Exploring the Development of Curriculum Materials for Teaching Mathematics in Lakota

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In Sanders (2011) I explored the impact of American Indian self determination policy on the teaching and learning of mathematics in an Oglala Lakota K-8 community school (denoted Lakota Owayawa). I studied the incorporation of what I call self-determination principles in both the makeup and operation of a school along with the impact of these principles in the teaching and learning of mathematics to Lakota K-8 students. Though my study showed a rich incorporation of Oglala Lakota language and culture in the school's operation, with both formal and informal Lakota culture/language curricula, there was a complete absence of both in the mathematics classroom. Consequently, my focus changed from describing what was present to what was absent in the Lakota K-8 mathematics classrooms in regards to Lakota culture/language and why. In addition I analyzed aspects of Lakota culture and language using an ethnomathematical framework developed by Bishop (1991). I focused on developing a Lakota mathematical framework to approach K-8 mathematics classrooms at Lakota Owayawa. With Bishop's framework I was able to describe cultural contexts that show potential towards the possibility of creating mathematics curriculum materials centered on Lakota culture. In this chapter I focus on some of the major findings as they relate to Bishop's ethnomathematical framework. I also discuss the potential of integrating mathematics and the Lakota language for the creation of mathematics curriculum materials written solely in Lakota.

The need for Culturally Relevant Education (CRE)

The National Assessment of Educational Progress's 2011 National Indian Education Study (NIES) shows the current condition of education in American Indian and Alaskan Native (AI/AN) communities. Among the many findings in academic achievement among 4th and 8th grade AI/AN students seen in NIES (2011) are two trends that are disconcerting for AI/AN educators. The first trend shows stagnant test scores in reading when compared to the 2005 and 2009 NAEP reading scores. The second trend is a widening gap between non-AI/AN and AI/AN students in mathematics achievement (NIES, 2011, pp. 2-3). In response to these trends the National Indian Education Association (NIEA) put out a call for "Stronger, more comprehensive efforts to provide all Native children quality teaching and excellent, culturally-based curricula" (NIEA, 2011). This call is justified in part because of the growing body of evidence that culturally responsive teaching and culturally based education have "proven to be effective in improving student success" (NIEA, 2011).

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The growing research in regards to mathematics teaching and curriculum in AI/AN education has shown positive impact in some AI/AN communities. The most documented and best example of the implementation of a culturally responsive pedagogy (CRP) and culturally responsive curriculum (CRC) development along with rigorous testing of both can be seen in the copious amount of research centered in the Yup'ik Eskimo communities in Alaska under the direction of Jerry Lipka and the Ciulistet teaching group. Most of the initial investigations into CRP and CRC can be seen in Lipka (1989, 1991, 1994a, 1994b), Lipka & McCarty (1994) and Lipka & Mohatt (1998). This early work led to the development of ideas regarding the type of pedagogy most at home in Yup'ik Eskimo classrooms. In addition it provided the basis for the development of CRC centered on traditional subsistence practices eventually leading to the creation of Math in a Cultural Context (MCC) curriculum materials.

Research on the effectiveness of the pedagogical practices used in teaching MCC have arisen since the mid-2000s (Sternberg et al., 2006; Lipka et al., 2005; Lipka et al., 2005c; Lipka et al., 2007; Webster et al., 2005; Kagl, 2007) and also on the impact of MCC on student achievement (Lipka & Adams, 2004; Sternberg et al., 2006, Lipka et al, 2005); Lipka et al. 2005b; Kisker et al., 2012; Lipka et al, 2007; Rickard, 2005, Kagle, 2007). This research confirms that mathematics taught in a culturally appropriate way using culturally based contexts as curriculum improves mathematics achievement among AN students.

Despite the growing body of research regarding the positive impact of the inclusion of CRP and CRC both seem to be minimally included in the methods and materials in the education of AI/AN students. The 2011 National Indian Education Study states the levels of incorporation in both teachers of mathematics and for AI/AN students learning mathematics:

- 76% of AI/AN fourth-graders had teachers who reported never having them study traditional AI/AN mathematics.
- 7% of AI/AN eighth graders reported knowing a lot about AI/AN systems of counting.
- 2% of AI/AN fourth-graders had teachers who reported relying a lot on AI/AN content or cultural standards when planning mathematics lessons.
- 60% of AI/AN eighth-graders had teachers who reported never having them solve mathematics problems that reflect situations in the AI/AN community. (NIES, 2011, pp. 30-33)

The development of CRE in self-determination principles

Culturally responsive education (CRE) dates back in AI/AN education at least to the 1928 Meriam Report (Brayboy & Castango, 2009). The Meriam Report (1928) focused on the inadequate assimilation efforts put forth by the federal government in regards to its dealings with AI peoples. It advocated for the use of Indian cultures and languages in the formal education of Indian students. Though the language was present for the inclusion of AI languages and cultures

in the schooling of AI children in the Meriam Report, it wasn't until the 1960s when it actually occurred. Favorable legislation coupled with efforts in Indian communities to gain local control of schooling brought concentrated, lasting efforts in the push for the incorporation of Indian cultures and languages in the education of Indian students.

Much of the initial work in this area occurred in the Rough Rock Demonstration School (RRDS) in Rough Rock, Arizona in the Navajo Nation under the direction of Robert A. Roessel. The type of schooling advocated at RRDS included aspects of what would later become pillars in CRE. Included in these early explorations into local control was a focus on curriculum centered on the culture of the local people, the inclusion of the Navajo language and their "etiquette, belief and lore" (Reno, 1967, p. 3). The efforts at RRDS were noticed nationally by AI educators. Other AI communities soon pushed for an inclusion of local traditions, languages and customs in the education of AI youth. Among these communities were the Ramah Navajo who opened the first locally controlled secondary school in 1970 (Manuelito, 2005) and the Oglala community on the Pine Ridge Reservation who sought a demonstration school of their own in 1970 as well. The spread of local control of the education system also occurred at the post-secondary level. Navajo Community College (now Diné College) opened in 1968 followed by the Lakota Higher Education Center (now Oglala Lakota College) in 1970 and Sinte Gleska College in 1971.

With the push for local control and the subsequent development of CRC a categorization of important aspects involved in shaping the infusion of culture and education can occur. These characteristics stem from the early literature as the push for local control took shape (Lose, 1962, Nash, 1964, Forbes, 1966; Reno, 1967; Roessel, 1968; Pfieffer, 1968; Witherspoon, 1968). I call the categorization of these characteristics the "seven principles of self-determination." They are important to classify because they offer a baseline to compare efforts in melding AI/AN cultures and languages at the local level in the formal education of AI students. They include: 1). Schools are Indian run; 2). Schools are Indian-centered; 3). Schools employ a bi-cultural educational philosophy which includes bi-lingual programs, an infusion of local culture in school structure and curriculum and attention given to developing skills necessary for success in dominant culture; 4). Elders and community provide direction and purpose of school; 5). Elders and community members are involved in the creation of curriculum materials; 6). Students are knowledgeable and appreciative of local Indian culture (evidence of language geared to self-esteem/self-perception of students) and 7). Local control of schooling meant to strengthen tribal governments by developing "qualified people for leadership roles" (PL-93-638).

My categorization is not unique among AI educational researchers. Many of these principles are reflected in Demmert and Towner's (2003) review of the literature of culturally based education. The important point is that CRE is dependent on local knowledge, it pays attention to local customs, it incorporates the local native language and it also is dependent on elders and community members for guidance and acceptance.

The early mathematical language in American Indian education

Mathematics was not part of the early push to integrate local AI/AN cultures and languages into curriculum in AI/AN communities in the 1960s and 1970s. The earliest language came in the1980s. It was primarily concerned with mathematics achievement (Cheek, 1984a; Cheek, 1984b; Scott, 1983; Trent & Gilman, 1985; Bradley; 1984; Schindler & Davison, 1985). Culturally based programs in mathematics and pedagogical practices are among the suggestions to counter the lack of mathematics achievement of AI students. Cheek (1984b, p. 18) also suggested that researchers examine the process of developing a culturally based mathematics curriculum. Approaches should be identified that have proved successful when tribe and school have worked together on similar projects in other disciples. Questions that should be explored included: "How much formal mathematics education do community members need to work successfully with the school? Must teachers also be tribal members?" What attributes of the school and the community are most important in developing a successful program?

