Understanding Our World Through Geometric Reasoning

Weaving Culture and Geometry into a Project-Based Learning Unit

Emily Leahy

Diné Institute for Navajo Nation Educators (DINÉ)

2023

Author's Note

Emily Leahy is a second-grade teacher at Kinsey Inquiry and Discovery School. Correspondence about this curriculum unit can be addressed to Emily Leahy, 1601 S. Lone Tree Rd. Flagstaff, AZ, 86001. Email contact: eleahy@fusd1.org

Context

This unit is written for second grade students at Kinsey Inquiry and Discovery School. A part of Flagstaff Unified School District, Kinsey is a Title 1 public school in Flagstaff, Arizona. Flagstaff, Arizona is a community of approximately 78,000 people. Flagstaff sits at the base of the San Francisco Peaks, Doko'o'osliid. One of the four sacred mountains of the Navajo people. Flagstaff borders both the Navajo and Hopi reservation land. It also is the home to many that are studying or working at Northern Arizona University. Due to this and the bordering of two Indigenous nations, it is a very diverse community with many different people calling it home. The school serves 349 students from grades Pre-K to 5th grade. Native Americans are the largest subgroup that make up Kinsey at 50% of students, followed by Hispanic at 22% then White at 20%. Other nationalities that students identify as at Kinsey include multiple races, Asian, and African-American. Most Native American students are either primarily from Navajo or Hopi families, with students coming from families with a wide range of adherence to cultural traditions: some very traditional and some much less so. Students that come from low-income families make up 55% of our student population (AZ School Report Cards).

Kinsey is a place-based magnet school. The place-based magnet program's intention is to provide students with experiences, mostly in the outdoors, that connect students to their place: Northern Arizona. Excursions and partnerships are experiences that help our students foster the connection between themselves and their place. Some of these excursions include trips to Red Rock State Park to see examples of erosion first hand, Museum of Northern Arizona to learn about cultures of Northern Arizona, Grand Canyon National Park, and Walnut Canyon National Monument. Partnerships that Kinsey has fostered throughout the years include Willow Bend Environmental Education Center, Terra BIRDS, and Grand Canyon Youth. Through these partnerships, Kinsey is able to provide engaging, high quality experiences that complement content learning that happens in the school building.

A school-wide initiative that Kinsey is focused on is project-based learning. Project-based learning helps students foster skills and gain knowledge while working on an authentic, engaging, complex problem, question, or challenge. Project-based learning (PBL) allows teachers to integrate multiple content areas and connect them to a driving question. PBL is often student-driven and provides students with voice and choice. Voice meaning that students' interests, ideas, and unique skills are included in the project and choice meaning that students have a choice in how they showcase the learning that has taken place. Choice can be in the form of the process or the product. Students could have choice in the way in which content is learned. For example, students can choose to read a book, watch a video, or complete an activity to learn about a specific standard or skill. Contrarily, students could have a choice in the product that shows that they have learned the content. For example, students could choose to create a podcast, newspaper article, cartoon, or drawing that demonstrates their understanding of a specific standard or skill. Voice and choice also provides opportunities for students to collaborate and demonstrate their learning through the creation of such products. This unit will be taught as a PBL unit, so specific PBL teaching strategies are integrated into the lessons and materials provided.

Second graders are at an age in which they like to explore and be exposed to new ideas and things. There tends to be both students who are unafraid of challenges, while there are some that are afraid to take risks or make mistakes. Second graders like to work alone or with a partner. Larger groupings can be overwhelming for students at this age and maturity level. In this specific classroom, there are 20 students. Their backgrounds include students from large and small families, students who are Navajo, Hopi, Hispanic, African-American, Caucasian, and some who come from mixed race families. This group of students is eager to learn about math and enjoys using manipulatives, building things, and creating. In this unit, I hope to help this group of students develop a way in which they can look at the world through a geometric lens, while developing strong math vocabulary, language, and reasoning skills.

Rationale

There are multiple facets as to why geometry is an important mathematical strand and is the central focus of this culturally responsive curriculum unit. When studying geometry, students will learn about geometric shapes and structures, examining characteristics and relationships, looking at objects with different perspectives, creating and maneuvering mental representations of two and three-dimensional objects. Students develop reasoning and justification skills through the study of geometry. This can also help interpret and describe physical environments, is important for problem solving, and is useful in other mathematical disciplines such as area and fractions, interpreting data using histograms or scatterplots, and coordinate graphing that uses algebra. Creating art, using maps, planning a route, or designing a floor plan all use spatial reasoning (Principles and Standards for School Mathematics, 2000).

Research suggests that geometry is given the least attention of the mathematical strands but has been shown to support other mathematical skills (Clements and Sarama, 2011). We know that when compared with children in other countries, the United States underperforms by a large margin. This could be due to geometry concepts being neglected in the elementary curriculum or rather the curriculum does not require a deeper level of analysis. The focus may be rather on recognizing and naming geometric shapes and does not help students reach the descriptive/analytic level or abstract/relational level. At the descriptive/analytic level, students are able to recognize and categorize shapes based on their properties. They realize that certain combinations of properties convey a class of figures and others do not. At the abstract/relational level, students can form abstract definitions and make logical arguments by classifying figures through the ordering of properties (Crowley, 1987). Although students may not reach these levels until middle or high school, it is crucial to move students beyond the visual level, so that they can think about properties of classifications of shapes (Clements, 2003).

When looking at math curriculum by different authors, oftentimes geometry is the last unit to be taught. In the current math curriculum that my school district uses, Eureka, it is the final module that is taught. It seems as though across grade levels, geometry is not a large math focus when prioritizing standards that should be taught. This unit is written with a geometry focus, so that those standards and mathematical concepts can be taught earlier in the school year and be given their own time for students to learn and explore. This is the intention rather than to rush through them or glaze over them at the end of the school year.

Project-based learning is a way in which to leverage culturally responsive teaching and learning in the classroom. There are several ways in which project-based learning is culturally responsive. Specially, project-based learning requires students to do in depth thinking and become the experts on a topic. Students are not dependent on teachers, but rather the ones that are required to research and showcase their learning in various ways. It also requires students to be advocates of their own learning, helping them to determine ways in which they can succeed to learn the best. Project-based learning asks students to create using the information they have learned through the project and thus are able to elaborate on the learned knowledge to create something new with stored information. It does not ask students to recall, recite or remember an easy answer, rather placing importance on the top of Bloom's Taxonomy pyramid. Many cultures value collaboration and it is an essential component to cultural knowledge surviving and thriving. Collaboration is a core component of effective project-based learning. Students love to talk and work together, so providing intentional opportunities for students to talk, work in varied groupings, and make meaning of academic concepts is crucial (Truss, 2018).

Content Objectives

This unit is going to teach students about attributes of shapes, symmetry, and tiling the plane by analyzing cultural artifacts that are important to the Indigenous people such as rugs, pottery, and jewelry. The purpose is to expose students to and develop geometric reasoning by demonstrating that geometry is present in the world around them and is valued by people and cultures.

