Art and Mathematics of the Pre-Colombian Maya

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INTRODUCTION

A class full of 6th grade students listened intently as their teacher described an ancient people who had a knowledge of mathematics so advanced that they independently came to know and use the number zero, calculate important dates on their calendars, and construct great cities – a people with an understanding of the relationship between mathematics and nature so highly developed that they could predict lunar and solar eclipses thousands of years in the future. However, the thing that impressed the students the most occurred when their 6th grade teacher described an astronomical event that takes place on a particular day of the year – the setting of the sun in conjunction with the position of a pyramid casting a shadow of a serpent moving up the side of the great structure. I was one of the 6th graders listening in awe that day. The people were the ancient Maya, and the pyramid is *El Castillo* in Chichén Itzá on the Yucatan peninsula in México, where on the fall and spring equinoxes, a shadow caused by the sun and the precise placement and configuration of the pyramid display a most extraordinary testament of a very advanced and complex understanding of mathematics and nature that the Maya possessed (Freidel, Schele, and Parker 35).

The story my teacher told of the Maya has proven to be a life-changing event for me. Though I was only eleven years old, I can remember his description of that special place in great detail, and this past year I had the opportunity to go and see the Mayan ruins for myself. The feeling that I experienced as I approached *El Castillo* can best be described as nostalgic, though it was my first time to visit any Maya city. The rich culture of the Maya is truly one of the world's great wonders. From their use of a vigesimal or base twenty mathematical system to their advanced calendar and beautiful gifts, the Maya have left behind a wealth of knowledge and insight of our planet and its laws, as well as the rhythms displayed in virtually every aspect of life from the heavens to the earth, most notably human birth and life.

While visiting Chichén Itzá, I realized that not only did the Maya possess a love for mathematical accuracy, with their numerous structures of temples, pyramids, marketplaces, and arenas, but also an affinity for *Art* as well. As an artist, I noticed the Maya's keen fascination with beauty and detail in their rock sculptures and wall beliefs. Decorated in stone throughout the city, Maya *hieroglyphs* are seen in a way that not only serves as a reminder of the past, but as a tribute to their craft and artistic ability. This pre- industrial culture cultivated and explored a variety of architectonics that included both geometrical precision and artistic beauty. Like many Pre-Colombian cultures, the Maya shared in common use for carvings, paintings, clothing, jewelry, writings, pottery and sculptures used in ceremonial festivals.

The central point of my lesson will be to educate my students on the intrinsic and essential relationship that art has with our everyday life. This relationship spans everything from the things used in a given routine to the things that serve as adornments for the beauty of life, as well as the countless objects that possess great functional use while preserving such beauty, that has inevitably lead them to museums as priceless artifacts to this day. "Clay objects, some of them finely decorated, had numerous uses, from everyday cooking, eating and drinking vessels to

storage containers and utensils such as *comales* (griddles) and ladles" ("Mesoamerica"). The thing that makes them so beautiful and at the same time functional, and essential to everyday life, is what my students will be thinking about and exploring for themselves.

My position is a high school art teacher at Jack Yates High School located in the Third Ward in Houston, Texas. The school lies between two colleges (The University of Houston and Texas Southern University). A large number of my students live in the Third Ward, a low-income neighborhood, and I teach art levels I and II students (9^{th} – 12^{th} grades). My hope for my students is to foster a love for the arts given the rich background of historical uses for handcrafted items, such as pinch pots and serving dishes that have been produced here on this continent. Centered on the enrichment benefit of incorporating pre-Colombian art and mathematics, this topic will include both mathematics and art, their relationship, and the way in which they have been used together throughout history. Teaching the Maya vigesimal system to the students as an alternative to our current decimal system will serve as a starting point. The unit will go through the steps and process of learning to work with clay, while relying on the mathematical measurements and numbering system used by the Maya.

OBJECTIVES

Math Objectives

Math 6.1 - Number operations and quantitative reasoning using base 20.