Enter ethnomathematics

The push to consider the teaching of mathematics in a cultural manner with cultural contexts in AI/AN communities provided the impetus for research in Indian education but it wasn't until the formulation of developing ideas within the field of ethnomathematics that what this might entail crystallized. Ubiratan D'Ambrosio, a Brazilian mathematician, began the discussion around non-Western mathematics in the late 1970s. He classified ethnomathematics as a field of study that lay in the intersection between anthropology and mathematics: "Making a bridge between anthropologists and historians of culture and mathematicians is an important step towards recognizing that different modes of thought may lead to different forms of mathematics; this is the field which we may call 'ethnomathematics'" (D'Ambrosio, 1985, p. 44). With the development of ethnomathematics as a field of study, and with the intent of "collecting examples and data on the practices of culturally differentiated groups" (D'Ambrosio, 1985, p. 47) a foray of research into indigenous cultures across the globe occurred. The purpose for this effort was to seek various forms of mathematics embedded in cultural activities and contexts.

Ethnomathematics helped change the perception of mathematics from one that was centered on certain processes (algorithm, proof, and structure) to one that is embedded in all cultures and as such is present in cultural activities the world over. This is important to note since mathematics has had the perception of being "above culture" and therefore accessible only in certain ways. In a discussion about ethnomathematics, Ascher and D'Ambrosio (1994) spoke about the impact of this field on the perception of mathematics. "Through the work with the quipas and your further work in other cultures you were able to generate a new conception of mathematics" (D'Ambrosio, 1985, p. 37). This came on the heels of the understanding that mathematics itself is not definitively defined even by mathematicians. Asher writes,

> I [Ascher] concern myself with mathematical ideas. That focus on, and talks to, what people have in common. Those ideas have to do with number, loci, and spatial configuration and, very important, the combination or organization of those into systems and structures. (p. 37)

In essence, this view of mathematics, broadly defined, allowed for an inclusion of mathematical activity and thought found in other cultures and also showed that mathematics "is more than technique" (D'Ambrosio, 1985, p. 37). What this did was to allow the bridge between activity and what most people consider mathematics – abstract, rigid and done a certain way and in certain places. "The carpenter is definitely dealing with mathematical idea; the mathematician who set those strictures on the problem was dealing with an idea. They are *both* important, but they are *different*. And, they are *linked*" (Ascher, p. 38, emphasis in original)

Ethnomathematics not only shows mathematics in activity but also the impact of culture in the development of mathematics. Mathematics did not develop in a vacuum. It was created, revised, redone, reshaped and added onto for more than three millennia by many cultures including the Greeks, the Babylonians, the Egyptians, the Arabs and Western Europeans. So when we think about mathematics, how it is taught and perceived, especially in relation to culture we realize it permeates everything; it is everywhere and as such everyone engages in mathematical activity. "Ethnomathematics relates to life in all its aspects. Indeed, it is a description of the evolution of mankind through diverse ramifications – that is, the civilizations, communities, families and individual. This calls for deeper recognition than is found in most anthropologies" (Asher & D'Ambrosio, 1994, p. 39). Barton (1996), in highlighting the development and changes within the field of ethnomathematics speaks to the importance of giving mathematics cultural connections/contexts, "Acknowledging the cultural component of mathematics will enhance our appreciation of its scope and of its potential to provide an interesting, artistic and useful view of the world" (p. 229).

With the field of ethnomathematics now defined many mathematicians and educational researchers began the study of mathematical cultural practices the world over (Knight, 1984; Gerdes, 1988a; Gerdes, 1988b; Graham, 1988; Turnbull, 1991; Selin, 2000). This literature provides, if nothing else, more proof to the notion that we all engage in mathematical activity on a daily basis.

The usefulness of ethnomathematics

With ethnomathematics resituating mathematics in culture it became important to decide what activities constituted mathematical behavior. The categorization of cultural mathematical activities from which to analyze non-Western mathematical contexts was described in D'Ambrosio (1985). There he classified the following activities as ethnomathematical in nature: "counting, measuring, classifying, ordering, inferring, modeling" (p. 46). Bishop (1991) proffered a slightly different categorization of mathematical activities used to help develop mathematical thinking. These were termed the six universal mathematical activi-

ties (SUMA). These activities included counting, locating, measuring, designing, playing and explaining. Bishop (1991) spoke of the importance of these activities in developing various aspects involved in mathematical thinking:

> counting develops number language, number imagery and number systems, locating develops spatial language, images and coordinate systems, measuring develops the language of quantifiers, units and measurement systems, designing develops images, shapes and geometrical ideas. Playing seems to develop the idea of 'game.' (p.44)

Ethnomathematics and AI/AN cultures.

These classification systems have provided researchers studying AI/AN cultures a bridge by which the discussion of tribal-specific mathematics can begin. Bishop's (1991) categorization was used in Barta et al. (2001) and Barta and Shockey (2006) to analyze mathematics in the Shoshoni and Northern Ute cultures, respectively. Evidence of these ethnomathematical categorizations are also found in the work of Lipka (1994a) where descriptions of the Yup'ik Eskimo counting system, the geometry in the designing of Parkas and the importance of abstract symbols in 'story knifing' are provided.

The mid-1980s marks the formal marriage of mathematics and Indian cultures as defined by ethnomathematics. Closs (1986) provides the first work describing this intersection. In his seminal work he analyzes counting systems, calendars and geometry used by indigenous peoples of the Americas. In other research concerning mathematics and AI/AN cultures many other cultural practices from various tribes emerged over the years (Pixten et al., 1987; Moore, 1988a; Moore, 1988b; Lipka, 1989; Hankes, 1998; Souhrada, 2001; Orey, 2000; Barkley & Cruz, 2001; Nueman, 2003; Engblom-Bradley, 2006; Eglash, 2009; Rauff, 2009). The analysis of AI/AN cultural practices and activities are a trend that has gathered much steam relatively late in the development of culturally responsive curriculum materials. It is evident that Indian cultures, their educational practices and cultural activities have gained the attention of mathematics educators since the mid-1980s and they continue to be contexts for inclusion in the field of ethnomathematics.

Native languages and ethnomathematics

Since one of the important facets of self-determination and local control is the maintenance of culture and language what purpose or role might Native languages play in looking at mathematics in AI/AN cultures (since we have already seen how aspects of culture have been included)? For the most part the research is quiet on this topic. Hankes (1998) described the ways in which the Oneida and Lakota expressed numbers in the language, and its inclusion in the teaching of Yup'ik students is discussed in depth in Lipka (1994b) and among his constituents (Lipka & Mohatt, 1998). Lipka (1994b) also described the power struggle and politics involved in using the Yup'ik language to teach in the formal classroom. The teaching of mathematics in the language came with some logistical issues,

for instance, not all teachers who taught in the mostly rural AN communities were from the tribe and therefore not typically able to speak the language, let alone teach mathematics in the language. Also there was a struggle within the Yup'ik community as to whether or not the Native language should be used in the formal classroom in the first place. Barta et al. (2001) and Barta & Shockey (2006) each looked at the use of the language to classify objects, numbers, etc. but did not mention the importance of using the language to teach mathematical concepts. As the push for self-determination aspects of local control into the mathematics classroom, of which the inclusion of native languages are deemed very important, continues one cannot help but note the absence of mathematics curriculum material written and made available in local native languages.

Findings in relation to SUMA #1 (counting) and SUMA #2 (measuring)

Bishop (1991) describes six universal mathematical activities (SUMA) which he argues are common to all cultures and necessary to construct mathematical ideas. These SUMA include counting, measuring, locating, designing, playing and explaining.

