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**Arapaho Mathematics:
The Symmetry of the Symbols**

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Abstract

This paper is about teaching a mathematic concept of symmetry in middle school on the Wind River Indian reservation. These were students I taught throughout the course of the school year 2013-2014 and each of them had varying abilities in math. The objective of each lesson was not to teach symmetry in isolation but to teach Northern Arapaho symbolism as a way to understand symmetry. I reversed the objective of the unit to teach about the culture of the Northern Arapaho people and used math as the tool to help the students understand traditional knowledge, and relate it to their mathematical concepts required for middle school students. Each student completed a project showing reflection, rotation, or translation symmetry.

Each group brought their own challenges. From this study there were several new revelations on cultural knowledge and symmetry. Teaching from the culture first was the biggest find. I recommended that more research be done in this area because the students demonstrated and used their tribal roles in problem solving. Another recommendation is to teach more math standards with the culture of the tribe. The students were able to share their family stories and research more about their own identity. Also, the students were able to bring in the community so they could share their stories.

Each student who was taught the unit showed growth in their mathematics and more confidence in whom they are. This was an important study for this community. More research needs to be done in the areas of teaching styles, curriculum that can be easily integrated with the communities' culture, and student learning styles.

Dedicated to my family and friends who supported me throughout my years in college

Acknowledgments

I would like to acknowledge to my teachers who helped me understand many of the mathematics involved in teaching one or more standard. Also, I would like to acknowledge my husband and children for taking the time to listen and make suggestions on the project. Last acknowledgement would be to my aunt Maxine Moss who always had to be the back up support for my children when I needed to travel to Laramie or to class.

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Chapter 1

ARAPAHO MATHEMATICS: THE SYMMETRY OF THE SYMBOLS

Introduction

In the art of the Northern Arapaho culture there is symbolism that is geometric in nature. These geometric symbols are displayed in the beadwork, par fleche (rawhide), quillwork, and most recently in the stained glass and other artwork of many tribal artists. This paper will explore how symmetry of the Arapaho symbolism is used in the crafts of the tribe. I will use the term artwork in this paper to describe all forms of crafts, garments, pictures, suitcases, and cradleboards, since these are often considered in today's society as pieces of art.

To begin to understand Arapaho symbolism one must look at where the Arapaho people lived historically. The Arapaho were a plains tribe whose homeland was primarily the Great Plains to the Rocky Mountains. From these lands and the creatures that lived in these areas the Arapaho created the symbols. These symbols depict animals, insects, plants, inanimate objects, land formations, and people.

Symbols of the Arapaho are used to construct a design to form a pattern. These patterns have a purpose or deeper meaning that is connected to the spirituality of the Arapaho belief in the creator. These meanings are always placed as a good omen for the person wearing them or prayers for that person so they may continue on the good road of life. Arapaho people are always cognizant of how life's circle impacts life. This is a teaching about how we travel in this life, we are always going in a circle and when we get back to that spot we want good things to come back to us. This belief transcends into the symmetry of the work that is placed in the item.

Mathematically these symbols show different types of symmetry. The most common symmetry present is the reflection symmetry. These different types of symmetry will be part of the units to represent the math. The main focus will be exploring the role of symmetry in the Arapaho life and culture.

Symmetry

Symmetry is the most obvious principle of composition (Anderson 2013: 75). For an Arapaho person to work on an item with the Arapaho symbols they must know how symmetry

works. In this exploration I will take a look at how this is done. I will interview various artists in the tribe and document how they use symmetry.

The interviews will consist from a wide range of community members. First, I will interview the artists. They are the people who work with the symbols the most. They are always trying to solve various problems when dealing with new projects, repairing old beadwork, or teaching new students. Next, I will interview the men and women who participate in the ceremonies. These individuals will have the stories of how symmetry is a tradition that defines a way of life. Interviewing the artists and the ceremonial people will help lay the foundation for how skill and purpose are explained through symmetry of the symbolism of the Arapaho.

Symmetry is not discussed amongst the people. It's just expected. By this I mean symmetry is always present. Symmetry becomes a way of showing balance in life; this is a way to reflect how nature shows balance. Arapaho always want balance in their lives and to display this we create these types of balances in the artwork.

To have balance then the belief is that our life is good. To have a good life is what is expected of an Arapaho person. The good life can be defined through its symmetry. This reflection symmetry can be observed in most of all the artwork in the tribe.

In Arapaho artwork there are often many types of symmetry present. I will discuss how this representation is used and the types of symmetry that are used. Rotational symmetry is rare. Going through historical photographs and observing beadwork I find that the symmetry is often either on a horizontal or vertical axis. To have rotational symmetry is to have a center like a circle. When working on a rectangular piece the center is like the origin and it is divided up into the quadrants in algebra.

To have symmetry, there has to be a center. To have rotational symmetry one must have a center where the art can be divided into more than half. Here you will often see the Four Hills of Life represented. The Four Hills of Life is a term that is always stated in the tribe. Each hill represents a life movement through a stage. Jeffrey Anderson explains this "First in sequence, yellow is the color of the east, childhood, and morning. Red follows as the south, youth, and summer. Black is the color of the west, sundown, adulthood, and night. White in turn is the color of the north, winter, and old age. Yellow and black were thus part of the duality of sunrise and sundown on the east-west axis, while red and white as north-south represented the seasonal duality of winter and summer." (Anderson 2013: 76) To know these dualities an Arapaho knows

their place in the universe. They are the center of their life and to find balance is what is desired for each individual as well as for the tribe.

Teaching Middle School Symmetry

From these interviews from the traditional ceremonial people and the artists, I will build a unit to teach to middle school students' symmetry using the Arapaho symbols from Alfred Kroeber (Kroeber 1983). Teaching students the very basic uses of symmetry will help them understand how symmetry is used in mathematics. Connecting the culture of the student to mathematics will help them in turn learn about their identity.

Districts on the Wind River Indian Reservation are often looking to make the connection between culture and western education. To help students become familiar with what is known in the community and bringing to the math classroom in middle school will let the students apply their background knowledge to educational approaches. Mathematics is an area where most the students struggle; to bring in their culture will help them see and apply mathematical reasoning to what they already know. Many students have family members who bead, work with rawhide, build ceremonial lodges, set up tipis, and create other items that are considered art.

To connect these two worlds the student will apply their mathematics to helping them understand the concepts of how math works in academia. Units can be built from the symbols to understand geometric theorems, concepts, and to construct proofs.

Students have difficulty connecting how math works in their "Arapaho world". Students will need to learn how to use measurement tools to set up symmetry with dividing a piece of construction paper into halves, fourths, or just finding the center of the paper. Most students know what a ruler is, but in my experience, the students do not know how to read it or use it. Having a lesson in the unit on measurement will help the students build their background knowledge and connect some cultural knowledge. Connecting the two will help them become more aware of their role in their community and how education can apply.