Navajo Rugs

Rug weaving is an aspect of the Diné people's way of life that connects both mathematics and culture in this unit. Navajo rug weaving and the use of certain tools is seen as both a way in which to connect and tell stories between Navajo people and their kin, and as an economic transaction to provide for one's family (Ahlberg-Yohe, 2008). There are many designs that are specific to stories, teachings, places, and values. A cross was a symbol or motif that represented the teachings of Spider Woman. Spider Woman is significant to the Navajo people, as she was the one that taught them how to weave and how to create and spread beauty in one's own life. The diamond and triangle are two important design elements that often demonstrate the importance of the Navajo homeland, *Dinétah*, noting the four sacred corners for the four sacred mountains. Triangles can symbolize prayer feathers when stacked on top of each other. Petroglyphs, pictographs, and pottery shards can also be found in traditional Navajo weavings. The use of color is also important to Navajo weavers. In early days of Navajo weaving, colors were limited to browns, blacks, whites, grays, and indigo blue with the occasional use of red (J.Freund, 2008-2009). This aspect of art and Navajo culture ties in geometry standards to create a unit, where students will reflect upon their artistic and mathematical abilities including understanding shapes and the meanings in which they hold in a design.

Ancestral Puebloan Pottery

In this unit students will focus on analyzing Ancestral Puebloan pottery as historically, Navajo pottery was typically left undecorated. Rather it was black or gray and crafted for ceremonial use. In Navajo pottery, several types of clay were mixed together for physical, chemical, and

aesthetic qualities. A hot, melted sap from pinyon trees was applied to the pot after firing before cooling to create a glossy finish. This pinyon pitch glossy finish made the pot waterproof (Digital Collections from St.Kate's). Not until recently have Navajo people began creating ceramics that have designs on them.

Ancestral Puebloan pottery is commonly found in the Southwestern United States. Ancestral Puebloans were maize agriculturists who lived across the northern Southwest from the emergence of farming until the coming of Spanish explorers in A.D 1540. Cultural traits of this group included dependence on heavily farmed foods, the construction of multi-room, multi-level homes called *pueblos*, characteristic pottery, and underground ceremonial spaces called *kivas*. Depending on where Ancestral Puebloans lived in the southwest, east or west determined their relationships and importance put on water. Ancestral Puebloans who lived in the west depended more on flood water farming thus concentrating religious rituals to rain making. Those who lived in the east practiced irrigation agriculture using the Rio Grande River in addition to flood water farming. These two groups practiced religion, social organization, architecture, and ceramics differently (American Southwest Virtual Museum, 2023). Modern Pueblo people are descendents of the Ancestral Puebloans. There was great movement on the same landscape after A.D 1300 and this made certain that multiple groups from extensive geographical origins make up the modern pueblo tribes. The Hopi people are descendents of the Kayenta and Little Colorado branches of the Ancestral Pueblos (American Southwest Virtual Museum, 2023). This information is especially important for the particular context of my classroom, as I will have Hopi students in my classroom.

Ancestral Pueblo pottery was built using thin coils of clay and the sides were smoothed out most likely using a gourd scraper. Ancestral Puebloans began painting black designs on their vessels around A.D 500. Beginning about A.D 700, they began adding white slip as a background (National Museum of the American Indian, 2010). This pottery was developed for trade and artistic status, as well as for practical and functional purposes (Pacific Grove Museum of Natural History, 2017). Most of the pottery that students view during this unit is Tusayan White Ware Kana'a Black-on-white. In this unit, students will analyze pottery to develop their understanding of shapes, tessellations, and patterns Indigenous artists use to create their designs.

Jewelry

In the late nineteenth century, Navajo silversmiths learned their artistry from Mexican metalworkers. This happened after the Navajo people were released from internment at Bosque Redondo in New Mexico in 1868. Navajo jewelry became an important way of showing one's standing in the community. This is reflected in the quantity and quality of jewelry pieces worn by a person. Traditional Navajo jewelry accentuated the use of large turquoise pieces combined with intricate silverwork. Different techniques that are used in Navajo jewelry include chip inlay and overlay. Chip inlay or Navajo inlay features small pieces of turquoise and coral that are fixed in without cutout places in the silver. The Navajo overlay looks similar to the Hopi silver overlay technique and it was borrowed from the Hopi people. This is often used with semiprecious stones and uses Navajo designs and themes. The squash blossom necklace is also an important piece in Navajo jewelry. In order to be a squash blossom necklace, it must have the *najahe* or pendant in the middle. Interestingly according to the Museum of Northern Arizona, "The term squash

blossom may be a misnomer. The rows of elaborate, flower-like beads that flank the central pendant probably represent the pomegranate blossom beads that historically decorated Spanish trousers." (Southwestern Native American Jewelry, 2023) In addition to the previously mentioned items, Navajos also stamped, hammered, casted, and soldered concho belts, belt buckles, and *ketohs* or bow guards to protect from the recoil of shooting an arrow (Southwestern Native American Jewelry, 2023). Students will explore Navajo jewelry to develop their understanding of the history, uses and significance of the jewelry and connect this to the geometric patterns and symmetry used in the designs.

Attributes of Shapes

Students need opportunities to learn how to identify and describe shapes by their attributes. Attributes are defined as characteristics of a shape. Some of these attributes can be thought of as defining attributes, meaning what makes the shape unique and distinguishable from other shapes. There are also non-defining attributes, meaning that shapes can have a certain color or be made out of a certain material thus the color nor material defines the shape. However, both are valid and important when discussing and developing geometric language with students. It is crucial that students develop their abilities to describe and analyze shapes based on their attributes. Without this important stage of development, the abstract/relational level will not be reached because students will be unable to see relationships within classes of shapes (Clements, 2011). Shapes are identified, distinguished, and classified from one another using definitions. When providing students with a definition, the definition must only include previously defined and cannot have contradictory meaning. Seah illustrates this point, "For example, if a triangle is defined as a 'three-angled shape', the expectation would be that the words 'three', 'angled', and 'shape' have been explicitly defined previously so that their meanings are known (Seah, 2015). Students should be given ample opportunity to explore and engage in activities that require them to name and define the shapes rather than learning the names and definitions by rote memorization (Seah, 2015).

Regular and Non-Regular Polygons

When students are working to identify and describe shapes based on their attributes, it is important to expose students to regular and non-regular polygons. A polygon is defined as a two-dimensional, closed figure with three or more straight sides and angles. Regular polygons are defined as any figure having all sides of equal length. Non-regular or irregular polygons are a figure that does not have all sides of equal length. Oftentimes, shapes or figures that are displayed on posters throughout the classroom display a regular triangle, regular pentagon, regular hexagon, or perhaps even a common looking rectangle with one set of opposite sides longer in length than the other set of sides. As Seah states, "Children quickly develop a stereotypical idea of how shapes should look. To a child, a rectangle is a shape with two long and short sides. A square has four straight sides with the base sitting horizontally on the plane. When the square is titled, many children think it is a rhombus or a diamond. Children also assume that polygons such as pentagons, hexagons, and octagons have equal sides" (Seah, 2015). It is clear from studies conducted that students are used to seeing equilateral or regular triangles in classroom environments, as from one study conducted only 60% of three-year olds were correct in classifying three-sided shapes as triangles. The researchers noted, "They are likely to accept

triangular forms with curved sides and reject triangles that are too 'long', 'bent over', or 'point not at the top'" (Clements & Sarama, 2000). .However it may be interesting to note that when the same study was conducted and compared with Kindergarteners and 8th graders, those grade levels correctly identified 64% and 81% respectively. Considering that this is the descriptive level, it is crucial that students be exposed to irregular polygons at an early age and have an in-depth understanding of classifying shapes by their attributes.