> All of these activities are motivated by, and in their turn, help to motivate, some environmental need. All of them stimulate, and are stimulated by, various cognitive processes, and I shall argue that all of them are significant, both separately and in interaction, for the development of mathematical ideas in any culture. Moreover all of them involve special kinds of language and representation. They all help to develop the symbolic technology which we call mathematics. (p. 23)

I (Sanders, 2011) used this classification framework to look at the mathematics that is inherently a part of Lakota culture. The initial purpose of this was to develop a "Lakota mathematics" to inform myself of the possible areas that might be presented in the K-8 mathematics classrooms I would be observing at Lakota Owayawa. I interviewed elders, Lakota educators and Lakota language teachers to help develop this framework. As I progressed through my study I began to see that nothing in the mathematics classroom was presented with a Lakota cultural context and there was no use of the Lakota language in the mathematics classroom. However, I was able to see the use of mathematical concepts as contexts in the Lakota language classrooms. I identified four main reasons for the absence of Lakota language and culture in the mathematics classroom: (1) The heavy influence of NCLB and a reliance on standardized test scores as a marker for mathematics achievement which lead to a fidelity to the curriculum mandate whereby strict adherence to a certain textbook series and assessments was prescribed. (2) The middle school mathematics teacher was white and a first year teacher with no knowledge of Lakota culture and language. (3) There was no communication between the Lakota studies department and the mathematics teachers to aid in the process of integrating Lakota culture and language into

the mathematics classroom. (4) A view that mathematics was an in-class only activity and not a part of our daily lives.

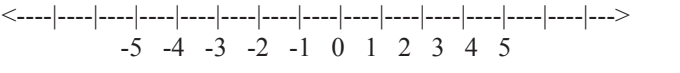
Below are some my findings regarding two of the SUMA, counting and measuring. It is beyond the scope of this paper to include a description of all six universal mathematical activities because of the sheer volume of the material (see Sanders (2011) for a description of the other four SUMA). Instead, I will focus in depth on the Lakota counting system and the language used in measuring in the hopes that my description captures the essence of the findings for all SUMA along with implications towards integrating the Lakota language with mathematical content. In the realm of counting I will describe the base ten Lakota counting system, very large numbers, very small numbers and numbers between numbers (rational numbers). We will also look at the origin of Lakota numbers and at the language used in expressing arithmetic operations. For the activity of measuring I will describe units, especially in standardized units in relation to time, distances, and rates.

SUMA #1: Counting:

> In summary then, counting, which we may perhaps have thought to be an important but relatively simple activity, is shown by this cultural perspective to involve many aspects, with subtle variations in the type of language and representational forms used to communicate products of counting. It is an activity relating firmly to environmental needs, and is subject to various social pressure. It is stimulated by, and in turn affects, the cognitive processes of classifying and pattern-seeking, and in our search for cultural 'universals' of mathematics it clearly offers many ideas. (Bishop, 1991, pp. 27-28)

The number line and sets of numbers: I approached the look at Lakota counting from a mathematical perspective, organizing it around the concept of a number line while keeping in mind some sets of numbers expressed in Western mathematics. From this perspective we have a starting point and the notion that there exist numbers whose values increase as they lie further in one direction, (in the positive direction – numbers bigger than zero) and whose values decrease as they are counted in the opposite direction (in the negative direction – numbers less than zero). The number line in Western mathematics is home to all sorts of numbers, though typically we see in mathematics curricula, especially at the elementary level, only integer values and a limited number of rational numbers. Figure 1 is a representation of a number line with which most people are familiar.

Figure 1. Number Line Representation



There are four sets of numbers recognized in mathematics pertinent to this discussion of Lakota numbers. I mention these sets of numbers because they will offer, like the number line, a way to approach Lakota numbers and help us make judgments as to what is present and what is lacking, from a mathematical perspective. The four sets of numbers include the counting or natural numbers, whole numbers, integers and rational numbers. Counting numbers include the following numbers {1,2,3,4,5,...}, whole numbers include the counting numbers and zero {0,1,2,3,4,5,...}, integers are the set of whole numbers and their opposites {...-5,-4,-3-,2-,1,0,1,2,3,4,5,...} rational numbers are the set of numbers represented as the quotient a/b where a and b are integers and $b \neq 0$. Each of these sets of numbers are integral in the development of mathematics over time and necessary to study mathematics further. Sets of numbers come into being because either mathematical development demands their creation or they are derived into existence because of observations made in developing human endeavors.

The number line can be used to show where counting numbers, whole numbers, integers and rational numbers (and irrational numbers) lie in approximate relation to each other; it thus provides a good framework to explore the types of numbers available in the Lakota language. In addition to looking at the types of numbers present and how to count in the Lakota language I also discuss some interesting cultural and linguistic issues regarding Lakota culture and counting.

Zero and infinity: As a starting point for my look at Lakota numbers I began with zero and mention the concept of infinity while giving the names of most of the counting numbers within this range. In Lakota, zero (0) is expressed as tákunišni, which means "nothing." This is not a numeral per se. The concept of infinity is expressed as oihaŋke šni waniče, meaning, "without end." Some elders and educators expressed this differently, "Oihaŋke šni waniče … Oihaŋke šni wanilya – it means without end. There is no end to it." Below I give the Lakota numbers 1-20 (see Sanders, 2011 for larger numbers).

1 Through 10: One (1) is spoken in Lakota in two ways, as waŋči when actually counting objects, e.g. 1,2,3,etc. otherwise it is wanži. White Hat (1999) spoke a little about the difference between wanci and wanji (wanji and wanži are equivalent here, just spelled differently because of differing orthographies): "Wanci is used when counting items or when reciting the numbers. It is usually used by itself rather than in a sentence that identifies the item being counted. Wanji in Lakota thought means "one of them." There are at least two items but wanji specifies which one" (p. 20). The other numbers are stated in Lakota as follows: (2) nuŋp or nuŋpa, (3) yamni, (4) tópa or tób, (5) záptaŋ, (6) šákpe, (7) šakówiŋ, (8) šágloǧaŋ, (9) napčiyuŋka or napčiyuŋk, and (10) wikčémna. As we see the numbers two, four and nine can be expressed in two ways in the Lakota language. An explanation for the multiple ways of expressing certain numbers can be found in the way the Lakota speak. There is a very formal way of speaking the Lakota language and then there is another way called "fast speech" or "rapid speech" where oftentimes certain words are combined and endings of some words are cut and then added to the next word. White Hat (1999) explains, "Sometimes in rapid speech, nupa will become shortened to nup or num because it makes an

easier connection with the next word. This difference depends on the speakers preference or tiospaye (family group)" (p. 21).

11 Through 19. The numbers 11 through 19 can be expressed in two ways also – by either keeping the tens value, signified by wikčémna, in front of the number and using the term "aké" as a way to add the ones value to the tens value. The other way is to disregard the tens value altogether but keeping the aké to let the hearer know that a tens value is assumed in the number. "Most of the time Lakhotas drop the wikčémna, and use only the aké portion of the number (Rood & Taylor, 1976, pp. 5-4)." Table I below shows the next nine digits.

Table I. Lakota numbers 11- 19

(11) wikčémna aké wanži or aké wanži
(12) wikčémna aké nuŋpa or wikčémna aké num, or aké nuŋpa or aké num
(13) wikčemna aké yamni or aké yamni
(14) wikčémna aké tópa or wikčémna aké tób or aké tópa or aké tób,
(15) wikčémna aké záptaŋ or aké záptaŋ,
(16) wikčémna aké šákpe or aké šákpe,
(17) wikčémna aké šakówiŋ or aké šakówiŋ,
(18) wikčémna aké šágloğaŋ or aké šágloğaŋ,
(19) wikčémna aké napčiyuŋka or wikčémna aké napčiyuŋk or aké napčiyuŋka or aké napčiyuŋk

Numbers between numbers – rational numbers: Some fractions can be expressed in the Lakota language. One-half is okhise. Okhise also means fifty-cents or a half-dollar in the Lakota language. All elders easily spoke this fraction. One-fourth was a fraction that came with a little more difficulty. One elder stated one-fourth to be šokéla, which is the Lakota word for twenty-five cents, a quarter. And still a speaker stated: "I wouldn't know how. It's something I would have to think about." Speaking with a parent I asked, "In your own experience, speaking the Lakota language, would you know how to say "one-fourth" or "two-thirds"?