To be a student in Arapaho a person must be able to think in the real world, or in math terms, 3-D. Most geometric concepts in school have students thinking on the Euclidian plane or 2-D plane. This often is difficult for students to think about how math switches from one plane to another. For example, the symbolism of the Arapaho is drawn on the 2-D plane. When students are creating their symbol for their poster they will do this in the 2-D plane. Symmetry on this plane is fairly simple. Now if the student needed to reconstruct this symbol on the 3-D

plane they would have to reconfigure all of their calculations. Symmetry on the 3-D plane is more difficult. The difficulty is within the process of understanding how things are changing mathematically. We as humans take for granted the 3-D world and don't realize how much math is really involved in creating things for this world. Many of the items used in beadwork are not symmetrical and to display balance in an item causes some confusion for the person. Does that person take into account the number of unsymmetrical beads they are trying to place in a symmetrical piece of art?

Identity through Symmetry

Identity of the student is one key component that is being lost in this modern day world. Through the lesson of the symbolism I hope to teach the students more than just symmetry. Each of the students will have to learn how to make a symbol out of their "Indian" name or their historical name. A naming ceremony is held and an elder of the family or tribe is called upon to give a child their "Indian Name", which helps the child through its life. (Anderson 2003) Their historical name is their last name. The last name of the family was often the name of an ancestor. For example, the last name Moss was once Young Chief. Young Chief was the younger brother of Chief Black Coal. Due to a fire at the BIA Headquarters in Ft. Washakie, WY, the families were then issued "government names". The new names consisted of English words that could be easily pronounced by the government officials.

To understand how to build a design from a name is a skill that is handed down through the generations. My aunt was the one who taught me this. She stated, "A person's name or the things that give them strength need to be present on the moccasins you are beading for them." This was a very difficult task for me to learn because I did not know how to combine geometric shapes let alone create perfect symmetry on the parabola shaped moccasin pattern. Through guidance of my aunt I perfected how to make the designs symmetrical and how to account for all the nonsymmetrical obstacles. Finding balance.

To combine the shapes you need to know how geometric transformations work: the degree of the rotation, how to reflect of the axis, and most of all be able to reproduce the symmetry on a piece of buckskin that is sometimes not even. The parabola shaped moccasin template can be a challenge for most and to center your design to create symmetry is the task that takes practice.

Geometric transformation is not intended in the Arapaho life. It is the way we duplicate the world around us. We see how the creator creates life through nature and our artwork is a replica of how we see it. For example, the spiral of the Fibonacci sequence can also be observed in some of the spiral symbols. A spiral symbol indicates the whirlwind and the stories of the types of weather occurrences in the Arapaho culture.

My intentions are to help my students find how to create symmetry with the Arapaho symbols. To learn this skill will help them read the symbolism that is always present in our community. We have old artifacts that are stored in museums that have a story to tell. To teach the students to read these will help them gain some history of how we believed and how things have changed. Storytelling through symbolism is an art that is being lost because the younger generations have not learned how the role of symmetry portrays Arapaho values.

Chapter 2

Symmetry

The definition of symmetry is defined by Google dictionary as the quality of being made up of exactly similar parts facing each other or around an axis. Symmetry works from a center point, the axis, or either a horizontal, vertical or diagonal line. In order to demonstrate a symmetrical relationship between the shapes, a line of symmetry needs to be present. The line of symmetry is often an invisible line but can often be seen once the transformation is completed in either the beadwork or the craft.

In mathematics symmetry begins in the primary grades with the simple transformation of reflection. As the students progress through the grades they are introduced to rotation, translation and dilation. I will explain how each of these types of symmetries works in mathematics, in other cultures and lastly the Arapaho culture.

For this chapter I will have examples of student work and how they demonstrated each of the symmetries. I will explain what each student did and how they learned what to do to show symmetry in either their rough draft drawing on the graph paper or the completed poster.

Reflection Symmetry

In reflection symmetry the image is changed by a flip. The flip occurs over a line of symmetry, which produces a mirror image of the shape. Each point in the reflection has a corresponding point and the distance from the line of symmetry between these two points are equal. In the picture below students built their design on the horizontal and vertical lines of symmetry.

In figure 1 this student flipped over a horizontal line of symmetry. In the reflection symmetry the line of symmetry is visible. In both figure 1 and 2 the student's line of symmetry is visible creating the mirror reflection of each side. Both students did struggle with visualizing how the reflection would work. They both knew where the line of reflection was in each poster. The position of the shapes and the measurements from the original placement was very hard for each student.

The corresponding vertices in the reflection symmetry of the posters are not exact but the students have shown different strategies to solve how reflection symmetry can be shown. One student did measure the points of vertices from the line of symmetry. This student drew in

parallel lines and marked the points after measurement. These points represented where the reflected vertices would be glued on the other side.

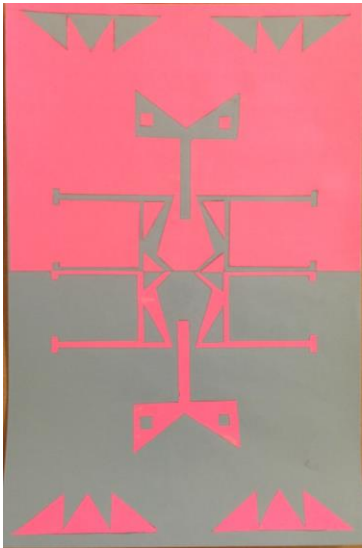


Figure 1



Figure 2

Rotation symmetry

Rotation symmetry is defined as a turn. The object is turned is from its original place and can be turned up to 360 degrees. When rotation is taught pictures of fans are shown to the students. The example will describe how the fan spins around an axis and the three or four blades rotate. The rotating blades are the visual clue of how rotation symmetry works. Rotation symmetry is demonstrated below from a student who used the Arapaho symbols to demonstrate how a design or pattern would look.

In Figure 3 this student took the symbol of the cloud and rotated the image around a center. Rotational symmetry is always rotated around a center point. This student did not complete the rough draft graphing of the poster. This student had left the district before it could be completed. I included it in this study because this was the only student who demonstrated rotational symmetry.

I have dissected the drawing and show the horizontal and vertical lines of symmetry. Each of these clouds rotates around either segment EF or CD. The rotation of each cloud is about 45 degrees from the line segment to the center of the quadrant. From the picture you can see the student has shown rotational symmetry.