Tessellations or Tilings

A tessellation is created when a shape is repeated over and over again covering a plane with no gaps or overlaps. Another term that can be used to refer to tessellations is tiling or tilling a plane. Different shapes can be used together to tile a plane. Certain shapes can be used solely to tile a plane, while others cannot. In this unit, students explore which shapes are able to tile the plane by using only that shape and which shapes might need to be tiled with additional shapes to fill in gaps (California State University Northridge). For example, squares and equilateral triangles can tile a plane solely using only squares or only equilateral triangles, however pentagons cannot. Pentagons cannot tile a plane because of the measures of their interior angles. Students use different combinations of shapes to create a rug pattern that tiles the plane.

Symmetry

Symmetry is an area of focus in this unit, as artists often use symmetry in their work. It is important to note that children have intuitive notions of symmetry from an early age. Some studies point out that even young children can learn manual procedures for producing transformations, although they may not learn to mentally perform the transformations until middle or high school (NCTM, 2003). Beginning at the third grade level, students can be exposed to symmetry to predict and describe the results of sliding, flipping, and turning two-dimensional shapes. Exploring symmetry with students is an opportunity to show young learners that geometry is incorporated in the world around us (Knuchel, 2004). In this unit, students are directly taught about reflectional symmetry and rotational symmetry by analyzing artistic designs. Reflectional symmetry is when one half is the reflection of the other half. Rotational symmetry is when a shape is partially turned, the shape looks the same. According to Moyer, "...For example, many Native American peoples have used rotational symmetry to produce intricate basket designs. By studying the patterns in these objects, students can visualize the concepts of line and rotational symmetry… After showing repeating patterns and symmetry in pottery, baskets, and blankets, teachers can demonstrate examples of repeating patterns… and identify those patterns that slide, reflect, or rotate, thus illustrating the concepts of transformations and symmetry (Moyer, 2001). When we look at designs on artifacts, students are exposed to these concepts of symmetry. They are invited to analyze whether or not their own creations have symmetry. Students also discuss how the use of symmetry does or does not please the visual eye.

Through the study of these cultural artifacts, students will learn the geometric concepts of symmetry, attributes of shapes, and tiling the plane. The importance and significance are discussed with students along with the materials that artisans historically and presently use to

design and create these artifacts. The following teaching strategies can be used with students to help them learn the content objectives.

Teaching Strategies

Elements of Project-Based Learning (Entry Event, Driving Question, Need to Knows, Milestones)

There are certain elements of a project-based learning unit that help to engage students, keep their inquiry sustained, as well as keep it authentic and student driven. Specifically, beginning the unit with some type of entry event can help to engage students in the project rather than simply introducing it. An entry event can be a guest speaker, learning excursion, a simulation or a video (PBLWorks.org). One example of an entry event that could be used for this unit or to watch a video or bring in a guest weaver for students to provoke their interest and inquiry. Another example of an entry event could be a learning excursion to a local museum. In Flagstaff, we are fortunate to have the Museum of Northern Arizona nearby. A worthwhile entry event for this unit would be to take students to the museum and allow them to explore and view the different artifacts that are present at the museum.

Another element of a quality project-based learning unit is a well-written driving question. A driving question does just as it suggests, drives the project and keeps students going. It should be a question that the classroom community can keep referring back to throughout the project. Criteria for a quality driving question should include considerations of whether or not it is engaging for students. Is it understandable? Is it interesting? Does it provoke more questions from students? Additionally, the question should be open-ended. It should not be something that can be easily found through an internet search. Finally, the question should align with learning goals. In order to answer the driving question, students will need to learn the targeted standards and skills (Larmer, 2018). The driving question for this project is: How do Indigenous artists use geometry in their artifacts?

Creating *Need to Know* with students helps steer the project in a student-led direction. As a teacher, one can most likely predict key student questions that students may need to understand in order to answer the driving question. From this driving question, students will most likely need to know what key terms such as *Indigenous*, *geometry,* and *artifact* mean. These *need to knows* help to shape the learning and flow of the project. When collecting ideas of *need to knows*, this is an excellent time to collect students' current knowledge regarding the topic (PBLWorks.org). Working with the *need to knows*, teachers can create milestones. These are goals that are shared with students to help them sustain inquiry throughout the project. Milestones that are created for this project includes the entry event, a formative assessment about attributes of figures, a sample design, a graph, a map, an art proposal, and a final project reflection. These milestones help students see where they are headed in the project. It also helps them develop self-advocacy skills to know if they are on or off track and ask for help if needed. These milestones can also help older students that may be working in small groups to stay on task similarly to how adults manage themselves with a project in the workplace.

Use of Manipulatives

In this unit, students use hands-on manipulatives such as spaghetti, geoboards, patty paper, pattern blocks, and digital resources to strengthen understanding of geometric concepts. Students use spaghetti and geoboards to build polygons. Patty paper is utilized to aid students in seeing symmetry present in different designs. Pattern blocks and Mathigon are used to help students explore tilings. Using manipulatives reinforces that students have a wide range of understanding and tools, as well as integrates both concrete and abstract ideas. In this unit, students also use digital tools to manipulate different shapes (Clements, 2003). Mathigon is a digital resource that is utilized in the unit, so that students have ample opportunities to create, reflect, and try again when creating and playing with shapes. Incorporating and exposing students to both concrete and digital manipulatives allow students the opportunity to have choice in how they want to create their final product. Providing students with voice and choice allows for student agency and their ability to choose what best works for them.

Geometry Walk

A Geometry Walk is a teaching strategy where students take a walk in the school or outside that is used to note geometry's existence and use in the real world, therefore providing motivation for the study of geometry. This approach extends the use of using classroom objects to illustrate geometric ideas, but rather take a walk outdoors to promote a greater awareness of geometry present in the world around us. Students will walk around our school and take note of geometric shapes they see in different places through written notes and sketches. When conducting a Geometry Walk, it is important to consider an object's shape may be determined by its function or use, an object's appearance may be determined by its shape, and describing shapes and spatial relationships may be aided by the use of geometric vocabulary. Examples of this are explained by Nelson and Leutzinger (1979), "A projector screen, for instance, is rectangular in shape because the images displayed on it are generally rectangular and a rectangular screen is easier to roll up than a circular screen would be. An abstract painting or sculpture may use a shape, or a combination of shapes, because a particular shape is pleasing in appearance. Many things, such as buildings or furniture, may be shaped as they are because of both function and aesthetics' ' (p. 2). It is helpful to take a walk on your own first to preplan questions that you can ask students during the Geometry Walk that you take together. Preplanning questions can help focus not just on shape recognition and the use of geometric vocabulary, but also on how the aesthetics and function help determine the shape.

Patty Paper Geometry

Patty paper is thin waxed paper cut in 5.5 or 6 inch squares that are commonly used between uncooked hamburger patties, however it can be used as an effective geometry tool with students. Due to its waxed and translucent properties, students can use it to trace lines or shapes to explore symmetry. When exploring reflectional symmetry, students can use it to flip or fold the mirror image to check images for reflectional symmetry. It is also incredibly useful when exploring rotational symmetry, as students can check images for rotational symmetry by finding a point, tracing part of the shape and rotating that tracing around the point. Students in higher grades can see how many folds of rotational symmetry a figure has and even the rotational degree by dividing 360 degrees by the number of rotations. Patty paper can also be used to explore

translational symmetry by using it to see if a pattern or design as a whole fills the same place in the plane before and after the translation. This is a hands-on strategy that teachers can use to help students understand and check for different types of symmetry. This strategy will be used to explore reflectional and rotational symmetry in the artifacts discussed above. Students will also demonstrate their understanding of reflectional and rotational symmetry when reflecting upon their own design that they create towards the end of the unit.