Math 6.1.02 – Use manipulative arts to represent and generate equivalent forms of rational numbers. Example, students will use clay coils as a basis for a measuring device.

Math 6.4.02 – Select and use appropriate units, tools, or formulas to measure and to solve problems involving length including perimeter.

Art Objectives

Art 1.1.06 - Understand the purposes of art elements and design principles in the creation of artworks, and how specific principles are used to organize art elements. As an example, critically thinking of how the Maya would have viewed their work, and what they would describe as beauty.

Art 1.1.07- Understand the expressive qualities of specific art elements and design principles in examples of Maya pottery and sculpture.

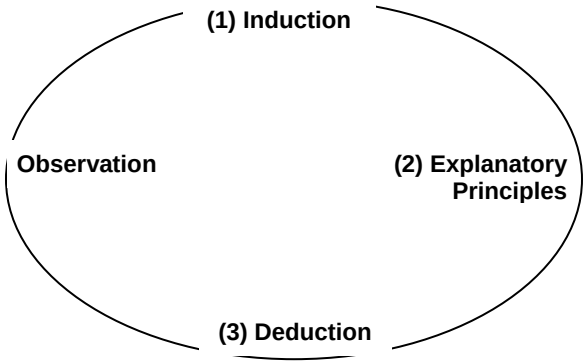
RATIONALE

The reason for this unit on clay with a strong mathematical focus is to help my students become aware of and critically think about ceramic objects that surround them in their everyday lives. The history of and the important connection between the functional and decorative element of ceramics is an essential part of the study and exploration of clay. When students realize that "clay was a primary material for fashioning both utilitarian and ceremonial artifacts, ranging from common household items to large-scale figural sculptures and masterfully carved and painted vessels," they will see how they too can use clay as the ancient Maya did ("Mesoamerica").

They will come to understand the important role that clay has had historically for mankind.

I will use the art of the Pre-Columbian Maya as a starting point to promote higher order thinking on behalf of the students as it relates to keen observations of the natural world and the way the Maya viewed and used mathematics. My choice of working with clay extends from the historical viewpoint that "clay was a primary material for fashioning both utilitarian and ceremonial artifacts, ranging from common household items to large-scale figural sculptures and masterfully carved and painted vessels" ("Mesoamerica"). With the knowledge of the versatility that clay possesses, the students will work with clay as they develop their higher order critical-thinking skills and create works of their own. With regard to higher order thinking, the Inductive-

Deductive Method will be a central point for my students while studying and working with clay. The Inductive-Deductive Method was one of Aristotle's most popular theories. He viewed scientific inquiry as a progression from observations to general principles and back to observation (Losee 5-8). Aristotle believed that when studying new things, such as science or creations, and in this situation, pre-industrial pottery and sculpture, one should "induce explanatory principles from phenomena to be explained" (Losee 5-8); in other words, from direct observation, one should produce principles explaining what is being observed. The next step is to check the explanatory principle with the original observation. With this method my students will need to analyze how specific clay objects were made, their purpose, and meaning. This method remarkably resembles the very thing the Maya were doing with regard to their observations of the stars, planets, moon, and sun. For example, the Maya, in the classic period (AD 500 – AD 900), would have observed things in the same way that a scientist might apply the inductive-deductive procedure to a lunar eclipse. He begins with observation of the progressive darkening of the lunar surface. He then induces from observation several general principles: that light travels in straight lines, that opaque bodies cast shadows. From these principles, and the condition that the earth and moon are opaque bodies, which in this instance have the required relationship to the luminous sun, he then deduces a statement about the lunar eclipse. He has progressed from factual knowledge that the moon's surface has darkened to an understanding of why this took place (Losee 5-8).