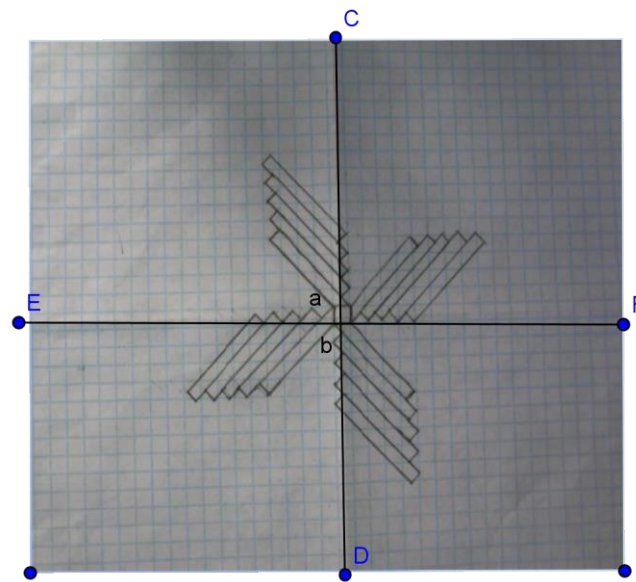


Figure 3

Translation

Translation is a type of transformational geometry but is often times taught along side reflection and rotation symmetry. Translation is the slide or moving of the object. (mathisfun.com) There is no resizing or rotating of the figure, just the slide or the movement in the same direction with equal distance. Here a student demonstrates a translation:

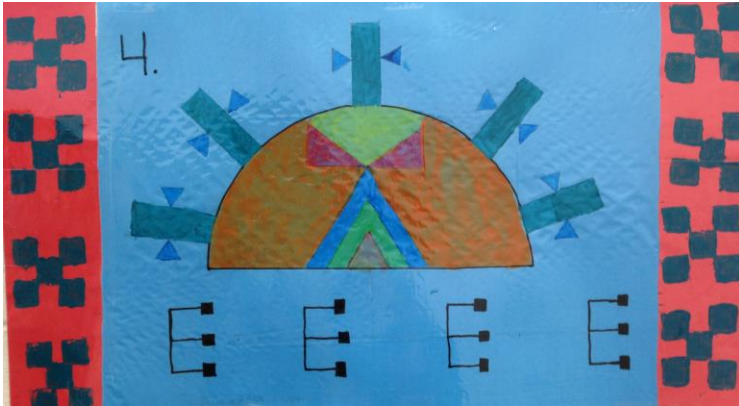


Figure 4

The turtle claw in this poster is the Arapaho symbol that was translated across the bottom of this picture. The turtle claw is the symbol that resembles an E. This poster was the only poster that clearly showed how translation works.

The symbols positioned on the arc of the semi-circle also have translation symmetry. The student has tried to demonstrate equal measures between each symbol. The symbol represents an insect. The symbols on each side of the poster are also a translation. The student made a stencil of this symbol and slid the stencil and filled in the squares. The five square here represents the turtle. His story was about the creation story of the Arapaho tribe.

Other Cultures and Symmetry

In the Yupik culture symmetry is visible in their parkas. The parkas are made up of the furs from various animals. The Yupik meaning behind the symbol, five squares, is the circle of life (Lipka, Andrew-Ihrke, & Yanez, 2009) The five squares are symmetrical vertically and horizontally, and also dilate. The story of symmetry is told through traditional Yupik stories and involves the importance of centers. What I found was the Yupik culture shared similar stories to the Arapaho about the role of symmetry in the culture. The Yupik researchers described the importance of why symmetry was present in their clothing. This presence signifies the life circle of a person. These short stories are shared in many of the articles from that region. The indigenous researchers include many of the culture behind the mathematics but can only share parts of the importance in the culture.

When a group chooses to share parts of their culture it is trying to define how that particular part is connected to the world of mathematics. These glimpses into a culture are only

there to help the reader try to identify a piece of the culture. These short glimpses do not share the whole culture or way of life. It only describes or explains to the reader what part of the culture applies to this particular part of the study in mathematics.

Symmetries are found around the globe. In the article Symmetries of Culture, Crowe gives many examples of how symmetries are found in ancient and modern day construction. In his examples he shows types of transformational geometry. The translations of the figures are shown as well the rotational geometry of the patterns.

In researching symmetry I can say that there are many cultures in the world that use some type of symmetry. I only mentioned a few because symmetry is found in every culture and the research was extensive.

When I say extensive I looked into how symmetry was researched. There were few examples where I seen how the symmetry applied to the culture or was discussed from the cultural point of view. There seems to be a need to have more research done in the stories about symmetry. These stories can help the teacher connect to their students if they know the stories that impact the culture.

Arapaho Symmetry

Symmetry to the Arapaho is an expectation that is formed unconsciously. This knowledge is handed down as an embedded piece of knowledge. By stating this as an embedded piece of knowledge I mean the teacher embeds the learning of symmetry into the lesson. The teacher could be an elder, a community member, or a person who is some type of leader in the tribe.

Coming from the culture I can was able to get a few people to share their knowledge. From the simple informal interviews of the community members they all concurred that the symmetry showed balance; the balance of life on this earth. There was discussion about how chaos was not valued in the Arapaho culture. The balance of the life had to be present in our tribe and so everything from the symbols in the crafts, the lodges, and ceremonies.

Each person I spoke with had similar stories about the symmetries in the Arapaho culture. These short interviews helped me understand symmetry from the different parts of my tribe. Each member of the tribe does not have all the stories about how symmetry works in the

Arapaho tribe. This may be the first time it has been discussed in all parts of the tribe. The discussion included the stories shared in ceremonies and in family beading circles.

Chapter 3

Methods

In this chapter I will discuss how I developed the lesson plans for the unit on symmetry. Developing lessons to directly tie into a culture is not often done in schools today. The school system usually adopts a standard curriculum from a publisher and this curriculum is never culturally sensitive to the needs of the students.

What I mean by not culturally sensitive is that if the students come from a diverse background the curriculum does not integrate cultural norms into their lessons. Lessons or units from a publisher come in a generic form assuming every student is middle class America. With this being said teachers who teach diverse students need to integrate the students' culture into the curriculum or develop units using the culture to teach the Common Core State Standards.

To develop lessons that integrate a student's culture the teacher must first understand the culture. I am an enrolled Northern Arapaho. I have taught math and the culture classes in my school district. In order to teach the culture, a person must be familiar with the language, food, dances, songs, crafts, stories, and the everyday expectations of what the tribe expects from its members. To be Arapaho is to live it. We have certain guidelines that we follow and to help each other grow as individuals and as a group.

As the teacher of the culture I was able to work with an elder as a co-teacher. My co-teacher was Joyce Duran. She was in her mid-sixties and a fluent speaker of the Arapaho language. We were instructed to develop an Arapaho language program from scratch. We built a program from Dr. Steve Greymorning's Accelerated Second Language Acquisition (ASLA). Dr. Greymorning trained us and kept us updated on his new ways of teaching the language so the students would become accelerated. In this form the students picked up the language very quickly. They outworked the elder and me. But during this time there was a time to explore why things were done the way they were done in our tribe.