Think-Pair-Share

This teaching strategy helps students consolidate their own thinking before whole-group discussion. This is important so that students can formulate their own thoughts without influence from peers. Students first should be given independent time to think on their own about the given question or prompt. Students then pair up with a partner and discuss the question or prompt. Each taking a turn to explain their thinking and what was formulated about the question or prompt. Finally, pairs or individuals share out with the entire class to discuss students' thoughts. This teaching strategy will be used throughout the unit during several activities including creating shapes with geoboards, spaghetti polygons, the geometry walk, and when students look at maps of natural resources.

Peer Feedback Using Critique Protocols

Using peer feedback in the classroom can improve the quality of work produced by students. Critique protocols are a structured process that students use to give and receive peer feedback. The specific protocol used can be chosen to to focus on big picture ideas or details of a specific product. By using a protocol to provide feedback, students must think critically about content in order to give quality feedback to another student. This also allows for student ownership as students are providing feedback to each other rather than solely from the teacher. There are different types of protocols that lend themselves to different categories: high-level feedback on multiple products or deep feedback on a single product (PBLWorks.org, 2020). If giving high-level feedback on multiple products a gallery walk would be an appropriate protocol. If giving deep feedback on a single product, one could use a rubric guided feedback protocol. These two classroom activities are explained in detail later in this unit, when students complete their art proposal individually and showcase their work for visitors.

Public Product

A public product is when students share their work with an audience beyond the classroom. There are different forms in which a public product can be represented. It can be a tangible product that students have created, it can be a presentation where students share their answer to a problem that was solved, or an answer to a driving question. It is important that someone beyond the teacher sees student work and has the opportunity to hear about their learning. A public product encourages high quality work and motivates students. This is also a time for students to discuss their work with others. Additionally, it is an opportunity to bring in community members and families. The public product for this project is an art showcase. Families, teachers, and community members are invited to attend the art showcase (PBLWorks.org). When guests arrive, students discuss their work and explain what they have learned about artists, artifacts, and

geometry. It is helpful to display a slide or have questions available to guests to help facilitate conversations and discussion with students. Sample questions include: Can you tell me about your artwork? What shapes did you use in your design? What type of artwork did you create? Does your design have symmetry? What inspired you to create this?

Project-Based Unit Plan Outline

Driving Question: How do Indigenous artists use geometry in their artifacts?			
Milestone #1 Key Student Question: What are different shapes? How do we classify them?			
Classroom Activities:	Entry Event	Geoboard Shapes and Analyzing Patterns in Rugs	Spaghetti Polygons and Analyzing Shapes in Pottery
Assessment:	Geometry Walk Scavenger Hunt		
Milestone #2 Key Student Question: Which shapes fit together and which do not?			
Classroom Activities:	Tessellations Exploration with Polypad	Patty Paper Symmetry Lesson using Navajo Jewelry	
Assessment:	Sample Design		
Milestone #3 Key Student Question: What are different types of artifacts that are designed with shapes?			
Classroom Activities:	Gallery Walk		
Assessment:	Graph		
Milestone #4 Key Student Question: Where do Indigenous artists get their materials?			
Classroom Activities:	Using Maps to Look for Natural Resources		
Assessment:	Natural Resources Map		
Milestone #5 Key Student Question: How do artists make their art better?			
Classroom Activities:	Art Proposal Creation & Praise, Question, Suggestion Protocol		

Assessment:	Art Proposal
Milestone #6 Key Student Question: How do artists prepare for a showcase?	
Classroom Activities:	Art Creation and Explanation Practice
Assessment:	Showcase and Reflection

Project Outline adapted from PBLWorks Project Planner

Classroom Activities

Geoboard Shapes

Begin by preparing four blank anchor charts that are easily displayed for students to see. As you are preparing the anchor charts, set expectations with students for using the Geoboards and rubber bands. Provide students time to play and explore with the Geoboard prior to starting content instruction. When ready, gather students and draw a scalene triangle for students on the first chart. Ask students to describe the shape without using its name. Students may say that it has three sides, three "corners", the sides are straight, and/or the sides have different lengths. Define for students that the "corners" are angles, the space or figure formed when two sides meet. Record these ideas on the anchor chart. Then invite students to create a three-sided, three-angled shape on their Geoboard that looks different from the one drawn. As students build their shapes, employ the Think-Pair-Share strategy. Students should first think and create a shape on their own without consulting with their neighbor. After a couple of minutes, ask students to share with their neighbor. Students should not change what they made, but rather show their neighbor that their shape has three sides and three angles. Then have students hold up their Geoboards to share with the class. As students hold up their boards, draw shapes that students have created on the first anchor chart. Refocus students to come back to the anchor chart after time has been given. Point out that even though these shapes look different, they have some attributes or characteristics in common. Name the attributes with students. (three sides, three angles, three vertices-where two line segments meet, straight sides) Point out that these shapes are closed, meaning there are no gaps or overlays. Draw an open shape for students to see the difference. Repeat this process with students by drawing a concave quadrilateral. Ask students: How would you describe this shape without using its name? (It has four straight sides, some of the sides are different lengths, it has four angles) Count the angles with students, then prompt them to create their own shape with four sides and four angles that does not look like the one drawn on the chart. Repeat the Think-Pair-Share strategy for the four sided-shape. Next, draw a non-regular pentagon on the third chart. Ask students the same guiding questions as with the three-sided and four-sided shape. Repeat the Think-Pair-Share strategy. Finally, draw a non-regular hexagon and repeat the previous steps using the fourth anchor chart (Adapted from Eureka Math Curriculum Module 8 Lesson, 2015). After this activity, analyze a Wide Ruins Navajo rug. Ask students what types of shapes they see used in this design. It may even be helpful to project the rug or print a photograph and use a page protector to draw over three-sided, four-sided shapes as students identify them.

Naming Polygons with Spaghetti

Students explore making and naming polygons through this activity using different sized pieces of spaghetti and a piece of construction paper. Provide groups of students with a few pieces of spaghetti and ask them to break them into different sized pieces. Students should also have a piece of construction paper as their background for building. Ask students to create a shape with three straight sides using pieces of spaghetti. Ask if students know the name of a three-sided shape. Discuss breaking the word apart into tri-angle. Draw students' attention to examples such as tricycle, triplet, and tripod. Record this term on the first anchor chart with the shapes drawn from the previous activity. Repeat this process by making a four-sided shape and using the term quadrilateral. Students may say “square” or “rectangle”. Help students understand that squares, rectangles, and rhombuses are quadrilaterals. Discuss with students that a rectangle is a quadrilateral, but we can also classify it is a rectangle based on its attributes. Label those on the anchor chart if they are present. Repeat this process by having students build a five-sided shape and six-sided shape. Name the shapes as pentagon and hexagon. After completing the spaghetti polygon activity, project or show a printed photograph of a piece of Ancestral Puebloan pottery. Ask students what shapes do they see that the creator used? How do you know they are those shapes? Use vocabulary from the anchor charts to describe what you see. As students discuss the geometry in the pottery, discuss what materials the pottery was made out of and when it was made. Repeat this process with another example of pottery, so students can foster their use of mathematical vocabulary. See appendix for a link to the image of the pottery.