> I would know "half," but I wouldn't know "one-fourth" or "two-thirds." It would be čonala (a few). There are words that are descriptive. The way we say things is descriptive. If I were to translate fractions, I would say okhise and then that's money, too. "Fifty cents" is okhise. And "fourth," I'm not sure, "two-thirds," I'm not sure.

All other fractions either did not come or they came with great difficulty for most Lakota speakers I interviewed. When I asked a Lakota speaker to express fractions like one-eighth or two-thirds he responded: "This is...one-eighth, I don't know. These two are kind of like – I've never used them or heard them, so I wouldn't know. Or even two-thirds, I wouldn't be able to do that." Riggs

(1893) affirms this notion that expressing fractions outside of one-half was not a natural part of the Dakota language:

> The Dakotas use the term hanke, one-half; but when a thing is divided into more than two aliquot parts they have no names for them; that is, they have no expressions corresponding to one-third, one-fourth, one-fifth, etc. By those who have made some progress in arithmetic, this want is supplied by the use of 'onspa' and the ordinal numbers; as onspa iyamni (piece third) one-third; onspa itopa (piece fourth), one-fourth. (p. 73)

A note is provided below this explanation in Riggs (1893) stating, "The language more recently adopted is kiyuspapi, divided. So that one-fourth is topa kiyuspapi wanzi" (p.73). So, using this notation of placing the number one (wanci), the dividend, and the divisor, four (topa), in the example given allows speakers a possible way to express all fractions as well. Thus it would seem that two-thirds could be expressed as yamni khiyušpapi nuŋpa. That is, two divided into three parts. Again, from a mathematics perspective could this way of expressing fractions be of use in the mathematics classroom since it is a very descriptive way of explaining exactly what a fraction is? So, 1/4 can be explained, and has to be explained in the Lakota language, as "one divided into four parts."

A Lakota educator had a different explanation for the expression of fractions other than one-half in the Lakota language stating:

> Okay, fractions, like 1/4...(writes on board), this 1/2 is okise, tópa khiksa is 1/4, šágloğaŋ khiksa (1/8) that's eight , aké šakówiŋ khiksa – sixteenths, and they keep going on...by halves...okay.... wikčémna yamni saŋm nuŋpa kihiksa – 1/32. Keep going into fractions like that...or if you are going to do thirds. yamni ksa...one-third.
>
> (So its just the name of the number and cutting?) "Yeah, the cutting."

The origin of Lakota numbers

In my examination of Lakota counting I also included some discussion of the origin of Lakota numbers and the use of fingers to count. It will become apparent that these areas are by no means settled and that further study is necessary to get a better grasp of the origins of Lakota numbers and how they might have developed over time.

Rigg's (1893) description of the use of fingers during counting implies a base-ten number system intact in Dakota culture prior to Western contact. In this description is also an illustration of how the fingers were used to keep track of place value:

> In counting, the Dakotas use their fingers, bending them down as they pass on until they reach ten. They then turn down a little finger, to remind

> them that one ten is laid away, and commence again. When the second ten is counted, another finger goes down, and so on. (p. 47)

No one that I interviewed in my study was able to tell me from whence the names for Lakota numbers originated. There were no attempts made, for instance, to show that waŋži had an association with anything other than its meaning as a number. Riggs (1893), however, gave a reasonable account of the origins of some of the names of numbers in Dakota:

> It is an interesting study to analyze these numerals. It has been stated above, that the Dakota, in common with all Indians, it is believed, are in the habit of using the hands in counting. It might be supposed then that the names indicating numbers would be drawn largely from the hand....
>
> 1. Wanca, etc. from wan! interjection – calling attention – perhaps, at the same time, holding up the little finger.
> 2. Nonpa, from en aonpa, to bend down on, or place on, as the second finger is laid down over the small one; or perhaps of nape onpa, nape being used for finger as well as hand.... (pp. 48)

Riggs (1893) was making an educated guesses as to the origin of the names of numbers in Dakota. It would seem a near impossible task to try to find the origin of the names of numbers in Lakota since the language is so old and its roots of it are clouded in the mist of time.

Arithmetic operations in Lakota

Addition: I showed an elder the following mathematical expression and asked him to say it in Lakota: 5 + 3 = 8. He responded, "Zaptaŋ na yamni he šágloğaŋ." The language used by this elder was also used in a middle-school Lakota language class in problems which were demonstrated on a worksheet:

wanži na wanži = _____ šákpe na šákpe = _____

Another elder offered this as another way of stating the mathematical expression 8 + 3 = 11. "Šágloğaŋ akta saŋm yamni kin aké wanži." Saŋm and na in Lakota are used in the same way, but saŋm seems more likely to be traditional.

A parent and former Lakota language teacher mentioned that she teaches her child at home in the Lakota language all the operations – addition and subtraction as well as multiplication and division. She stated, "Me and my little grandkid were doing pluses. And before Christmas, the other granddaughter, she was doing that, too, pluses...nuŋpa na wanži tona he?

Clearly addition is something that is easily expressible in the Lakota language and is being used in the Lakota language classroom. Using the word na for the term addition and also in place of the symbol for addition, seems to be customary.

Two other words that came into my conversations with elders when speaking of addition was akaǧapi – which means "something made in addition to; falsehood; exaggeration (BLED, p. 67) and akhe' ȟokte which, an elder explained, meant "add some more."

Subtraction. A worksheet in the middle-school Lakota language class where subtraction was being taught used the following examples:

wanži yuȟeyab iču wanži _____
šakówiŋ, yuȟeyab iču záptaŋ_____

Yuȟeyab iču means to remove something. So wanži yuȟeyab iču wanži means to remove one from one and šakówiŋ, yuȟeyab iču záptaŋ means to remove five from seven. Thus yuȟeyab iču is used to signify subtraction in the mathematical sense. The mathematical expression for subtraction was stated by a Lakota educator as follows: 9 - 5 = 4. Napčiyuŋka etaŋ záptaŋ yuȟeyab iyaču kin tópa. Literally this means, nine - from five - you remove - and have four. That is, five removed from nine leaves four.

A key question here is the need to extend this notion to include negative numbers or at least a way to express negative numbers. If we asked the question in Lakota: Zaptaŋ etaŋ šakowiŋ yuȟeyab iču. Tóna luha he? What would a Lakota person say in response? Slolye šni (I don't know.)?

Multiplication. The two operations, multiplication and division are expressible in the Lakota language. Let me reiterate here the notion that these concepts weren't always easy to express for most of the speakers even though they do exist. One elder stated: "Multiplying....let's see...(long pause)... I really don't understand that word. When I was growing up we hadn't spoke English...we spoke Lakota." Another elder stated, "I couldn't think of it right away." More work needs to be done in looking for ways in which Lakota speakers can find contexts for multiplication and division.

A Lakota educator had written the multiplication problem 5 x 2 on a chalk board for me during our interview when I asked him about multiplication and the Lakota language and stated, "Two times five.... Zaptaŋ nuŋpa akhiyagle." He then said "Loyuota -means you multiply. Zaptaŋ nuŋpa akhiyagle loyuota." Then he asked me, Tóna luha he? (How much do you have?). The mathematical expression 3 x 4 = 12 was stated by another Lakota educator as follows: 3 x 4 = 12. "Yamni tópa kigle ilawa kin aké nuŋpa."

SUMA #1 Summary

The Lakota have a base ten number system by which they count. The counting system may be base ten because of the cultural way of using their fingers to count in a systematic fashion. The set of counting numbers [1, 2,3,4...] and the set of whole numbers [0, 1,2,3,4,5,6…] can be expressed in the Lakota language. Negative integers [...-1, -2, -3, -4, -5] are completely omitted, that is, they do not exist in the language and neither do most rational numbers, i.e., numbers that can be expressed as an integer divided by an integer [1/2, 5/8, 3/4, 2/3, etc.],

though as seen in Riggs (1893) a system for expressing these had been devised by the Dakota in the 19th century. The Lakota can express certain fractions in the language, namely 1/2 and 1/4, both of which are references to a half-dollar and a quarter-dollar coin, respectively. Zero and infinity are also expressible in the language, though they don't necessarily have a mathematical connotation. Lakota people also can state very big numbers, though with some difficulty in doing so. The term for a "million" is not an agreed upon term.