Aristotle believed that scientific inquiry begins with knowledge that certain events occur, or that certain properties coexist. Scientific explanation is achieved only when statements about these events or properties are deduced from explanatory principles. Scientific explanation is a transition from knowledge of a fact (point 1 in the diagram) to knowledge of the reasons for the fact (point 3) (Losee 5). Though the Maya would not have known of Aristotle, it is clear that they employed a method that resembles the inductive-deductive procedure by their ability to not only track the movement of the sun, but also to predict astronomical events such as the path traveled by the planets and lunar eclipses far into the future. Likewise, I will have my students analyze and predict, after the proper observation of the affects of heat has on clay, for example, and how much a clay pot will shrink after being dried and fired in the kiln. Such higher order thinking will also include the practical use of mathematics – using the Maya numerology with addition and subtraction to solve measurement and volume questions.

While working with clay, my lessons will include that all seven of the *Elements of Art* are derived from the natural world and promote analysis to seek evidence that mathematics and art are intrinsically connected. Through **Color, Value, Texture, Shape, Form, Space,** and **Line,** students will find a mathematical force that influences and governs the decisions made by the Maya. In addition to the *Elements of Art,* the *Principles of Design*, **Contrast, Emphasis, Balance, Unity, Pattern, Movement,** and most importantly, **Rhythm,** are all directed by forces found in nature and were cultivated by the Maya. Students will need to learn how the Maya used their calendar to plan and understand the world. With the use of the Maya calendar, the students will date their work, find their birthday, and track dates important to them or to their families.

The Maya used hieroglyphs to communicate through art a timeless and universal language. The pictographs used by the Maya are a distinctive visual language that has a great resemblance

to the icons we use in our computers, and I intend to teach the basic elements of the icons and the visual language to challenge my students to create a variety of personalized elements to finalize their work as the Maya would have done. This final step will be the most personalized, and each student will need to support his or her decision making processes. In doing so, an understanding of the functional and decorative elements of clay will need to come together, and each student will need to demonstrate his or her ability to communicate, at least in a small measure, the way the Maya have done in the past.

UNIT BACKGROUND

North America has a long and rich history. My student's knowledge of the people that have inhabited this land is a most relevant starting point for the background of this Pre-Colombian Maya unit.

> The Maya evolved the only true written system native to the Americas, although only 4 Codex survive today. Alonso de Zorita wrote that in 1540 he saw numerous such books in the Guatemalan highlands which "recorded their history for more than eight hundred years back, and which were interpreted for me by very ancient Indians." Fr. Bartolomé de las Casas lamented that when found, such books were destroyed: "These books were seen by our clergy, and even I saw part of those which were burned by the monks, apparently because they thought [they] might harm the Indians in matters concerning religion, since at that time they were at the beginning of their conversion." They left us their art and script in Stelas, Wooden lintels, Murals, Petro-carvings and ceramics to read about their lives, believes and culture. ("Ancient Guatemala")

The application to the material in the classroom extends from an everyday need for the use of both mathematics and resources crafted to sustain a society such as that observed with the Maya, and are just as vital today. A strong mathematical introduction followed by the steps to learning how to manipulate the clay will reflect the study of precision, craftsmanship, and attention to mathematical accuracy. The students will begin by learning how to count in Mayan, the base 20 (vigesimal system), add and subtract, borrow and carry, all with the purpose of working with clay. (See appendices.) Since clay was used in every day life, including the functional and the decorative, it took on the role of being the "most democratic medium of the Americas" because all American cultures had utilized clay in one form or another" (Koontz). Furthermore, the association of art with everyday life was just as closely paralleled with mathematics. The use of mathematics was employed on a daily basis as a vital activity. Perhaps the most direct point on the use of mathematics for the Maya was their very real and immediate need for counting. Counting was not only used for trade among other groups, but also for the counting and quantifying of natural phenomena. The ability to take observations of nature, the heavens and human life, then apply mathematical reasoning, lead to a deeper understanding of rhythms found in virtually every aspect of life. This is the type of mathematical application the Maya employed on a daily basis. Moreover, mathematical calculations, addition and subtraction, as well as the discovery of mathematical cycles and patterns found in nature, aided the Maya to gain insight deep into the world's many wonders.