Geometry Walk Scavenger Hunt

Students go on a Geometry Walk Scavenger Hunt to promote awareness of geometry in the world around them. Set expectations how students stay safe while on a Geometry Walk as well as provide students the Scavenger Hunt worksheet they will use on the walk. Review the worksheet so students understand the columns they must fill in and hunt for while on the walk. Determine which areas of the school students will walk to and what types of questions you can ask students to develop their understanding of geometry in the real world. Questions can fall in specific categories such as discussing functional shape, aesthetic shape, and geometric vocabulary. An example of a functional shape question is *Why is the slide in the general shape of a triangle?* An aesthetic shape question is: *This sign is in a different shape than the other signs, why do you think it is this shape? Which one do you like better?* A geometric vocabulary question could ask: *I see a large sign that is shaped like a regular octagon. What color is it and where is it?* (Nelson and Leutzinger, 1979) When students come back to the classroom after the Geometry Walk, have a class discussion about what they discovered. Follow-up activities include having students share one of the shapes they observed on the walk and also have students think about an object that is shaped a certain way because of the job it needs to do. Remembering that the walk and activities should provide answers for students as to why students study geometry (Nelson and Leutzinger, 1979).

Tessellations Exploration with Mathigon Polypad

Students explore tessellations through using the digital resource of Mathigon. Help students navigate to the Mathigon Polypad. Demonstrate to students how they can choose shapes by clicking on it. Draw students attention to how the shape can be rotated. Allow students time to explore and build. When students have had ample time to experiment and explore using the tool, provide students with the definition of a tessellation: the covering of a surface using one or more geometric shapes, called tiles, with no overlaps or gaps. Model for students what an overlap and a gap would look like using your Polypad. Next, pose the question of whether or not you can tile the plane with only equilateral triangles. Allow students time to use the equilateral triangle pieces to find out that yes, you can tile a plane with only triangles. Then, prompt students to try with squares, pentagons, hexagons, and octagons. Keep track and create a list that is viewable by students of which shapes are able to tile the plane. Next, prompt students whether or not you can use more than one type of shape to tile a plane. Invite students to choose two different shapes and explore whether or not they can work together to tile a plane. Walk around and have conversations with students about what they are trying. Keep track of student responses on the same list. When students have shared their ideas, ask students to Think-Pair-Share why certain shapes can tile and certain shapes cannot. Students will most likely arrive at the conclusion that some shapes can fit together to take up all the space so there are no gaps, while others leave a gap. It is above grade level to perhaps have conversations about the degree measure, but that is where students could go if some advanced thinkers want to know more.

Patty Paper Symmetry Lesson with Navajo Jewelry

In this classroom activity, students explore concepts of geometry by looking closely at different types of Navajo jewelry. Begin by introducing the concept of symmetry to students. Tell students that symmetry is when we look at an image and there are parts of that image that are repeated in some way. Most often, this is appealing and looks nice. Show students a picture that has reflectional symmetry and ask what is repeated or how it is repeated. Have an open discussion with students to hear their ideas. Highlight students' thoughts when they express that they see the same thing on both sides. Provide students with language to call this reflectional symmetry. Tell students that artists use this to make the art look appealing to us. Use patty paper on a printed image to model for students how to trace one side of the image and then flip the patty paper to show that the same shapes are reflected on the other side. Provide students with images to let them try with the patty paper. Some may have reflectional symmetry and some may not. Prompt students to draw the line of symmetry on the image. Come back together and discuss that the line of reflectional symmetry can be vertical, but it can also be horizontal. Model this for students with a square shape. Next, look at a different image with students that has rotational symmetry. Ask students what pattern they see in this image. They may say that they see the same shape turned around and around a given point. Model for students with an example how to place a point in the middle, trace one copy of the shape and rotate the patty paper so that as it turns, it holds the same shape that was traced. Once students have had time to practice on their worksheet, pull students back together to analyze images of Navajo jewelry. Ask students if they see symmetry in the artifact. If they do, did the artist use reflectional or rotational symmetry? How does the use of this geometry concept make the artist’s work appealing to us? Also show 1-2 examples of jewelry that does not have symmetry. Discuss that even though this artist did not use symmetry, the artifact and design is still unique and appealing but in a different manner.

Remind students that they can use symmetry when designing their own artifact for the art showcase.

Gallery Walk Data Collection

Before students complete a gallery walk and a bar graph about shapes they see in artifacts, introduce taking data and creating a graph using a familiar question. For example, help students take data on favorite ice cream flavors, or type of pet at home. Model filling in the four categories that students choose from i.e chocolate, vanilla, strawberry, and cookies and cream on a large piece of paper or on a piece of paper under a document camera. Ask students to think about their favorite choice. Model for students drawing a tally to represent one person's choice. Ask students to come to the poster or paper and record their choice. Use that data set to create a class bar graph using favorite ice cream flavors. Provide each student with grid paper and together, write in the category names and titles. Complete 1-2 categories together and then let students practice with partners filling in the rest of the bar graph. Ask students simple addition and/or subtraction problems about the data set i.e How many students like vanilla and chocolate? How many more students like cookies and cream than strawberry? When students have finished their graph, move onto introducing the gallery walk to collect data. Instruct students that they will complete a gallery walk to collect data on which shapes are used by artists. Ask students how they would create a data set that they could use for their gallery walk. Students could use more open ended classification such as quadrilaterals or more specific classifications such as square, rectangle, rhombus. For the gallery walk, students will move around the classroom analyzing images of artifacts including rugs, pottery, and jewelry. Remind students that if they see more than one specific type of shape in an artifact, to only make one tally. Thus showing which type of shape an artist used rather than how many of that shape. Provide time for students to move around the room and analyze the images. Once students have created their data set, provide students with the same grid paper used in the ice cream graph. Remind students of the work they did during this learning activity to create their graph about shapes. On the bottom of the grid paper template, provide a fill in the blank question that students can use to create a question about their data set similar to the questions asked in the practice graphing activity. i.e How many artifacts used _____ (fill in with shape category) and _____ (fill in with shape category) together? or How many more artifacts had _____ (greater shape) than _____ (lesser used shape)? If needed, help students fill in the categories in the questions, but allow students to solve independently using whatever strategy works for them. Provide a space for students to earn an exemplary grade by creating and answering their own question about the data set without a template. Use the rubric in the Student Assessment section to assess students' work.