When developing a curriculum for language acquisition, we had to research what was considered the cultural norms in our tribe. We discovered that the elders were the teachers in the tribe and this is how the knowledge is shared throughout the generations. We discovered that the stories of the old timers were disappearing and this worried Joyce. She was the moccasin

maker for her family. She talked about how she loved to make new designs and how beautiful everything was when it came together.

Joyce looked at the symmetry of her work and would get upset if something was not symmetrical. This was the first clue that math was involved and it was not simple math. What upset her was how a design would end up off center once the moccasin was turned. This math is very complicated because the patterns start out on the 2-D plane and this perfect symmetry has to keep its symmetry after it is transformed to the 3-D object.

This type of mathematics is very complex. This study is just to look at how to help develop lessons from the culture of the Northern Arapaho. Also, to have a unit in mathematics start from the Northern Arapaho culture and branch out into the required CCSS for any grade level.

Looking at the Culture

To take in the culture of the Arapaho means to live it. I have always heard this said in my community. What did this saying mean? As I continued to learn and grow I began to understand this saying a little more. To be Arapaho is to know things about how to live peacefully and with humbleness. The spirituality of the life of the Arapaho is to live in harmony with everything here on earth.

Do I have full understanding of this concept yet? I am still young and I tell my students this. I have to remind them that we are still learning no matter how old we get. They seem to be lost sometimes between worlds. Today we are so modern that they accept the norms of the American culture as their own and don't question why they don't see their culture in their schools.

For me this lesson development is to help them navigate their way in both worlds and find their place in today's society. I have always been asked how I succeeded. People who ask this question see my success as a teacher (educated in western education) and being able to help out in my tribe and understand the protocols that are expected from an individual as success. I see it as a balance of both worlds. I understand how I must help myself, and my family in the western world and how I must help in the Arapaho world. Sharing this balance is what these lessons are about. I will try to discuss how I had to explain the mathematics of the symbols and the culture behind the symbols. In chapter 4 I will discuss the results of what teaching the lessons did for the students and me.

Integrating the Culture into Mathematics

The Arapaho Symbols have always been geometrical. We have different shapes in geometry and this helps us visualize many things. For the Arapaho we use these symbols as stories and try to help the person who wears the symbols.

The Arapaho symbols are geometrical and are always shown with some type of symmetry. The symmetry itself is defined as the balance of life. The symbols are the strength, hope, prayers, or names of the person to tell a story about that person. In the culture classroom, I tried to get the elders I worked with to share these stories with the children. We had to integrate their history and knowledge into the Wyoming state foreign language standards and show we were meeting the state standards. Doing this did not please the elders. They said the way the schools teach do not fit into the way we (elders) teach. This is still the common argument. They mention that there is not balance between the two teaching styles and they dislike the way the teaching of school is not the way Arapahos teach.

That statement has given me insight on how we as a tribe teach our generations about our way of life. Being a trained teacher and coming from the tribe I am able to help open up discussions about what is best practices for our Arapaho students. How can any teacher who comes to our reservation help our students be successful in academics? This question helped me build the lessons I built for the symmetry unit.

To develop the unit in symmetry and to use the symbols of the Arapaho would be to have it accepted by the elders. I first did this type of lesson in the culture classroom. It was an informal lesson about how we build designs for moccasins. From these first initial lessons I began to pick out what was important and what was not. At what grade level do the students start comprehending the complexity of the math behind the design making? These types of reflection questions helped me build my lessons that I taught this year to my 7th grade class.

My first step was to investigate what the students knew about the designs from the Arapaho tribe. Finding out what their background knowledge was on the symbols of the tribe was crucial. If they knew nothing then I started from the beginning. What is a symbol? How does math play a role in the symbolism? I explored basic questions for the first lesson to get things started.

The second lesson involved drawing the designs. This lesson I also experimented on in our summer school sessions. For two summers I would have students work with the

designs and just play with drawing them out and playing with the transformation of the design. One summer we used tarpaper to make a stencil, each student drew a design, cut it out and we painted it on the sidewalks of our school. But we also had the middle school students create new designs by having one or more designs painted in one square of the sidewalk. For me that mini lesson was just for me to see how much more instruction the students would need on lines of symmetry and how much they knew about symmetry. Could they make a design that was symmetrical?

In the third lesson, we integrated the stories. What do the symbols mean and when you put them together can they tell a story? For each of these questions I had to research known stories of the tribe. Anderson's book *Arapaho Women's Quillwork* helped my students this year understand how the stories were more important and how the history of the tribe is often told through symbols. But in my first few experimental lessons I had to rely on the elders and their stories about how they were taught the importance of the symmetry.

The Fourth lesson includes the mathematics and tying all the lessons into the math, including: how to draw a line of symmetry, finding the center, drawing line segments, connecting vertices, making things parallel, perpendicular, and using intersecting lines to form adjacent sides, using corresponding side lengths and angles to make the symbols symmetrical. Each of these types of math had to be covered while the students were making their design.

All of these lessons had to be infused with mathematical language. I tried to incorporate as much academic language into each sentence I spoke so the students could learn these terms in context. For me, as the math interventionist for middle school, I see how my students are often times stuck on the math words when they read. If I ask them to restate what that means they have no comprehension of the math terms so they state they do not know what it is asking. Reading in content areas is weakness in my students and using the mathematical terms in each lesson helps them identify and comprehend a little more in math.

Chapter 4

Teaching the Arapaho Symbols

To teach the Arapaho symbolism has been something I had to learn how to do. Over the years I have had to learn from various people in my community how the symbols were used. Each part was all for my own personal knowledge since I was using the symbols in my own beadwork. I never applied any of my cultural knowledge into teaching mathematics.

In this study I made the culture the focus and the math the tool they used to help them build their poster. The students' poster project was a unit that applied the use of the Arapaho symbols to learn about symmetry and use their knowledge about similarity. In mathematics education, math is always the main focus and the teacher can insert community knowledge of how math is applied to certain situations. When I was the culture teacher I used to apply math to many of the lessons I taught, for kindergarten and first grade we learned how to count in Arapaho. Counting in Arapaho is fairly simple if you are only counting numbers. To add the plural/singular and animate/inanimate form, counting became more challenging for the learner. From my experience in teaching from the culture first I used this method to teach the concept of symmetry to my students.

My students are middle school students in grades 6th, 7th and 8th. In my 6th grade classroom I have a mixture of math abilities. For example, I have some who are gifted and some who are your average 6th grader and I also have some who are below grade level. Most are enrolled in the Northern Arapaho Tribe and some are non-native. The 7th grade classes I teach are students that have tested near grade level, at, or above. My 8th grade students are the advanced students; they are above grade level in math. The symmetry unit was basic geometry using middle school math standards. So each class did get a varying degree of difficulty as the groups became more advanced on their abilities.