The next step will be to explore the Mayan calendar, which employs the same mathematics bar-and-dot, base-twenty system. The Maya's complex calendar served a very real everyday purpose as:

> The calendar round. Representing cycles of thirteen numbers and twenty names create the 260-day Ritual Almanac. The permutation of the Ritual Almanac against the 360-day Solar Year system creates the Calendar Round of 18,980 days, or 52 solar years. (Henderson 53)

The System of the Tonalpohualli

> The system of the tonalpohualli can be best understood by imagining two wheels that are connected to each other. One wheel has the numbers "one" to "thirteen" written on it. The second wheel has twenty symbols on it. In the initial situation, number "one" combines with the first symbol. This is the first day of the tonalpohualli. Now the wheels start moving and number "two" combines with the second glyph. This is the second day. After fourteen days, a Maya or Aztec week (trecena in Spanish) of thirteen days has passed. The wheel with the numbers shows number "one" again. The other wheel now shows the fourteenth symbol. After 260 days, the two wheels have returned to their initial position. The tonalpohualli starts all over again. (Voorburg)

The students will compare this calendar, exploring its mathematical principles, with the differences in our current solar calendar. The correlation to the everyday use of the calendar will be echoed with the tracking of student progress. In art, it is most important to date work when it is completed, but with the use of clay, the students will also need to keep a journal with the dates noting the condition of the clay, work done, alterations, and firings. In addition to keeping track of the progress of work with dates, the students will need to measure the shrinkage of the clay, as it is considerable, nominally 12%. The calendar then becomes the official notation tool used during this unit because the clay is a process needing multiple steps over a period of time. The student will also find their own birthdates in the Maya calendar as they learn of the symbols that represent particular days. They will need to be able to reproduce the symbols on the clay as their personalized signature. By learning and exploring the calendar, the students will need to further their ability to read the Mayan numerals, count, and identify dates of the progress made in the class while learning the steps of working with clay.

The importance of working with clay is based on its every day function as well as the artistic culmination of functional form. Clay is an essential part of Mesoamerica, and the Maya elegantly joined representational forms and function. My students will follow this model of form and function as they explore some of the same techniques found in Pre-Columbian pottery and sculpture.

> Forms, decorative techniques and manufacturing methods sometimes coincided within a stylistic tradition, but frequently did not. Clay was obtained from local sources and tempered for plasticity and strength by adding sand, crushed shards and shells, volcanic ash, or organic fibers. Forms were made by three basic methods used singly or in combination: hand molding, coiling and molding. Small vessels and some figures were hand formed. The walls of larger vessels were built up from a base by joining layers of concentric clay coils. Clay slabs draped on hemispheric convex or concave moulds were used to produce round shapes. Clay press-moulds served as a simple means of mass production for entire objects, such as figurines, or for decorative panels and details. Hollow figures and composite forms were individually constructed of assembled from a combination of hand-built and mould-made sections. ("Mesoamerica")

LESSON PLANS

Lesson One: Maya Numerology (the vigesimal system) and the Representation of Symbols and Glyphs

Objectives

- MATH.6.01.A.01 Number, Student will use the Maya counting system with values to represent whole numbers.
- Study place value notation using vigesimal or base-20 system.

- Compare and contrast base-20 (Mayan) and our current base-10 (Arabic) systems.

Introduction

Students will be asked for some input on their prior knowledge of ancient American cultures and civilizations in the North and Central regions of the continent. A Location Map of Mesoamerica (Please see Appendix D in this HTI publication) will be given to the students to prompt discussions on the area, and to further assess student's prior knowledge of the topic. Students will then be asked about other cultures that have demonstrated the use of mathematics, such as the Roman Numerals, and our current Arabic system. The next step will be to introduce the main objective of counting (Appendix A) with every day items such as those found in nature, (pebbles, small stick, seashells, etc.) followed by an explanation of the complex and independent mathematical place value system deeply rooted in every day life the vigesimal system. (Please see Appendix C.)