Using Maps to Look for Natural Resources

In this classroom activity, students first analyze a selection of maps that show various types of information. The first map students will analyze is a map showing where the Ancestral Puebloan people lived. This connects to cultural content as students have looked closely at Ancestral Puebloan pottery as they analyzed the shapes used to design them. A second map shows where the Ancestral Puebloan people obtained different resources that were within and beyond the Four

Corners region. Another map that students analyze is a modern map of where tribes currently are that have descended from Ancestral Puebloans. The intention here is to show students that the culture of Ancestral Puebloans is still alive in many *pueblos* or villages around where we live, especially for the many Hopi students that are present in my school. As students see the features of the map, ask questions to help them practice reading the map. Students then use the map key to understand and orientate themselves to the map. Questions that can be asked include: How does the map key help me understand where a Pueblo is located? (Noted by a brown dot) What does the dotted line represent? (Where state boundaries are) Which river runs between many Pueblo villages? (The Rio Grande) Ask students to synthesize what all the maps that were analyzed have in common? What types of map features help someone read and understand the map? Brainstorm a list of these features together i.e map key, symbols, a title, a compass rose, colors, lines etc. Tell students that they will be constructing a map of their own. The map should show which natural resources outside the school building one could use to create an artifact similar to the ones that we have been looking closely at. Take a nature walk outside with students. Students can bring clipboards to help them take notes or draw pictures of things they see outside. Collect these ideas into one class list once back into the classroom. Natural resources could include grasses, trees, rocks, flowers, etc. After the nature walk and list generation, provide students with a map template. On the template, the school building will already be drawn for students to help orient them. Ask students to think about which natural resources they would use to create an artifact and how they would represent that on their map. Provide time for students to use the map template and walk outside together so students can construct their map. Display the rubric provided in the student assessment section so that students can self-assess their map and make edits as needed.

Art Proposal and Praise, Question, Suggestion Protocol

Before students create a final product integrating geometry and culture, they complete an art proposal that helps them brainstorm the mathematical content and culture learned in this unit. Then, distribute the Art Proposal worksheet (See appendix). Review the different elements of the design proposal with students: type of artifact, how students will create it, which culture their artifact came from, what types of natural materials were used, and a sketch. After students have had time to work on their art proposal, pair students together to provide peer feedback. When students give peer feedback, use the Praise, Question, Suggestion Protocol with students. Model with an example created by yourself or another student. Define the words praise: something you like about the design, question: something you are wondering about the design, suggestion: something you could change about the design or a different idea. Make these words and definitions visible for students as they complete the protocol. Review steps for students and display timers for each step. The following sequence can be used: Partner 1 explains his or her design to Partner 2 (3 min.), Partner 2 provides praise, a question, and a suggestion to Partner 1 (5 min.), Partner 2 explains his or her design to Partner 1 (3 min.), Partner 1 provides praise, a question, and a suggestion to Partner 2 (5 min.) After peer feedback has been given, have a class discussion about how the protocol went. What went well and what did not? How could it be improved? Invite some students to share how they will improve their design for their final product using their peer feedback.

Art Creation and Showcase

In this final part of the unit, students apply their knowledge about geometric concepts to create a piece of artwork inspired from Indigenous artistry. Students are given choices regarding how and what they create. Students will have decided upon these specifics prior to receiving materials and creating their artwork. Some ideas for implementation include the materials students can use and resources or tools that can be utilized. Students have the option to create a rug pattern, a piece of pottery, or a piece of jewelry. If students choose to create a rug pattern, they have the option to create their design using pattern blocks or use the Polypad. In order to save their design, students can take a picture with their iPad or draw the design on a piece of paper using coloring tools and a ruler. If students choose to create a piece of pottery, they are given molding clay to form a vessel. Once the vessel has dried, students can use markers to paint their design onto their vessel. If students choose to create a piece of jewelry, they are provided with cardstock paper so that they can design the shapes that will either attach to a cardstock band or string. No matter the product students choose to create, all students complete a reflection about their art. Students are asked which shapes are used in their product, how do they know those shapes are used, and if their product has symmetry or not. Students then take time to prepare for an art showcase. This is the public product that students prepare for and practice with a partner explaining their artwork, so that they are prepared to discuss it at the showcase.

Student Assessment Plan

Formative Assessments

Geometry Walk Scavenger Hunt

Students are formatively assessed through the Geometry Walk Scavenger Hunt. As students complete the geometry walk, they are required to identify real world examples where they see different shapes. Students need to be able to recognize the shape by its attributes and draw a picture of the object. Students demonstrate their understanding of attributes of shapes through this activity. Students use a worksheet with a table to organize and record their ideas.

Sample Design

Students are formatively assessed through the sample design that they create using the Polypad. Students will be informally assessed through observation as they talk about their design sample with a partner. Students should explain what shapes are used in their design and name their attributes.

Art Proposal

Students are formatively assessed through the art proposal that is created before they make their piece of artwork. Students name the shapes that are used in their artwork by labeling the shapes on their design. Students must also include the shape's attributes when labeling. Students should also record whether their design has symmetry.

Summative Assessments

Graph

Students are assessed on the 2nd grade measurement standard using the graph they create with the data taken on the frequency of shape used within Indigenous artifacts. Students submit their data table with tally marks indicating the number of artifacts that had a specific shape. That data table and information is used to assess the graph that is created by the student. Students are given the proficient grade if they can draw a bar graph that represents the data taken on the artifacts and there is no error when drawing their bar graph. Students also earn a proficient grade if they can solve simple addition and subtraction problems using the data presented in the graph.

Map

Students are assessed on the 2nd grade social studies standard using the map they create showing the natural resources they collected. Students are summatively assessed on map skills and demonstrate proficiency if their map contains a map key, symbols, and a compass rose. Students maps should show accuracy in terms of where students find natural materials in the school yard.

Showcase and Reflection

Students are summatively assessed on the 2nd grade geometry standard of naming and classifying shapes by their attributes through the piece of art they create and the reflection completed about their artwork. Students reflect upon what types of shapes their artwork uses in the design and if their artifact has symmetry. Students show proficiency if they can identify the shapes they have used in their design using vocabulary words such as sides, angles, and/or vertices. Students explain this during the showcase, but also in a reflection to be completed before the showcase to prepare them to present their artifact to visitors.

Rubrics

Graphing Rubric-Mathematical Standards

Standard:	Exemplary	Proficient	Progressing	Struggling
2.MD.D.10	-I can draw a bar graph to represent data taken on shapes with no error. -I can create and solve my own problem using the data presented in the graph.	-I can draw a bar graph to represent data taken on shapes with very little error. -I can solve simple addition and subtraction problems using the data presented in the	-I can draw a bar graph to represent data taken on shapes with some accuracy. -I can solve some simple addition and subtraction problems using the data	-I cannot draw a bar graph to represent data taken on shapes. -I cannot solve simple addition and subtraction problems using the data presented in the graph.

		graph.	presented in the graph.	

Mapping Rubric-Social Studies Standards

Standard:	Exemplary	Proficient	Progressing	Struggling
2.G1.1 Use and construct maps, graphs, and other geographic representations of familiar and unfamiliar places in the world; and locate physical and human features.	-I can construct a map with a map key, symbols, and a compass rose. -I can create and answer a question about the map I created.	-I can construct a map with a map key, symbols, and a compass rose. -I can answer a question about the map I created.	-I can construct a map with some map features. -I can answer a question about the map I created.	-I constructed a map but it did not have any map features to help someone read my map. -I cannot answer a question about the map I created.

Design Rubric-Mathematics Standards

Standard:	Exemplary	Proficient	Progressing	Struggling
2.G.A.1	-I can identify all the shapes that I have used in my design using the number of sides, angles, and vertices.	-I can identify the shapes that I have used in my design using the number of sides, angles, or vertices.	-I can identify some shapes that I have used in my design using the number of sides, angles, or vertices.	-I cannot identify any shapes that I have used in my design using the number of sides, angles, or vertices.

