1 When counting 15-10 he skipped 13. When counting 34-27 he skipped 33. When counting 72-67 he said 72,71,70,60,69" **A2** He counted BNWS for all assessment tasks. Gave the NWB for all tasks.
Numeral ID: A1 He can ID numbers to 100. He answered 123, 341, 820 correctly but he missed 206 and said 160 then 260 then 206. **A2** He identified all numerals. At first rushed in answering but self-corrected. When asked to slow down he was completely accurate.
+/- Strategies: A1 He is a perceptual counter. He is trying to model addition and subtraction but has difficulty keeping track of addends and subtrahends. **A2** He counted on and down to for addition and subtraction. He is not able to use the most efficient strategy even though he gets the right answer. This student is close to stage 5 but it is for this reason alone he is stage 4. He is also able to use additional strategies for solving written expressions. i.e. two screened subtraction 15 to 11. "I know 1 + 4 is five, so 11 + 4 is 15, so the answer is 4".
Structuring Numbers: A1 He can subitize regular and irregular dot patterns to 6. He can partition and combine to 5 but still needs to count out to solve on occasion. This is a developing skill and has not reached fluency. **A2** He can utilize reference numbers in the range of 1 to 10 and 11 to 20 involving a sub-base of 5 and 10+, and doubles for addition. He does not consistently use this for subtraction and reverts on occasion to counting down-to, to solve.
Tens and Ones: A2 He can add tens and ones with dot strips, written expressions. He has some difficulty with subtraction. He has not been introduced to bundling/borrowing in subtraction.
General comments: He can sequence 45-66. Can count a collection with a pull-off strategy and retains cardinality.

Isabella						
Date	FNWS	BNWS	Numeral ID	+/- Strategies	Structuring #s	10"s & 1's
9/19	4	3	2	1	1	
12/12/13	5	5	4	4	3	2

FNWS: A1 She can produce the FNWS from one to 112. She missed the NWA for 65 "67". She says "a" hundred instead of "one" hundred. **A2** She completed all assessment tasks for FNWS and NWA.
BNWS: A1 She can count down from 23 but missed 30 when counting down from 34. She could not count down from 72 at all. She missed NWB for 100 and called it "90" **A2** She completed all assessment tasks for BNWS and NWB.
Numeral ID: A1 She identified all numerals on the assessment except 99 "90", 123 "103", 820 "eight two thousand". She did not drop back to one to figure out names but she did take a very long time. I asked her if she was counting and she said no. She missed most of the numerals 46-55 and could not order them in sequence. **A2** He identified all numerals in the assessment, completed sequencing task for 46-55 correctly
+/- Strategies: A1 She is a perceptual counter and needs to see the addend collection. She does count on when adding a concealed collection. **A2** She can count on and down to for addition and subtraction. He is not able to use the most efficient strategy even though she gets the right answer. This student is close to stage 5 but it is for this reason and that she still uses perceptual replacements (fingers to keep track), she is stage 4.
Structuring Numbers: A1 She can subitize regular and irregular dot patterns to 6. She counted out the irregular dot patterns by ones. The flashed and answered the partitions and combinations of 5 without counting. She flashed all finger patterns 1-10 including partitions. She does not know the partitions and combinations of 10 and has to count them out. **A2 S**he can utilize reference numbers in the range of 1 to 10 and 11 to 20 involving a sub-base of 5 and 10+, and doubles for addition. She does not consistently use this for subtraction and reverts on occasion to counting down-to, to solve. Uses fingers to keep track to solve and does not have all reference numbers memorized.
Tens and Ones: A2 She can add tens and ones with dot strips, written expressions but sometimes reverts to counting perceptual replacements by ones to solve. She has some difficulty with subtraction. She has not been introduced to bundling/borrowing in subtraction.
General comments: She counts collections of objects with a pull-off strategy and retains cardinality. She recognized the 5 and 10 frames and said she used them in kindergarten