It is important to keep in mind as we try to see how we might come to integrate the Lakota language in the mathematics classroom that many mathematical terms regarding the expression of numbers will need to be invented in the Lakota language. If negative numbers and fractions continue to be by passed, then an inclusion of arithmetic operations (which are expressible in the language) will continue to be incomplete, i.e., even though there are ways to describe arithmetic operations in the language (addition, subtraction, multiplication and division) there do not exist ways to describe such things as the sum of 5 and - 8 or the quotient 3 divided by 32. These two mathematical expressions can be stated in the language, but their answers cannot. So as the push to include local Lakota culture and language in the schools continue, we must also consider what this means for the mathematics classroom. If it is deemed reasonable and important to create a mathematics in Lakota, a closer look at the Lakota language and worldview in regards to mathematics needs to be taken up by the local community and instituted mathematically in the school and in the classroom.

SUMA #2: Measuring

The next universal mathematical activity is measuring. Measuring, because it necessarily deals with comparing and ordering, both of which are tied to the notion of scales, is a very rich context for the learning of mathematics. Measuring in this study included taking a look at how the Lakota kept track of time historically and in present times; this meant looking at how the years, seasons and months were noted. With the coming of Western culture and Christianity the Lakota began to conceptualize time not only in winters and moons but also in the in-between (weeks) and also began to number days. Because of the influence of the clock time took on new forms of expression – the Lakota adapted words for hours and minutes and found a new way of telling time. Distances provided another context for measurement. In Lakota culture distances were expressed in terms of time and thus offered a way of looking at space and time as interrelated phenomena rich in description. Since distance is not separated from time (or effort) the concept of rates was explored.

Bishop (1991) states measuring is "concerned with comparing, with ordering, and with quantifying qualities which are of value and importance" (p. 34). He calls the words used in comparing within a culture "comparative quantifiers" (p. 35), words like, "heaviest, longer, faster, slowest, etc." (p. 35). In Lakota culture measuring is done with minimal precision in many cases. There are words in the Lakota language for tall and short, big and small, hot and cold, etc. All of these are relative terms, that is, there is not a universal scale of measurement for

these things. This "personal scale" is reflected in the language the participants in this study used when describing the measuring of something. For example, An elder talked about her method of measuring when I prompted her about her use of measuring utensils in her cooking, "I know how much flour I'd use. (Is there a name for how much you put in?) Probably a pinch of that...(laughs) a handful of this... (laughs). I remember my grandma making bread, she used her hands. I never saw her using a cup or a spoon to measure." The scale used in these two instances of cooking by the woman I interviewed, and her grandmother speak of the use of the body, the hands and fingers (a handful of this, a pinch of that), to measure the ingredients used in making bread. This personal scale is not unique to Lakota people.

Often, because of the lack of a "universal scale" within the Lakota language Lakota speakers will rely on the use of English for exactness. For example, in discussing miles per hour an elder stated: "When I was a boy, we would emphasize going fast as 50 miles an hour. "Aata 50 miles an hour ki glikiya." "Geez, that was fast!" Or when asking an educator about how he would express temperature he stated, "You'd probably have to use the English understanding of it. For 75 degrees, okȟate, means it's hot, not that hot, lila okȟate is really hot. Oluluta means kind of beyond hot. You have to use those terms and then (the) degree, with the number." Exactness takes a back seat to practicality in many instances and practicality oftentimes came out in the form of efficiency in the use of the English language. It was easier for many to express some types of measurements using the English language.

Measuring Time

Years: The passing of years is stated by the number of winters that have passed. Waniyetu is the Lakota word for winter. "The Dakota have names for the natural divisions of time. Their years they ordinarily count by winters. A man is so many winters old, or so many winters have passed since such an event" (Riggs, 1893, p.165). (His emphasis) The Lakota kept track of the passing of years with a tool called the "winter count." Each band (thiyošpaye) had a person designated as their Keeper who took care of the winter count. The winter count was a collection of symbols drawn on animal hides. Each symbol represented one major event that occurred during a year:

> Winter counts are histories or calendars in which events are recorded by pictures, with one picture for each year.... The Lakota call them waniyetu wowapi. Waniyetu is the word for year, which is measured from first snowfall to first snowfall. It is often translated as "a winter." Wowapi means anything that is marked on a flat surface and can be read or counted, such as a book, a letter, or a drawing. (Smithsonian National Museum of Natural History, n.d.)

The winter count, then, was essentially a way for the Lakota to record their history through the passing of time – one event per year. (The winter count did

not surface in my conversation with elders and Lakota educators and so I do not know the extent of their knowledge about the topic.)

Seasons: There are four seasons in the Lakota year. One educator told me that in spite of having names for the four seasons there is no Lakota name for season per se, "'Seasons,' there really isn't any word for seasons. What was that word I was using? I think we were saying 'makpašpe' , which is the four – right there again, the four. I think that's what we were using. And 'years' is omakȟa, 'months' is 'wi.'" The seasons are expressed in the Lakota language as follows: waniyetu (winter), wetu (spring), bloketu (summer) and ptaŋyetu (autumn).

Months: Months are measured in "moons" as in the number of moons that have passed. As seen above, wi, is the Lakota name for moon and thus month. According to some of the Lakota participants in this study there were thirteen months in the Lakota year. This was somehow adjusted so that the months did not get too far off track.

Weeks: The Lakota did not divide the month into weeks as is the custom in modern times. "They have no division of time into weeks (Riggs, 1893, p. 165)." The current Lakota word for week is oko. Oko means the "space between; crack, hole, gap, opening, aperture" (NLD, p.165). If week in Lakota refers to "between" or to "a gap or opening the questions remain, between what? or a gap in what? A Lakota educator stated, "Oko really means there is an opening. I think that this word was selected for one week, the Lakota month is from one moon to the next and the settlers chose to divide a month into four weeks, so in essence oko' became each of the four weeks in between two moons."

Days: The Lakota did not name days prior to the coming of the white man. Monday translates to the first day, Tuesday is the second day, etc. Saturday refers to cleaning, washing up. One educator stated,

> I understand that originally there was no word for Saturday, but when days of the week were established with the coming of the settlers, then the days were numbered and repeated every 7th time. (Saturday) became known to the Lakota it was called OWANKA YUJAJAPI. The Christian religions that came into Indian country, the Episcopal, Catholics and Presbyterian...is probably what led to the naming Saturday as Owankayujajapi Anpetu, it was a day to clean after working for 5 days, Monday to Friday, to clean up in preparation for Sunday. Sunday was viewed as the day of rest and prayer.

In my interviews with a Lakota educator Saturday translated meant "the day you wash the floor." The days that this elder/educator gave me matched with the names of days given in NLD:

Monday – Aŋpetu Tȟokahe, Anpetu Tȟokaheya (the first day)
Tuesday – Aŋpetu nuŋpa (day two)
Wednesday – Aŋpetu Yamni (day three)
Thursday – Aŋpetu Topa (day four)

Friday – Aŋpetu Zaptaŋ (day five)
Saturday - Owaŋkayužažapi (day to wash the floor/clothes)
Sunday – Aŋpetu Wakȟaŋ (holy day)

Telling Time: The time of day was approximate in Lakota culture. However, with the coming of the clock the language goes from the telling of time via actions in nature (i.e., the position of the sun and stars) to the telling of time via mechanical apparatuses. One elder told me that her grandmother used to tell time by planting a stick in the ground and then looking at the shadow to get an approximate time, "They used the sun. My mother's mother used a circle they never had a clock, what they do is draw a circle and put a stick in the middle... it kinda....if it was noon there was no shadow, if it was one o'clock there is a shadow...by shadows (they told time)." Hours, minutes, and seconds were foreign to Lakota culture.