Concept Development

- The relationship between art and mathematics. To promote higher order thinking on behalf of the students, they work in small groups, describing several instances where art and mathematics work together.
- Art of the Pre-Columbian Mayan and the way they viewed and used mathematics.
- Counting, adding, and subtracting simple problems in the Maya vigesimal system while incorporating place value.

Student Practice

- Students will copy from the board Maya numbers 1-10, then asked to speculate on how numbers 11-20 would be noted. Allow 2-3 minutes of volunteers. If a student is able to properly identify the correct number notation, he or she will add it to the board; if not, the teacher can add the remanding numbers for copying by the students.
- Students will then be asked to think about numbers 20-40, keeping in mind the base twenty systems. (3-5 minutes) Just as before, if a student is able to properly identify the correct number notation, he or she will add it to the board. If not, the teacher can add the remaining numbers for copying by the students, with special attention to place value.
- Students will be given time (up to 10 minutes) to calculate as high as they can, using their new found knowledge of Maya mathematics.
- Dissection of the vigesimal system followed by a short Q and A section will lead to addition and subtraction of Mayan numerals (Appendix B) with 2 or 3 simple problems on the board, worked on step-by-step with the teacher and the class, followed by two simple problems to be worked on by the students independently, with 5 to10 minutes for completion. Check answers with class.

Assessment

Students will be asked to show work of Mayan math problems, and asked for the Arabic equivalents, to demonstrate proficiency. Teacher should look for proper use of the bars and dots, as well as the “0” (zero) within the place value system.

Closure

Students will be asked to write down their observations of the Mayan numerals, and copy 2 to 3 simple addition problems for homework. At this time a handout will be given for student reference while at home.

Lesson Two: Mayan Numerology and the Integration with Clay (Part One)

Objectives

Math Objectives

- MATH.6.01.A.01 Number, operations, and quantitative reasoning. Students will incorporate mathematics with art as they measure, count, and date their clay works of art. With applicable measuring, the student is expected to follow place value notation using the vigesimal or base-20 system.
- 6.12.A Using manipulatives to communicate mathematical ideas using language, efficient tools, and appropriate units.
- Applying Maya numerology to a medium. Creating manipulatives as measuring devices with Maya numbers.

Art Objectives

- Introduce the clay: working with several techniques to develop skills to promote creativity and functionality.
- Analyze the techniques for carving and impressing into the clay. Explore the inherently different media and the texture while manipulating the clay.
- Explore the development processes in sculpture.
- Create three stamps for use in the following lesson (using drawings as a guide).

Art TEKS Objectives

Art 1: 1A, 1B, 2A, 2B, 2C, 3B and 4A. (TEKS Objectives Art 1.1.14, 1.1.15, and 2.1.14)

Concept Development

Develop an understanding of the relationship between art and mathematics. To promote higher order thinking on behalf of the students, as they individually create works that incorporate mathematics with their clay work, illustrating how art and mathematics work together. Incorporating the Maya calendar will be the main concept in this lesson as the students begin to mold their clay stamps.

Introduction

- Class will begin with a review of the Maya numerals, and 2-3 math problems (this can also be done as a warm-up activity.)
- A look at the mechanics of the Mayan Calendar, its mathematical components, and the twenty day names – or pictographs. (Please see Appendix E - Calendar Wheel- Stencil Forms.)
- Several slides of the Ancient Maya pottery, and other sculptures shown at this point to help foster an interest in working with the clay noting the both functional and artistic qualities in the clay work.

Student Practice

Students will work individually to create up to three clay stamps that will be used in the following lesson. The students will need to measure the amount of clay (with by height by depth) and make the journal entry in Maya.