Sixth Grade

For the 6th grade group it was let's learn what symmetry is. Do we know what this is? There were some varied responses of yes or no. To introduce this into this small group I had them pick two to three of the symbols from the booklets and try to reflect the symbol across

a line of symmetry. This basic piece was just getting the students familiar with lines of symmetry and drawing straight lines. How did the students find the line of symmetry? Most folded the paper in half, one measured the paper and found the midpoint and lightly drew in the line.

The different methods of finding the lines of symmetry let me see the different strategies they had. The next step was how to make the symbol a reflection. What happens to the shape when it is reflected? I let the students do this on their own to see how they would demonstrate their knowledge. The results: most of the students reflected the shapes in their poster.

When the students drew out their symbols on the graph paper they drew the reflection. They seemed to know how the shape was going to look if it was reflected. I had confidence in them that they were going to do it correctly. I had the students take their graph paper drawing and try to make a final poster on construction paper. Students were told they could only draw half of their design on the 9 X 12 construction paper. They were told the 12-inch edge was the line of symmetry. Most students had trouble with this. They could not see how their design was going to match. The most surprising for me was getting them to take their drawing on the graph paper and cut it in half. I had to fold it in half for them and show them which half they had to draw. From my observations many of the students kept unfolding their paper and then folding it again. The students were trying to picture how half the drawing was going to a complete picture in the end.

Once the students started drawing, I watched how many measured with the ruler and developed a rule that one square on the graph paper was going to equal one inch or one centimeter. Some just measured their lengths on the graph paper and tried to replicate it. With this procedure the students discovered that the shapes were too small and they needed to figure out how to enlarge it. This is where the students began scaling their drawing. Scaling was never discussed with this group. This group of students was only taught about symmetry.

Taking a closer look at how the students' problem solved the issue of the shapes is smaller on the graph paper than the construction paper was a great find for me. The 7th graders were struggling with scaling. But to see the 6th graders solve their way through an issue because it "didn't look right" helped me understand their thinking and how to help the 7th graders. The scaling generated discussion between the students and me. These discussions were about how the shape or the drawing "didn't look right". What did they mean? They were talking about the

proportional relationship of the graph drawing and their drawing on the construction paper. This was a discovery for the 6th graders and this is when I mentioned scaling for the first time to the students. There was no lesson on this concept. It was an informal discussion on what scaling was and how you could use it to help you make something larger or smaller. There was also discussion about similarity and how they were trying to make the shapes similar.

What did the 6th graders know about similarity? They knew that two shapes could be similar; they were using their background knowledge of how they looked for similarity. Their rule for similarity was the shapes had to be the same. One could be smaller or larger, but they had to be the same. They did not recognize the corresponding angles or the corresponding side lengths. They just looked at the shape. This was a great start to introducing students to similarity.

After the students completed their drawing on the construction paper the next part was to cut out the pieces. Once the pieces were cut out they had to glue them on the larger piece of construction paper. Step one consisted of gluing the 9X12 construction piece down with all the parts cut out. They then had to use the edge of this construction paper as the vertical line of symmetry to reflect the cut out parts onto the larger construction paper. This task was difficult. Many students had to draw in a horizontal line of symmetry and measure their distances from the center of the design. One student flipped his 9 X 12 construction paper onto the other side and drew in the missing shapes so he knew where to place the cut out parts. This led the other students to do the same. Eliminating the measuring and drawing in the horizontal line of symmetry. After they traced their shapes or drew in their lines of symmetry they had to glue the parts on. This section of the project was where I observed students translating the shapes and not reflecting.

Students either had the measurements of where their shape had to be placed or a traced shape of where they needed to place the cut out part. There was one student who recognized that the reflected shape would be flipped from the original position. This student placed the shape in the original position then flipped it so it was reflected. Most of the students rotated the shape across the line of symmetry instead of reflecting it. The students did not recognize the difference between the 180-degree rotations from a reflection. In the completed posters below you can see how some students demonstrated this.

In this picture example the students used tipis (isosceles triangles with two connected right triangles), bees (rectangle with scalloped edge), the symbol for saddlery (symbol resembles a goal post in football), and the beetle (square in the middle).

The “bees” symbol clearly shows the rotation symmetry. The scalloped edges indicate the student rotated the symbol 180 degrees onto the yellow construction paper and did not reflect (flip) the symbol. This student was trying to demonstrate diagonal symmetry with reflection and rotation. If I did not watch this student I would not know if I could say which shape he reflected or rotated. The only piece you can see as a rotation is the “bees” symbol. The tipi and saddlery symbols indicate rotation but are they reflected and rotated? The beetle symbol was reflected.

This student put the small black rectangle in first and described to me what a reflection was and demonstrated this by placing the cut out black



Figure 5

construction paper into the

original place then flipping it across the line of symmetry and then gluing it. As the student progressed through the gluing the reflecting was not as careful. From the first demonstration I can say this student understands reflection but was not consistent with the other parts. When the student was asked about the “bees” symbol, the student could not explain what they did when they glued the part in place. The statement given was “oops”. They did not recognize the rotation of the symbol and just accepted the fact that there was a mistake on their symmetry.

7th grade

The 7th graders were the largest of all three groups. This class met every day with me. Their lesson came from the story from *One Hundred Years of Old Man Sage* by Jeffery Anderson. In this book, chapter 2 describes the importance of an Indian name. I read this story the students and talked about people in the community who still gave Indian names. Their homework for that night was to find out what their Indian name was from their parents, grandparents, guardians, or from the person who gave them their Indian name. There were a few who did not have an Indian name so I asked them to ask their family about their family name. I gave my maiden name as an example. Moss was once Young Chief. Why were named Young Chief? The story is told that Young Chief was the younger brother of one of the Arapaho Chiefs. So he was called Young Chief. That was all the information I gave them.

Once the students had their Indian names the lesson preceded to the Arapaho symbols. The task was to illustrate their Indian names using the Arapaho symbols. Graph paper was handed out along with the handout Arapaho Symbolism and Arapaho Designs and Symbols. Students had to research the symbols and find a combination of symbols that would best fit their Indian name. For some of the kids this task was personal. What I mean by personal are the students who shared their names with the class they did not know how their peers would react to them and vice versa with the student who did not have Indian names. This symmetry unit for the 7th grade became more about identity. Today the younger Arapaho do not know how our communities identified each other by their Indian names. This tradition is being lost. Today we only call each other by our English name. The only story I could share was about a man who still is known in the community by his Indian name. Some of the students had heard of him or even knew him. There were a few who had not heard of this person. From this lesson came the question of why do we have English names? The discussion led to a brief history lesson of the past when the government needed to place names on the allotments so they issued English names. The tribal members called these “government names”.