The Lakota use the clock to tell time nowadays. Mazaškaŋškaŋ is the word for clock in the Lakota language. It literally means "moving-iron" which is a reference to the moving hands on a clock or the moving of the pendulum back and forth.. In stating a specific hour one would state mazaškaŋškaŋ followed by the number indicating the time of day. So, for instance, one o'clock would be mazaškaŋškaŋ waŋži, two o'clock would be mazaškaŋškaŋ nuŋpa, etc. An educator had this to say about telling time: "Today we use the clock (looks at clock) 'Waŋna šakpe, šakpiyape samiya,' then 'Mazaškaŋškaŋ, škaŋškaŋ wikčemna nuŋpa.' Twenty minutes after. It's close to twenty minutes after...six... šakpiya means 'right on the dot' – six o'clock."

I asked a Lakota educator to translate a couple examples where minutes and seconds might be used. In the first example I asked him if he would you be able to say in Lakota that it is 3:27. He responded, "3:27 would be mazaškaŋškaŋ (wičhokaŋ/haŋčhokaŋ - am/pm) hiyaye saŋm yamni saŋm nuŋpa saŋm šağaloğaŋ kiyela." The second example was to translate the following statement into the Lakota language, "The runner ran 100 yards in 11 seconds? "Kiiŋyaŋke kin lila okahuŋya (11 seconds) čaiyutȟapi opawiŋğe inyaŋke."

Distances: A long time ago the Lakota measured distances at least in a couple ways. For the Dakota large distances were measured in the number of nights it would take to complete a journey. "When one is going on a journey, he does not usually say that he will be back in so many days, as we do, but in so many nights or sleeps (Riggs,1893. p. 165)." Most people I spoke to suggested that the Lakota measured distances in the number of days it would take to get from one place to the next. In either case distance was not viewed as we might view it today, in the physical distance from one place to the next, but more as a rate. That is, it was inherently tied to the amount of days it would take to get from one place to the next. Measuring in days is measuring in time.

Even though a "day" (or night) was an approximate fixed measurement of time the distance one was able to travel in one day depended obviously on the mode of transportation as time progressed– first on foot, next on horseback,

later by wagon perhaps, then by car. One elder followed this procession in his description of the explanation of Lakota distances with the language:

We pretty much measured things on how you'd get there in a wagon or on horse. I found (that when we) were on horseback, of course, you'd get there a little quicker (than by foot). If we came to the Sundance powwow in Pine Ridge from Manderson in a wagon, we'd say, "Aŋpetu opta." "It took a whole day to get there." We measure distances by days. An educator mentioned this as well,

> Oh, the distance. A long time ago, the only distance that they calculated by was a day's walk or a day's ride. "Makȟa manipi aŋpetu waŋžiča." How long it takes one person to walk in one day. If they are going from here to Ethete, Wyoming, my grandpa was telling me in Lakota one time, "Aŋpetu aké nuŋpa ekta waŋžiyapi ekta waŋpipi." That says, "It took them twelve days to get from here to Ethete, Wyoming crossing Wyoming...that's by wagon.

In another instance an elder discussed that distances were determined by the number of moccasins a person went through (wore out) for the duration of a trip if he was walking. In this case time is not referenced for the distance but in the effect the distance had on the footwear of a person:

> And then from the stories I heard, before the horse, they would tell 'em how many moccasins you need to take with you because when you ran or walked, you wore out moccasins, so you had to have moccasins to wear. There's a song, "Tȟahaŋpa kidi din mani," that they hung the moccasins around their neck to show the distance that they were gonna travel. That's how – before the horse, that's how they would measure how many pairs of moccasins they would take.

This second way of measuring distances has interesting connections to modern times and technology. Do we not measure the wear on a car based on the number of miles our cars have been driven? In such a case we could measure the distance a car travelled based on the number of oil changes the car has had.

The Lakota have adopted ways of expressing distances from the English language. iyutȟapi means to measure in the Lakota language. The Lakota equivalent for miles is makhiyutȟapi. This is a combination between the words makȟa, meaning earth, and of course, iyutȟapi. Thus the literal translation for miles is "measuring earth." Čae'glepi in Lakota is a step and čaiyutȟapi is the Lakota word for measuring a step. Literally čaiyutȟapi means measuring the length of a step. By quantifying a step with the word for one, waŋži, we get "one step measure" – that is, a yard. A foot (twelve inches) is stated in Lakota as siiyutȟapi. Si is the Lakota word for foot. I do not know the Lakota word for an inch. I asked an elder and he stated, "No, I don't – there is, but I can't say it. I think there is." A kilometer can be defined as makhiyutȟapi lečhala. Lečhala means "lately, a little while ago, soon." I interpreted it in this context as, a new

way, thus makhiyutȟapi lečhala means a new way of measuring which I believe refers to the coming to the later arrival of the metric system. Meter is defined as čaiyutȟapi lečhala, which is essentially measuring the earth by means of a new step. I did not find any words for centimeter or millimeter. A Lakota educator/elder commented on some of these Lakota words and their veracity in the language:

> I remembered some of the words in Lakota numbers like a yard was – cagle (like the steps we take when we walk) 1 mile, (maka iyutapi), makoce okise (half a section of land), makoce sokela a quarter section of land), one feet was si iyutapi (from the heel to the toes of your feet), inch was mapso tanka (the thumb)."

Rate: Rates are a difficult concept to express in the Lakota language if the speaker is constrained to rate as expressed as a certain distance travelled over a certain amount of time. Most speakers I interviewed relied on the English language to express this idea.

> Yes. That's different (saying 32 miles per hour) when you have to describe it that way. 32 miles per hour. [laughs] "How fast are you going?" You'd say in Lakota, Tona wakȟalahe nish ka hi. Long time ago, I don't know if you remember _____, but he used to drive so slow. I'd call him kheya (turtle) and all kinds of stuff, descriptive.

A current Lakota teacher struggled a little as well with this concept. Her thought process is interesting to follow as she tries to wrap her head around expressing it in Lakota:

> "OK, oȟaŋko means "fast," and lila means "faster than oȟaŋko." So lila oȟaŋko is "really fast." He lila oȟaŋko ksto onahe 65 miles an hour is the speed limit, and you go on describing it. So I think it's going 80, so then you'd say probably Ko.. ila oȟaŋko wikčemna šakowiŋ ičeyahaŋ makhiyutȟapi. How do you say "miles" ? ___.iyutȟapi probably means "to measure...Yeah. makhiyutȟapi. But that doesn't sound right. makhiyutȟapi means "miles." I don't know. I never really thought about it. If you were gonna describe it like that, it'd be just oȟaŋko and then lila oȟaŋko makhiyutȟapi owapiki 15 miles. Or we always say He iyečhiŋkiŋyeka ki lila oȟaŋka ye. That means "really fast." Lila oȟaŋkaye or you say le oȟaŋka ye, it means kind of fast but not that fast. "Lila oȟaŋka he tuktel kaptaŋyin kte ye ksto." You might turn over some place, you know? It's not really – that's kind of hard.

Another educator stated that English provides the simplest, and probably a more efficient way, of stating rates at least in terms of how to describe a change in distance over a unit of time. "Over here we go by, let's say you're going 65 miles an hour, you'd use the English term because it's...ah...easier, so a lot of

people say "Waŋna okiyape nahaŋ waŋna aata 65 okiyaŋka. We're running at 65 miles an hour."

Some standard units expressed in the Lakota language

There are terms in Lakota for solid, liquid, and distance measurement units. Table II shows those terms for solid measurements. Most of these words came from the New Lakota Dictionary (NLD). I included this to reinforce the fact that the Lakota have ways of expressing common English measurement units. Once again if these concepts are readily available and used in the Lakota language then one could assume that they are available for use in the Lakota mathematics classroom. This wasn't the case at Lakota Owayawa. I stress that their inclusion could help Lakota K-8 students come to understand standardized units as described in the Lakota Language since the translation is very descriptive.