Assessment

Teacher and student will assess jointly the functionality as well as the form and beauty of the ceramic stamps that will serve as a personal signature for each of the students. Stamps should be

large enough for students to engrave their day sign from the Mayan Calendar in the following lesson.

Closure

Students will be given an assignment of locking up their day signs from the Mayan Calendar for engraving their ceramic stamps in the following lesson.

Home work will include: looking up their birth dates, sketching their day signs, and writing down the meaning of the signs.

Materials

Clay, modeling tools, pencils and paper.

Lesson Three: The Mayan Calendar and Working with the clay (Part two)

Objectives

• Introduce the Maya calendar, its days, and the symbols used to represent the days.

• Working with the clay continued. The main objective here is to become proficient in coiling, wedging, impressing, hand-building and making pinch pots.

Art Objectives

Create several drawings of the Maya twenty day names found in the calendar. (Please see Appendix E -- Calendar Wheel- Stencil Forms.)

Art TEKS Objectives: Art 1: 1A, 1B, 2A, 2B, 2C, 3B and 4A. (TEKS Objectives Art 1.1.14, 1.1.15, and 2.1.14)

Math Objectives

- MATH.6.01.A.01 Number, operations, and quantitative reasoning. Students will incorporate mathematics with art as they measure, count, and date their clay works of art. With applicable measuring, the student is expected to follow place value notation using the vigesimal or base 20 system
- 6.12.A Using manipulatives to communicate mathematical ideas using language, efficient tools, appropriate units.

Introduction

A look at the mechanics of the Mayan Calendar, its mathematical components, and the twenty day names – or pictographs. Please see Appendix E - Calendar Wheel- Stencil Forms.

Concept Development

Students will become familiar with the Maya calendar, used by all of Mesoamerica. A knowledge of how to read the calendar, and recognize the twenty day signs.

Student Practice

- Students will be given a handout of the Maya calendar (Appendices E, F, and G) as they will find several days given by the teacher as a treasure hunt activity.
- Students will engrave the ceramic stamps with their birth day signs from the Maya Calendar.
- Using coils, or hand-building techniques, students will create three functional ceramic works.
- Students will use bisqued stamps on wet coil pots after completion of forms to label work.

Assessment

Check for student craftsmanship in working with a larger quantity of clay. Work must be functional for completion of this assignment.

Materials

Wood boards, Clay, modeling tools, pencils and paper.

Lesson Four: Decorating and Personalizing Functional Work for Final Critique and Display

Introduction

This lesson is designed for finalizing the functional artwork. The last stage to working with clay involves *glazing*; however, the Pre-Colombian ceramics never involved glaze. The students will paint their fired work in the style of the Mayan artifact (slides will be provided). Students will also measurer final stamps and pots for shrinkage during hardening and firing.

Objectives

Expanding prior knowledge of 3D forms, and developing designs to support a creative interest in the way ceramics works are finalized, displayed, and or used.
3D Design -- the way form and shape come together to create a mass, with the main objective in this last lesson being to ready the art work for a final critique and display.

(TEKS Objectives Art 1.1.14, 1.1.15, and 2.1.14)

Student Practice

Students will be guided to paint the exterior of their functional pots with the day signs, and continue working on pots for final display. Using tempera pain as needed to complete work. (1^{st} half of class will be for individual practice. 2^{nd} half of class is devoted to group discussion and class critique of work.)

Assessment

Each of the students will give a report of their day sighs (from Internet research on the Maya Calendar and their birth day) as the display their ceramic work.

The final assessment will include the Maya numerals, measurements, and notes from the unit, as well as the finished stamps and pots.

Resources

- Teacher made worksheet.
- Wood boards, Clay, papers and pencils, Tempura pant and modeling tools.
- Beans or pebbles, and sticks or twigs (since cacao pods are not available)

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