With the 7th grade group I kept the culture first in every lesson. As I went through the lessons on symmetry Arapaho culture was the main topic. There were questions that arose that needed some short discussion but nothing that required some research. This may be because I am an enrolled Northern Arapaho and this knowledge is first hand. I will discuss more on these short discussions in chapter 5.

The 7th graders showed excitement about the posters and didn't think the task was going to be challenging. Once they found their symbols, then the arrangement of these symbols gave them some challenges. The first challenge was placement of the symbol. They were thinking about how the symbol would reflect, rotate, or translate. Many of the students in this group all choose to reflect. There were attempts at rotation, but the end results were all reflection. My observation of the students while they were working there were discussion amongst each other about what a line of symmetry was. I deliberately left out that part, assuming most of the students would know have this knowledge. The peer teachers helped along the students who were struggling on the poster. The peers seemed to be aware of each other's ability or knowledge about symmetry and worked as a large cooperative group. From this the peer leaders seemed to come ask me for the next step and then return to the group to help the others. From the culture standpoint this is how the children should work together. In the reservation community there are leaders selected to help the others and those leaders have the approval of the elders to help. These leaders also have permission to ask the elders questions when an issue arises. The students demonstrated this during their poster building sessions. I as the teacher took on the role as the person with the knowledge and the students sorted out their roles as either the leader or the learner. I do not know if this behavior came because of the fact that I taught from the culture first or if it was determined by something else. This will have to require more research on the students doing more projects using the culture as the focus and the academic subject as the tool.

As the students worked I would make comments using the math vocabulary. Since this particular group were learning about similarity I would use terms such as: scaling, corresponding angles, corresponding side lengths, ratio, equivalent ratio, proportion, stretching, shrinking, half of, two times, four times, quarter of, compass, angle, complimentary angles, supplementary angles, degrees in a triangle? , degrees in a rectangle? , ruler, protractor, and other related terms. Using the math vocabulary I hoped would deepen their understanding. With the data from reading and math the 7th grade students showed that they struggled with reading. By my use of the math vocabulary I hoped that would help them gain a better understanding when reading in the math content area.

The posters that were made should varied levels ability. Some students made intricate patterns while others made simple ones. Below are examples of student work.

This student used the symbols: mountains, buffalo track, and turtle claw.

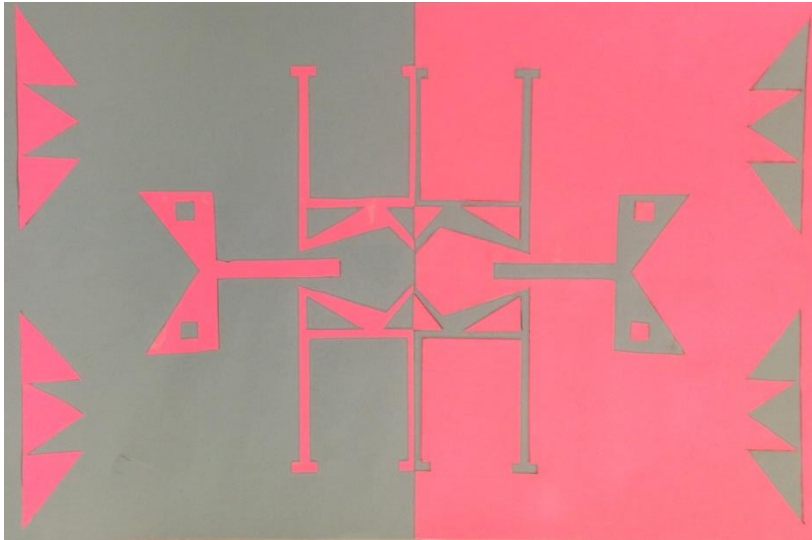


Figure 6

This particular picture was not the student's Indian name. The student chose the symbols as symbols they would surround themselves with if they had to construct an item for themselves.

Chapter 5

Recommendations

In this chapter I will reflect and make recommendations for the lessons on symmetry. The study on teaching middle school students from the Northern Arapaho cultural focus had some insights that could be helpful to teachers who teach diverse populations.

Diverse learners are often times labeled as at risk students. These students have few resources in their communities or at home. Most of these students are in a Title I school and are often be labeled as low income.

As part of this project I wanted to help my students make those connections between mathematics and their culture. When I was first a teacher I taught 7th and 8th grade math. As a new teacher I taught what I was told to teach. I used the curriculum given to me and followed the units. This was what my district required of me so I did what I had to do. For the students this was really their first time having a middle school math teacher that was enrolled in their tribe. That year there was nothing from my culture that I brought into the lessons. This year has been my first year back teaching middle school math. When I started teaching in 2006 our district used Connected Mathematics 2 (CMP2) and this year our district decided to use CMP2 again.

Using the same curriculum first without the culture helped me understand more about how I needed to link the two worlds. First of all the curriculum has many projects for students that help them understand the objectives. There are projects after some of the units and the students really do not relate to the project. My first time teaching this I skipped the projects.

Background

In 2007 the school board asked my husband and I to help the culture classes at our district. I became the culture teacher for the girls and my husband became the culture teacher for the boys. Having the two separate gender classrooms was the first thing the elders requested. Both my husband and I worked with elders in our classrooms. We would discuss the tribal customs and what they would like to see taught in the classrooms.

Step one was to have the genders separated. The female and male elder said they would be comfortable with teaching the students Arapaho language if there were girls' only classroom and boys' only classroom. The elders discussed the issues they would have to address and some of the language that would be spoken. Each elder did not want show any disrespect

towards the other when teaching the language or be embarrassed by a student who mispronounces a word. There was a discussion on how to correct the students' pronunciations and each male and female elder preferred they would rather correct their gender only.

These types of relationships between the genders were seen as a sign of respect for one another. The elders I asked said this was the tradition that was being lost and the one that bothered them the most. So setting up the culture classroom with the genders helped ease the elders into working through some curriculum that would help develop language learning.

In my middle school math classroom I cannot teach either the boy or girl separately. The educational classroom in America is set up so all students can learn about a subject equally. The academic language does not cause any embarrassment to the teacher or disrespect.

When doing this project there was a time I wished I had an all-female class and an all-male class. There were some discussions that were hard for me because I was addressing the boys. For this I would have to go over things with my husband. My first question was what is important for the boys to know? Where will they learn these? Who will teach them? For the females I could take the same questions and answer them without any issues.

Learning with the Culture

In this project the separation of genders was not a huge issue. In the culture classroom that was an issue, in the mathematic classroom there were only subtle issues I needed to address. These issues were for the male student. Addressing and getting the students involved in the project took time to do.