Art Piece Rubric-Mathematics & Social Studies Standards

Standard:	Exemplary	Proficient	Progressing	Struggling
2.G.A.1	-I can identify all the shapes that I have used in my design using the number of sides, angles, and vertices.	-I can identify the shapes that I have used in my design using the number of sides, angles, or vertices.	-I can identify some shapes that I have used in my design using the number of sides, angles, or vertices.	-I cannot identify any shapes that I have used in my design using the number of sides, angles, or vertices.

Alignment with Standards

This curriculum unit aligns with Arizona Math, Arizona Social Studies, and Diné Content standards. One Arizona Math standard that this unit aligns to is identifying and describing specified attributes of two-dimensional shapes according to the number and shape of faces, number of angles, and the number of sides and/or vertices. Students meet this standard through instruction of the attributes of shapes and naming regular and non-regular polygons. Students demonstrate their understanding of this standard through the creation and explanation of their own artifact. Another Arizona Math standard that is aligned to this unit is the measurement standard of drawing a bar graph to represent a data set with up to four categories and solving simple addition and subtraction equations. Students meet this standard through the classroom activities of creating a bar graph together on a familiar topic, and then demonstrate their understanding by collecting data through a gallery walk of shapes used in artifacts. Students create their own bar graph using the data collected thus meeting that measurement standard. The Arizona Social Studies standard that aligns to this unit is a geography standard of using and constructing maps of familiar and unfamiliar places in the world and locating physical and human features. Students meet this standard by analyzing maps of where specific materials grow and come from in relation to where certain tribes have lived and currently live. Students then demonstrate their understanding of the standard by constructing their own map using the school outdoor area to gather natural resources to create an artifact. Students must then map where the natural resources came from using a key to help a reader understand their map and locate the physical features. This unit is aligned to the Diné Content standard of recognizing cultural items and jewelry. Students meet his standard by analyzing many different Navajo cultural items such as rugs, pottery, and jewelry. Throughout the unit, the Navajo tribe is referenced when looking at cultural items and the significance of such items in explained and discussed.

Arizona Math Standards

2.G.A.1 Identify and describe specified attributes of two-dimensional and three-dimensional shapes, according to the number and shape of faces, number of angles, and the number of sides and/or vertices. Draw two-dimensional shapes based on the specified attributes (e.g., triangles, quadrilaterals, pentagons, and hexagons).

2.MD.D.10 Draw a picture graph and a bar graph (with single-unit scale) to represent a data set with up to four categories. Solve simple put-together, take-apart, and compare problems using information presented in the graph.

Arizona Social Studies Standards

2.G1.1 Use and construct maps, graphs, and other geographic representations of familiar and unfamiliar places in the world; and locate physical and human features.

Diné Content Standards

Concept 1. I will acknowledge and value my thoughts and personality.

PO 3. I will recognize cultural items and jewelry.

Resources

(a) teacher background reading

American Southwest Virtual Museum. Ancestral Puebloan. 2023 https://swvirtualmuseum.nau.edu/wp/index.php/cult_land/archaeological-cultures/ancestral-puebloan/

This resource provides background reading about how the Ancestral Puebloan people lived.

Arizona School Report Card https://azreportcards.azed.gov/schools/detail/4806

This report gives information about Kinsey Inquiry Discovery School collected by the state of Arizona.

Clements, D. and Sarama, J. Young children's ideas about geometric shapes. *Teaching Children Mathematics*. *(2000) April 482-488.*

This article details what young children know about shapes and implications of childrens' misconceptions regarding geometry.

Clements, D. and Sarama, J. Early childhood teacher education: the case of geometry. *J Math Teacher Educ (2011) 14:133–148.*

This article provides reasoning why geometry is often ignored or taught in a way that allows young children to develop spatial reasoning, as well as why geometry is an important area of mathematics for young children to be strong in.

Clements, D (2003), Teaching and learning geometry. *A Research Companion to Principles and Standards for School Mathematics. 151-178.*

This chapter of the Research Companion details geometric theory, as well as big ideas that are essential for the thorough teaching of geometry to students.

Crowley, Mary L. "The van Hiele Model of the Development of Geomemc Thought." In *Learning and Teaching* Geometry, *K-12, 1987 Yearbook of the National Council of Teachers of Mathematics, edited by Mary Montgomery Lindquist, pp.1-16.* Reston, Va.: National Council of Teachers of Mathematics, 1987.

This selection details the van Hiele model of geometric thought, a way in which children and adults move through five levels of understanding geometry. This selection helps a reader determine where their students may be in regards to geometric understanding.

Digital Collections from St.Kate' s https://omeka.reclaim.stkate.edu/exhibits/show/swp/storytellers/navajo

This website provides background reading about the pottery created by Navajo people including uses, style, and form.

ELEducation (2023). Simple critique protocol for primary and & students

https://eleducation.org/resources/simple-critique-protocol-for-primary-elementary-students
This resource is a tool in which educators can reference to learn different critiquing protocols that can be used with students.

Eureka Math. (2014). Eureka Math: A Story of Units.

Larmer, J. (2018) Using a gallery walk for formative assessment in PBL. PBLworks.org https://www.pblworks.org/blog/using-gallery-walk-formative-assessment-pbl
This website provides a detailed explanation of how to teach students the critiquing tool of a gallery walk.

Larmer, J. (2018) A tricky part of PBL: writing a driving question PBLWorks.org
https://www.pblworks.org/blog/tricky-part-pbl-writing-driving-question
This website details how to write a driving question and why a driving question is essential in a project-based learning unit.

Moyer, P. (2001) Patterns and symmetry: reflections of culture. Teaching Children Mathematics. November.
This article discusses how lessons on tessellations and symmetry can be used to connect students' culture to mathematics through studying architectural designs, pottery, blankets, and other art forms.

National Museum of the American Indian, 2010
https://americanindian.si.edu/exhibitions/infinityofnations/southwest/067156.html
This museum's collection record provides background information for teachers about Pueblo Ancestral pottery.

Nelson, & Leutzinger, L. P. (1979). Let's Take a Geometry Walk. *The Arithmetic Teacher, 27(3), 2–4.*
This article explains the purpose of a geometry walk and details how to conduct one with students.

National Council of Teachers of Mathematics (NCTM) (2003). *A Research Companion to the Principles and Standards for School Mathematics.* NCTM: Reston, VA.

Pacific Grove Museum of Natural History, 2017
https://www.pgmuseum.org/blog/2017/1/11/treasures-from-the-basement-ancestral-puebloan-black-on-white-pottery
This blog from Pacific Grove Mueum of Natural History provides background information about Ancestral Pubeloan pottery.

PBLWorks.org. (2020) Critique protocols.
https://my.pblworks.org/system/files/documents/PBLWorks_Critique%20Protocols_Strategy%20Guide_0.pdf

This website provides information and discusses the importance of using a critique protocol in the classroom and several examples that can be implemented when students critique each other's work.

PBLWorks.org (2023) Gold standard pbl: essential project design elements https://www.pblworks.org/blog/gold-standard-pbl-essential-project-design-elements
This website provides the Gold Standard of project-based learning. It details the essential elements of a well planned project. This resource can be used to evaluate an already created project, or can be used when designing a project.

PBLWorks.org Managing projects https://my.pblworks.org/resource/blog/managing_projects
This article offers guidance on how a project-based learning unit can be mangaged to ensure student success. Elements discussed in this article include how to launch a project, how to create teams, and how to implement the use of a project wall.