Table II. Solid measurements (Weight)

English Word	*Lakota Word*	*English Translation*
Ton	Tke iyutapi thanka (NLD, p. 1065)	Tke – weight, iyutapi – to measure, thanka = big
Pound	Tke iyutapi (NLD, 984)	Tke – weight, iyutapi – to measure
Ounce	Tke iyutapi cikala?	Tke – weight, iyutapi = to measure, cikala - small

Some of the Lakota words for solid measurements are used below in a recipe found in Rood and Taylor (1976). This recipe provides an example of how the Lakota language has adapted and used standard units. In addition the example below shows the wide range of possibilities when using these terms in both the mathematics and Lakota language classrooms:

Wigli?ukagapi – (Frybread)

Aguyapiblu wiyatke topa	4 cups of flour
Asanpiblu chinska thanka num	2 tablespoons of Powdered Milk
Winakapo chinska thanka num	2 tablespoons of Baking Powder
Mniskuya chinska cistila wazi	1 teaspoon of salt
Wigli chiska thaka wazi	1 tablespoon of shortening
Mni wiyatke num	2 cups of water

Aguyapipaskapi ki phasphaszoa hehanya pat?iza pi kte hecha.
Wathokhelkehltuya chi pi ke wahehanyan kaga pi na wigli el giya pi. (Rood & Taylor, 1976, p. 12-24)

Summary of SUMA #2

Measuring is inherent in all cultures. It involves comparing, quantifying and ordering. A characteristic of the Lakota language is that it is rich in description. This characteristic is seen in the many ways it is used to describe things like time, rates and distances. All three of these concepts take root in nature. Distance as measured in Lakota culture cannot be separated from time therefore it more resembles a rate. This rate has the units of distance per time and also distance per work (wear). The Lakota way of measuring time has changed as a result of interaction with the Western world. Though the Lakota language is rich in description in terms of how it measures it is reliant, to a large extent on the English language to meet the Western need for greater and greater precision. This takes nothing away from the Lakota. As one educator said to me, "it is easier," to use the English as a way of stating some of these things.

An aspect of the Lakota language is that it is very descriptive and relies on the physical senses in order to relate phenomena. This is a very positive thing about the language and can be used in the explaining of mathematical concepts. However, in regards to mathematics, if we were to rely exclusively on the Lakota language to explain it, we would find it to be incoherent. The use of the Lakota language to explain mathematical phenomena, not just pieces of it, is the next step, I believe, in the relationship between and integration of the culture and the understanding of mathematics.

Conclusion

An aspect of the Lakota language is that it is very descriptive and relies on the physical senses in order to relate phenomena. This is a very positive thing about the language and can be used in the explaining of mathematical concepts. However, in regards to mathematics, if we were to rely exclusively on the Lakota language to explain it, we would find it to be incoherent. The use of the Lakota language to explain mathematical phenomena, not just pieces of it, is the next step, I believe, in the relationship between and integration of the culture and the understanding of mathematics.

When I mention these types of ideas to community members the initial reaction is that there is really no connection between Lakota culture and the mathematics classroom. Their perception begins to change when I start describing mathematics in ethnomathematical terms. I mention to them that they probably do mathematics on a daily basis. Do they not estimate time and distances when they decide that they want to go to town? Do they check to see if they have enough gasoline to make it to town? Don't they measure when they cook or cut fabric for powwow outfits and don't they decide on shapes when making designs? Math is involved in all of these activities. I mention also games and how games are rule-bound and show the interplay between games with the similar way mathematics is rule-bound. Aren't there probabilities and guessing strategies involved in Hand Games? Once these ideas are contemplated many community members come to see that indeed Lakota culture can be a context for the teaching and learning of mathematics both in and out of the formal classroom. One teacher commented

during our discussions about directions, geometrical shapes and distances about the usefulness of these ideas and the fact that she had never considered the things she was doing as mathematical:

> I'd like to know more about that from whatever you can – because we never did implement them. We do the numbers...Symbols and designs and patterns, they all have math in it, but it was never – We do it, but we don't think of it as math. Like a star quilt design, that's math right there. The shapes', that's geometry... This is interesting. You really opened my eyes to a lot of ways to teach...You don't know it, but I'm receiving quite a bit. I'm also gonna take some lesson on that math you was talking about...we can use that!

The Lakota language has been included in the formal education of Lakota children since the early 1970's. It has been used to help students learn conversational Lakota. It has yet to be the main vehicle by which traditional classroom content is taught. By exploring the use of Lakota culture and language in the formal math classroom connections to daily life, real world contexts and the development of mathematical thought is made explicit. Using the Lakota language to teach mathematics not only may prove beneficial in terms of the impact it could have on the teaching and learning of mathematics but may also provide another avenue to teach the Lakota language.

References

Ascher, M. & D'Ambrosio, U. (1994). Ethnomathematics: A dialogue. For the *Learning of Mathematics, 14*(2), 36-43.

Barkley, C. A., & Cruz, S. (2001). Geometry through beadwork designs. *Teaching Children Mathematics*, *7*(6), 362-367.

Barta, J., Abeyta, A., Gould, D., Galindo, E., Matt, G., Seaman, D., & Voggessor, G. (2001). The mathematical ecology of the Shoshoni and implications for elementary mathematics education and the young learner. *Journal of American Indian Education, 40*(2), 1-27.

Barta, J. & Shockey, T. (2006). Mathematical ways of an aboriginal people: The Northern-Ute. *The Journal of Mathematics and Culture, 1*(1) pp.79-89.

Barton, B. (1996). Making sense of ethnomathematics: Ethnomathematics is making sense. *Educational Studies in Mathematics, 31*(1/2), 201-23.

Bishop, A. J., (1991). *Mathematical enculturation: A cultural perspective on mathematics.* Kluwer Academic Publishers, The Netherlands.

Bradley, C. (1984). Issues in mathematics education for Native Americans and directions for research. *Journal for Research in Mathematics Education, 15*(2) Minorities in Mathematics, 96-106.

Buechel, E. (1939). *A grammar of Lakota: The language of the Teton Sioux Indians*. Rosebud Educational Society.

Brayboy, B.M.J., & Castango, A.E. (2009). Self-Determination through self-education: Culturally responsive schooling for Indigenous students in the USA. *Teaching Education, 20*(1), 31-53.

Cheek, H. N. (1984a). Increasing the participation of Native Americans in mathematics. J*ournal for Research in Mathematics Education, 15*(2), 107-113.
Cheek, H. N. (1984b). A suggested research map for Native American mathematics education. *Journal of American Indian Education, 23*(2), 1-9.
Closs, M.P. (1986). *Native American mathematics*. University of Texas Press, Austin, TX.
Demmert W., & Towner, J. (2003). *A review of the research literature on the influences of culturally based education on the academic performance of Native American students.* Retrieved from http://educationnorthwest.org/webfm_send/196
D'Ambrosio, U. (1985). Ethnomathematics and its place in the history and pedagogy of mathematics. *For the Learning of Mathematics, 5*(1), 44-48.
Eglash, R. (2009). Native-American analogues to the Cartesian coordinate system. In S. Nelson-Barber, B. Greer, S. Mukhopadhyay & A. Powell (Eds.), *Culturally responsive mathematics education* (pp. 281-294). New York: Routledge.
Engblom-Bradley, C. (2006). Learning the Yup'ik way of navigation: Studying time, position, and direction. *The Journal of Mathematics and Culture, 1*(1), 90-126.
Forbes, J.D. (1966). An American Indian university a proposal for survival. *Journal of American Indian Education, 5*(2), 1-7.
Gerdes, P. (1988a). On possible uses of traditional Angolan sand designs in the mathematics classroom. *Educational Studies in Mathematics, 19*(1), 3-22.
Gerdes, P. (May, 1988b). On cultures, geometrical thinking and mathematics education. *Educational Studies in Mathematics,12*(2), 137-162.
Graham, B. (1988). Mathematical education and Aboriginal children. *Educational Studies in Mathematics, 19*(2), 119-135.
Hankes, J. T. (1998). Investigating the advantages of constructing multidigit numeration understanding through Oneida and Lakota native languages. *Journal of American Indian Education, 38*(1),15-35.
Indian Self-Determination and Education Act of 1975, Public Law 98-638.
Kagle, M. S. (2007). *Math in a Cultural Context: A Third Space between school and Indigenous cultures,* Unpublished doctoral dissertation, Harvard University.
Kisker, E.E., Lipka, J., Adams, B.L., Rickard, A., Andrew-Ihrke, D., Yanez, E.E., & Millard, A. (2012). The potential of a culturally based supplemental mathematics curriculum to improve the mathematics performance of Alaska Native and other students. *Journal for Research in Mathematics Education 43*(1).
Knight, G.H. (1984). The geometry of Maori art-rafter patterns. *NZ Mathematics Magazine, 21*(2), 36-41.
Lipka, J. M. (1989). A cautionary tale of curriculum development in Yup'ik Eskimo communities. *Anthropology & Education Quarterly, 20*(3), 216-231.
Lipka, J. M. (1991). Toward a culturally based pedagogy: A case study of one Yup'ik Eskimo teacher. *Anthropology & Education Quarterly, 22*(3), 203- 223.
Lipka, J., & McCarty, T. (1994). Changing the culture of schooling: Navajo and Yup'ik cases. *Anthropology & Education Quarterly, 25*(3), 266-284.
Lipka , J. M. (1994a). Culturally negotiated schooling: toward a Yup'ik mathematics. *Journal of American Indian Education, 33*(3), 14-30.
Lipka, J. (1994b). Language, power, and pedagogy: Whose school is it? Peabody *Journal of Education, 69*(2), 71-93.
Lipka, J. M., & Mohatt, G. V. (1998). *Transforming the culture of schools: Yup'ik Eskimo examples.* Mahwah, NJ: Lawrence Erlbaum & Associates.