One major advantage I had was I know the families of my students. I knew who my students needed to talk to in their families to gather their information from for this project. There was an interview that the students had to do and my first initial response to them was to talk to the eldest member of their family. That is basic protocol. All advice and guidance comes from the elder in the family. All elders are valued and seen as a person who advises the family.

The simple protocols of the tribe need to be followed. In this unit I tried to get the students to recognize them on their own. My questions were: whom does your family go to for advice? Is there a grandparent or great-grandparent you can talk to? These types of questions may be leading them to the elder, but they are typical questions that are often asked.

When learning from the culture the students need to have the simple protocols in place. The recommendation would be to have staff trained in what are the protocols of the community.

Some of the families here on the Wind River Reservation have simple beliefs of what can and cannot be done. The elders have made a list of these types of things but many do vary from family to family. The variance comes from the intermarrying with different tribes or clans. A teacher came have a family day and ask the parents to share their customs with the teacher. This may help the teacher understand and to also use in their lessons.

Using the Arapaho symbols for the symmetry project has helped the students understand more of their culture. When I started this project I had the assumption that most were familiar with the symbols. After completing this project I now know that most of my students are not familiar with any of Arapaho Symbolism.

Finding this out I had to reflect on my own upbringing. I was raised by my grandparents and was often at my great grandparents' house. From my elders I have stories about different beliefs and customs of my tribe. My grandparents made sure those stories were passed down. But I can say that most of my in depth learning about what the symbols meant came after my schooling. It was like I was returned back to my tribe. After high school my family started teaching me more about what I needed to know.

This project has opened my eyes to this. My next question would be: will this happen for my students also? After some discussion with different community members they state that like me they were taught some things from their grandparents, parents, or older siblings. But the real learning took place after the schooling.

There seems to be a gap in the education of my students. This project has given me more questions about my culture then it did about teaching math. So in the next section I will recommend what needs to be researched more so the students on the Wind River Reservation can have more success in academics.

Providing access

In this project I saw how much my students needed to access their culture. They were unfamiliar with the stories or the uses of the symbols. Connecting to mathematics is a great way to help them gain access to the geometry of the Northern Arapaho Tribe. It also helps the mathematics teacher teach about all the geometry in the Common Core Math Standards.

These types of units can help the indigenous students relate to the academics of the schools and also to help them build their identity. The identity of the youth here border on gang or other ethnic groups customs. The loss of the Arapaho identity is a concern of the tribe

Limitations

This study was only applicable to my classroom and my tribe. The artifacts collected were from the students in my middle school classroom. This was an action research project in an attempt to learn from the students about what knowledge they had. The knowledge I was looking for was in math content about symmetry and if they knew about their cultural naming ceremony. These two specific items were used to build upon each other so they could learn both together. The naming was used as an attempt to teach symmetry for the middle school students.

Below is some of the students work on their interpretation of their Indian names. Figure 7 is Red Eagle. Here the student reflected the symbol for eagle with the four hills of life on the outer edges.



Figure 7

Figure 8 is also a representation of a student with the Indian name Morning Star Woman. The outer edges of are symbols that represent the person(square), woman(arrow) and a lake(6 sided polygon).



Figure 8

Recommendations

For future study in my classroom I would recommend that I look at teaching styles, student learning styles, and presentation of material.

For teaching styles I would experiment with teaching from the culture first than the core objective. In class they demonstrated their community roles and helped one another complete their project. Each table had a leader and this peer leader was then sent to me for further explanation. I often see these types of cooperative learning in the community when there are events taking place. These types of roles in the community need to be studied more because how much are the students using these roles in the classroom.

Student learning styles would be my next recommendation. This year our school board had the teachers administer a survey and the results that were given were that our students were mostly visual-spatial learners. I did not do any part of my study with this in mind. So I would recommend another study just for student learning styles in the math classroom.

Last recommendation would be the presentation of the material. By this I would like to see more curriculums integrated with the culture of the community. I think one unit is not enough for the students to grasp all the content they need to learn in math. If the students had more opportunity to learn about mathematics from their cultural point of view they may form stronger connections to the content. Several of my students have stated that they would always remember this unit because they learned about symmetry through their Arapaho name. If all teachers could make units that could help students become more familiar with the mathematics being taught there may be more retention.

Conclusion

In this study I set out to teach about symmetry by using the Arapaho symbols. What I found was that all of the students did not have any knowledge of Arapaho symbols or their Indian names. I also can conclude that the students have never used mathematics to learn about their culture.

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Appendix A

Lesson Plans

Lesson Title:	Arapaho Symbols
Overview:	Middle School grades 6-8 In this multi-day lesson, students will learn what the Arapaho symbols are and their meaning. Student will try to identify the different symbols in historic beadwork and look at the symmetry of the patterns.
Materials:	Booklets of Arapaho Symbols, pictures of Arapaho beadwork, graph paper, pencils rulers, and
Big Ideas /Essential Questions	Northern Arapaho people have distinct symbolism and it can be recognized on beadwork, suitcases (par fleche items), and in artwork.
Content Objectives:	By the end of the lesson, students will: <ul style="list-style-type: none"> • Recognize Arapaho symbols • Identify how and where the symbols are used in the community • Construct a design or pattern using the symbols and able to explain the importance of the pattern
Academic Language Objectives:	Right Triangle, isosceles Triangle, equilateral triangle, mid point, center, angles, rotation, reflection, symmetry, hexagon, polygon, geometry, line segment, vertex, degrees
Standards:	<ul style="list-style-type: none"> • CCSS.Math.Content.6.NS.A.1 • CCSS.Math.Content.6.NS.B.2 • CCSS.Math.Content.6.NS.B.3 • CCSS.Math.Content.7.G.A.1 • CCSS.Math.Content.7.G.A.2 • CCSS.Math.Content.8.G.A.1 • CCSS.Math.Content.8.G.A.2 • CCSS.Math.Content.8.G.A.3
Introduction:	Teacher will introduce the symbols in beadwork by showing artifacts, pictures, and other items.
Procedure:	<p>Day 1: After the Introduction the teacher will discuss how important it was to know symbols. Symbolism for American Indians was important. It was a type of identification when traveling. The symbols, style of dress, colors worn, and often decoration of horses was a way to identify different tribes.</p> <p>Day2: Teacher will have the students identify any math shapes or words they recognize. Make a list of their words and introduce new math vocabulary.</p> <p>Day 3: Students will be given graph paper and told to construct a</p>

	poster using the symbols. Tell a story about yourself or illustrate your Indian name.
Accommodations & Differentiation	<p>Accommodations:</p> <ul style="list-style-type: none"> • Additional support • Time • Large print • Microphone will be used in classroom during read aloud and with any directions needed. <p>Differentiation:</p> <ul style="list-style-type: none"> • Word posters- students can create word posters for the math vocabulary
Extension / Enrichment:	Investigate the symbolism of the tribe or other tribes.
Clean-up	In all activities, students will know the procedure. There will be a designated place where the materials are available for them to use. Students will need to replace items back in the designated place before leaving the classroom.
Assessment / Evaluation	Final Narrative of an expository writing essay by re-telling what the symbols mean in their pattern on the graph paper.
Closure:	Students should know the main vocabulary words: Equilateral triangle, isosceles triangle, right triangle, polygon, symmetry
Resources:	See the Reference Page