PBLWorks.org Need to knows
https://my.pblworks.org/system/files/documents/PBLWorks_Need%20to%20Know%20Questions_Strategy_1.pdf
This resource details how to brainstorm need to know questions with your students when beginning a project-based learning unit. It discusses that the need to know questions are then used to build the learning goals of the project and why that is important for student engagement.

Rubenstein, R. & Thompson, D. (2002). Understanding and supporting children's mathematical vocabulary development. *Teaching Children Mathematics.* October.
This article provides insight into the language challenges students may have when learning mathematics and offers suggestions and guidance as to how teachers can help students develop strong mathematical language.

Seah, R. (2015) Reasoning with geometric shapes. *The Australian Mathematics Teacher. Vol. 71 Number 2.*
This article examines some of the issues there are when learning about two-dimensional shapes. This article offers paper folding as a strategy to help students reason about geometric shapes.

Southwestern Native American jewelry. [Exhibition]. (2023). Museum of Northern Arizona, Flagstaff, AZ, United States https://musnaz.org/on-view/jewelry/
This exhibition at the Museum of Northern Arizona provides background information for teachers about Navajo and jewelry from other Indigenous tribes including history, significance, and uses.

Truss, J. (2018, September 18). 5 Things that make project-based learning culturally responsive. *Getting Smart*. https://www.gettingsmart.com/2018/09/17/5-things-that-make-project-based-learning-culturally-responsive/
This website offers insight as to why project-based learning is a culturally responsive teaching method.

(b) student reading

Duncan, L. (1996) The Magic of Spider Woman.

This book can be used with students as a read aloud to connect the geometry and mathematical concepts in this unit to the cultural significance of weaving for the Navajo people.

Freeman, A.H (2021) Shaped by Her Hands: Potter Maria Martinez.

This book is about a Tewa who learned about traditional pottery from her aunt. This book can be used to support the cultural content on Ancestral Puebloan pottery including how it is made and its uses.

(c) materials for classroom use

Image of Wide Ruins Navajo Rug. https://shopmusnaz.org/collections/navajo-rugs/products/wide-ruins-handspun-rug

This image of a Wide Ruins Navajo rug from the Museum of Northern Arizona collections can be used to analyze patterns and symmetry during the classroom activities.

Rug. https://americanindian.si.edu/collections-search/objects/NMAI_278172

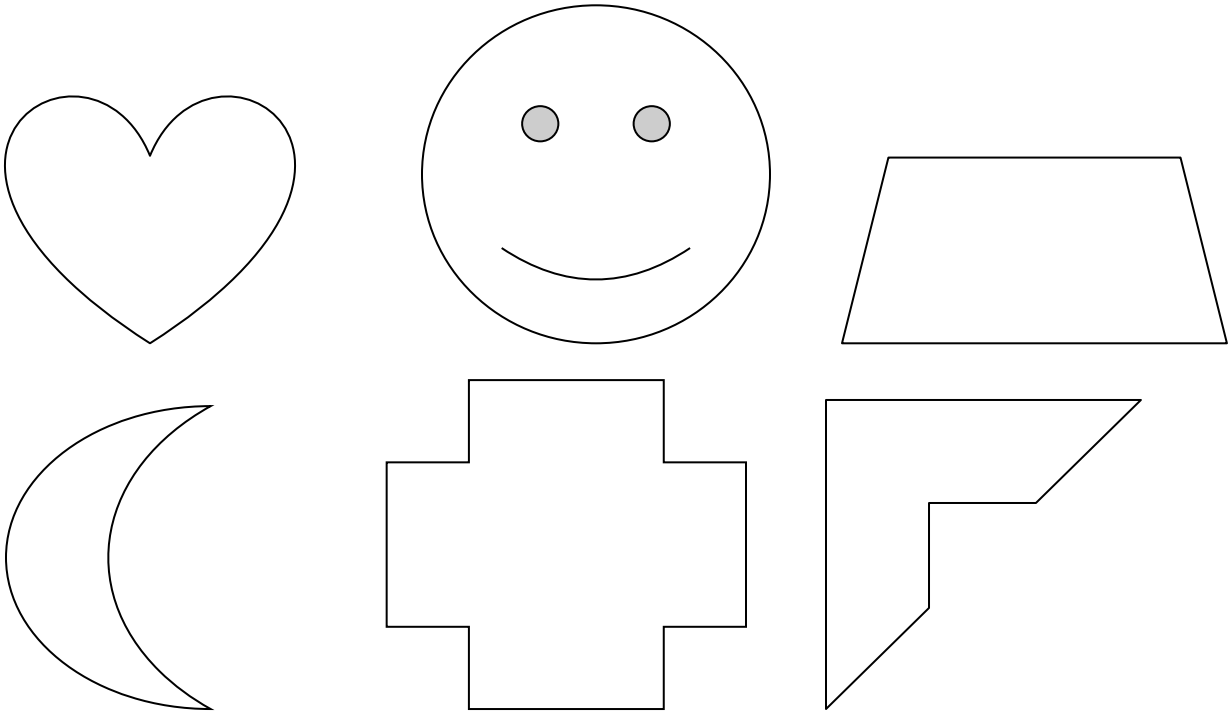
The patterns and symmetry can be discussed using this Navajo rug accessed from the National Museum of the American Indian.

d) printables for classroom use

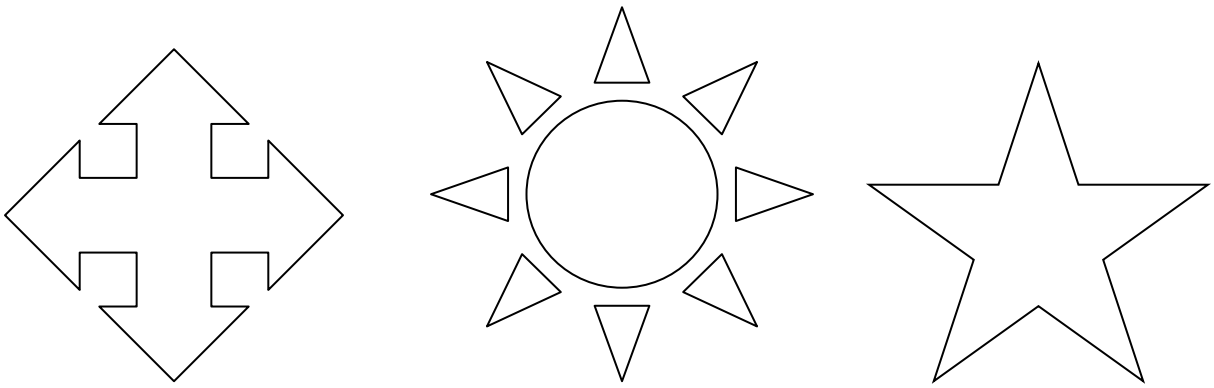
Name: _____

Symmetry Exploration

Use your patty paper to sketch the line of reflectional symmetry.



Use your patty paper to check for rotational symmetry.



Name: _____

Art Proposal

Type of Artifact (circle one):

Rug design Pottery Jewelry

How will you create your artifact (circle all that apply):

Polypad Pattern Blocks Use paper shapes Draw/paint on clay

Which culture did your artifact come from: _____

What types of natural materials were used to make your artifact: _____

_____

Sample Design (Sketch your design in the space below. Label the shapes that are used.)