Lipka, J., & Adams, B. (2004). *Culturally Based Math Education as a way to improve Alaska Native students' math performance.* Working Paper Series (#20). Published at Ohio University, Athens, Ohio by the ACCLAIM Research Initiative.

Lipka, J., Hogan, M. P., Webster, J. P., Yanez, E., Adams, B., Clark, S., & Lacy, D. (2005a). Math in a cultural context: Two case studies of a successful culturally based math project. *Anthropology and Education Quarterly, 36*(4), 367-385.

Lipka, J., Webster, J. P., & Yanez, E. (2005b). Factors that affect Alaskan Native students' performance. *Journal of American Indian Education, 44*(3), 1-8.

Lipka, J., Sharp, N., Brenner, B., Yanez, E., & Sharp, F. (2005c). The relevance of culturally based curriculum and instruction: The case of Nancy Sharp. *Journal of American Indian Education, 44*(3), 31-54.

Lipka, J., Sharp, N., Adams, B., & Sharp, F. (2007). Creating a Third-Space for authentic biculturalism: Examples from Math in a Cultural Context. *Journal of American Indian Education, 46*(3), 94-115.

Lose, N. (1962). Why we need our education. *Journal of American Indian Education, 1*(3), 22-25.

Manuelito, K. (2005). The role of education in American Indian self-determination: Lessons from the Ramah Navajo Community School. *Anthropology & Education Quarterly, 36*(1) pp. 73-87.

Meriam, L., Brown, R.A., Roe Cloud, H., Dale, E.E., Duke, E., Edwards, H.R., McKenzie, F.A. , Mark, M.L., Ryan, W.C., & Spillman, W.J. (1928). *The problem of Indian administration.* Baltimore, MD: Johns Hopkins Press for the Institute for Government Research.

Moore, C. (1988a). Mathematics-like principles inferred from the petroglyphs. *Journal of American Indian Education, 27*(2), 30-36.

Moore, C. (1988b). The implication of string figures for American Indian mathematics education. *Journal of American Indian Education, 28*(1), 16-26.

Nash, P. (1964). The education mission of the Bureau of Indian Affairs. *Journal of American Indian Education, 3*(2), 1-4.

NIEA (2011) http://niea.org/News/?id=138&utm_source=Copy+of+Copy+of+NIEA+Advocacy+Wire+Volume+1+Number+2&utm_campaign=NIEA+Advocacy+Wire+Vol.+1+%235l+1%2C+No.+4&utm_medium=email, retrieved 7/4/12

NIES (2011). *National Indian Education Study: The educational experiences of American Indian and Alaska Native students at grades 4 and 8. National Center for Educational Statistics*. Washington, DC: Institute of Education Sciences. US Department of Education. NCES 2012-466.

New Lakota Dictionary (2008). Bloomington, IN: Lakota Language Consortium, Inc.

Nueman, M. D. (2003). The mathematics of Native American star quilts. *Mathematics teaching in the middle school, 9*(4), 230-236.

Orey, D. C. (2000). The ethnomathematics of the Sioux tipi and cone. H. Selin (Ed.), *Mathematics across cultures: The history of non-Western mathematics* (pp. 239-252). Dordrecht, Netherlands: Kluwer Academic Publishers.

Pfieffer, A. (1968). Educational innovation. *Journal of American Indian Education, 7*(3), 24-31.

Pixten, R., van Dooren, I., & Soberon, E. (1987). *Towards a Navajo Indian geometry*. Gent: K.K.I. Books.

Rauff, J.V. (2009). Native American dice games and discrete probability. *The Journal of Mathematics and Culture, 4*(1), 50-63.

Reno, T. R. (1967). A demonstration in Navaho education. *Journal of American Indian Education, 6*(3), 1-5.

Rickard, A. (2005). Constant perimeter, varying area: A case study of teaching and learning mathematics to design a fish rack. *Journal of American Indian Education, 44*(3), 80- 100.

Riggs, S.R. (1893/2004). *Dakota grammar with texts and ethnography*. First published by the Department of Interior, U.S. Geographical and Geological Survey of the Rocky Mountain Region. St. Paul: Minnesota Historical Society Press.

Roessel, R.A. (Jan, 1968). The right to be wrong and the right to be right. *Journal of American Indian Education, 7*(2), 1-6.

Rood, D. S., & Taylor, A. R. (1976). *Beginning Lakhota (*Vols. 1 & 2). University of Colorado Lakhota Project. Boulder, CO: University of Colorado.

Sanders, D.W. (2011). *Mathematical views within a Lakota community: Towards a mathematics for tribal self-determination.* Unpublished doctoral dissertation, University of Colorado, Boulder. http://search.proquest.com/docview/867835110.

Schindler, D. E., Davison, D. M. (1985). Language, culture, and the Mathematics concepts of American Indian learners. *Journal of American Indian Education, 24*(1), 27-34.

Scott, P. B. (1983). Mathematics achievement test scores of American Indian and Anglo students: A comparison. *Journal of American Indian Education, 22*(3), 17-19.

Selin, H. (Ed.) (2000). *Mathematics across culture: The history of non-Western mathematics.* Dordrecht, The Netherlands: Kluwer Academic Publishers/

Souhrada, T. (2001). *American Indian housing*. NCTM Student Math Notes. National Council of Teachers of Mathematics.

Sternberg, R., Lipka, J., Newman, T., Wildfeuer, S., & Grigorenko, E.L. (2006). Triarchically-based instruction and assessment of sixth-grade mathematics in a Yup'ik cultural setting in Alaska. *Gifted and Talented International, 21*(2), 9-19.

Trent, J. H. & Gilman, R. A. (1985). Math Achievement of Native Americans in Nevada. *Journal of American Indian Education, 24*(1), 39-45.

Turnbull, D. (1991). *Mapping the world in mind: An investigation of the unwritten knowledge of the Micronesian navigators*. Deakin University Press, Geelong.

Webster, J. P., Wiles, P., Civil, M., & Clark, S. (2005). Finding a good fit: Using MCC in a "Third Space." *Journal of American Indian Education, 44*(3), 9-29.

White Hat, A. (1999). *Reading and writing the Lakota language; Lakota iyapi un wowapi nahan yawapi.* Salt Lake City: University of Utah Press.

Witherspoon, G. (1968). Navajo curriculum center. *Journal of American Indian Education, 7*(3), 36-41