Lesson Title:	Symmetry of an Arapaho Name
Overview:	MS Grades 6-8 In this lesson the student will be learn about what an Indian Name is. How this can be illustrated or constructed using symbols found in the Northern Arapaho culture.
Materials:	Story from “100 Years of Old Man Sage” Chapter 1. Graph paper, ruler, pencil, protractor, compass
Big Ideas /Essential Questions	Indian names were are a part of a tribes custom. This ceremony took place either in small gatherings of only family members or in large groups. We will find the meaning of our own naming ceremony and the story behind why we were named this name.
Content Objectives:	By the end of the lesson, students will: <ul style="list-style-type: none"> • Know their Indian name • Retell the story of the name given to them or understand the naming process if student does not have a name • Write an explanation of their name and the symbols they could use to illustrate their name.
Academic Language Objectives:	Symmetry, reflection, rotation, translation, 180 degrees, 360 degrees, line of symmetry, vertical, horizontal, diagonal, axis, quadrant
Standards:	<ul style="list-style-type: none"> • CCSS.Math.Content.6.NS.A.1 • CCSS.Math.Content.6.NS.B.2 • CCSS.Math.Content.6.NS.B.3 • CCSS.Math.Content.7.G.A.1 • CCSS.Math.Content.7.G.A.2 • CCSS.Math.Content.8.G.A.1 • CCSS.Math.Content.8.G.A.2 • CCSS.Math.Content.8.G.A.3
Introduction:	Teacher will read Chapter one from Jeffery Anderson’s book “100 Years of Old Man Sage” with the students.
Procedure:	<p>Day 1: The story from Anderson’s book will be discussed and students will be given homework to research their own name or to find their historical family name.</p> <p>Day2: Students will share their research with each other and find differences and similarities. Start a list of common attributes of naming.</p> <p>Day 3, 4, 5, 6: Students will research the booklets of Arapaho Symbols and find symbols that could represent their names. Begin constructing a design on the graph paper to present their names. On the final day students will share their drawing with the class.</p>
Accommodations &	Accommodations: <ul style="list-style-type: none"> • Additional support

Differentiation	<ul style="list-style-type: none"> • Time • Large print • Microphone will be used in classroom during read aloud and with any directions needed. <p>Differentiation:</p> <ul style="list-style-type: none"> • Word posters- students can create word posters for the math vocabulary and similarities/differences of the naming ceremony.
Extension / Enrichment:	Research other tribes naming ceremonies.
Clean-up	In all activities, students will know the procedure. There will be a designated place where the materials are available for them to use. Students will need to replace items back in the designated place before leaving the classroom.
Assessment / Evaluation	The evaluation will be the sharing out at the end of this lesson. The students must share their drawing of the symbols and use some mathematical language in their explanation.
Closure:	Students should be able to connect the mathematical terms to their drawing and be able to explain how math helped them build a symmetrical graphic representation of their Indian name or historical family name.
Resources:	See the Reference Page

Lesson Title:	Symmetry in math
Overview:	MS Grades 6-8 In this lesson the students will learn how mathematics can be connected to the Northern Arapaho culture. Students will learn how math is applied to construct symbols that are have to have symmetry.

Materials:	Symmetry handout from Connected Math 2 curriculum. Rulers, pencils, graph paper, construction paper, compass, protractor, erasers, scissors, glue, Arapaho symbol handout
Big Ideas /Essential Questions	How can symmetry be used to represent a person? Students will be able to demonstrate the difference between reflection, rotation and translation symmetry.
Content Objectives:	By the end of the lesson, students will: <ul style="list-style-type: none"> • Know what symmetry is • Be able to perform the different tasks to build a symmetrical image on graph paper • Be able to reconstruct their imagery onto construction paper with no lines.
Academic Language Objectives:	Symmetry, reflection, rotation, translation, 180 degrees, 360 degrees, line of symmetry, vertical, horizontal, diagonal, axis, quadrant
Standards:	<ul style="list-style-type: none"> • CCSS.Math.Content.6.NS.A.1 • CCSS.Math.Content.6.NS.B.2 • CCSS.Math.Content.6.NS.B.3 • CCSS.Math.Content.7.G.A.1 • CCSS.Math.Content.7.G.A.2 • CCSS.Math.Content.8.G.A.1 • CCSS.Math.Content.8.G.A.2 • CCSS.Math.Content.8.G.A.3
Introduction:	Teacher will model how to construct a poster using the graph paper drawing from previous lesson
Procedure:	<p>Day 1: Students will watch and listen to the teacher on how to scale up their drawing using a ruler.</p> <p>Day 2: Students will practice drawing on construction paper and finding their lines of symmetry and figure their scale factor.</p> <p>Day 3, 4, 5, 6: Students will work independently on their poster.</p>
Accommodations & Differentiation	<p>Accommodations:</p> <ul style="list-style-type: none"> • Additional support • Time • Large print • Microphone will be used in classroom during read aloud and with any directions needed. <p>Differentiation:</p> <ul style="list-style-type: none"> • Teacher will help and explain to individual students on a one-to-one basis during independent work.
Extension / Enrichment:	Research other tribes naming ceremonies.
Clean-up	In all activities, students will know the procedure. There will be a designated place where the materials are available for them to use. Students

	will need to replace items back in the designated place before leaving the classroom.
Assessment / Evaluation	The assessment will be the final poster.
Closure:	Students should be able to use math strategies to help them scale up their drawing onto the construction paper. Students will be able to use tools to help them make straight lines and draw circles.
Resources:	See the Reference Page

Reference page

See attachment for handout on Arapaho Symbolism

See attachment for handout Arapaho Designs and Symbols

See attachment for handout Three Types of Symmetry

Appendix B
Arapaho Symbolism

See Attachment

Appendix C

Arapaho Designs and Symbols

See attachment

Appendix D

Three Types of Symmetry

See Attachment

Appendix E
Student Work

See Attachment

Appendix D

Three Types of Symmetry

See Attachment

Author's Biography

Iva Moss-Redman is an enrolled member of the Northern Arapaho Tribe from the Wind River Reservation. She currently works at Arapahoe School teaching math. She is married to Michael Redman and they have three children.

Iva has worked at Arapahoe School for eight years and has taught math, language and culture of the Northern Arapaho, and has been a math coach. She currently works in math intervention for grades K-8, with 2014 focusing on 6-8 math.