Mayan Mathematics and Architecture

Goals 2000 - Partnerships for Educating Colorado Students

In Partnership with the **Denver Public Schools** and the **Metropolitan State College of Denver**

El Alma de la Raza Project

Mayan Mathematics and Architecture

By Julie Murgel

Grades 5-8

Implementation Time for Unit of Study: 3 weeks

Goals 2000 - Partnerships for
Educating Colorado Students
El Alma de la Raza Curriculum
and Teacher Training Project

Loyola A. Martinez, Project Director

El Alma de la Raza Series

Mayan Mathematics and Architecture

Unit Concepts

- Understand and use the Mayan numerical system
- Compare and contrast the Mayan numerical number system to the Egyptian, Roman, and Babylonian numerical systems
- Measure and calculate area, volume, and perimeter in a Mayan temple
- Create a three-dimensional Mayan temple
- Design a Mayan temple replica on the computer

Standards Addressed by This Unit

Math

Students develop number sense, understand and use appropriate math vocabulary, understand and use numbers and number relationships in problem-solving situations, and communicate the reasoning used in solving these problems. (M1)

Students develop spatial sense and use geometric concepts, properties, and relationships in problem-solving situations and communicate the reasoning used in solving these problems. (M4)

Students use a variety of tools and techniques to measure, apply the result in problem-solving situations, and communicate the reasoning used in solving these problems. (M5)

Students link concepts and procedures as they develop and use computational techniques, including estimation, mental arithmetic, paper-and-pencil, calculators, computers, and other manipulatives in problem-solving situations and communicate the reasoning used in solving these problems. (M6)

Students understand and use appropriate technologies to perform mathematical constructions and computations, simulate mathematical experiences, and to access, process, and communicate information related to the application of mathematics in problem-solving situations. (M7)

Reading and Writing

Students write and speak for a variety of purposes and audiences. (RW2)

Students read to locate, select, evaluate, and make use of relevant information from a variety of media, reference, and technological sources. (RW5)

Visual Art

Students know and apply visual arts materials, tools, techniques, and processes. (A3)

Introduction

The Golden Age of the Maya Civilization existed from around 250 B.C. to A.D. 800. About seven million Mayan Indians still live in parts of Honduras, El Salvador, Guatemala, Belize, Nicaragua, and southern Mexico.

Two particularly intriguing elements of the Maya civilization are mathematics and architecture. The Mayan number system used base 20. Numbers were represented by dots and bars. Also, the number system contained the number zero, a concept unknown to the Greek and Egyptian civilizations.

Mayan architecture is a fascinating subject. The Maya built many ornate temples of great height. They put vaulted hollows inside the roof sections to reduce weight. The structures contained many chambers and rooms. Within the city of Tikal alone, there were 3,000 buildings and more than 200 monuments. In the Yucatan Puuc region there is evidence of great site planning and architecture techniques. The Puuc design—buildings faced with limestone, archways framed by round columns, and elite mosaics—is named after this area. Many of the designs contained figures such as turtles, gods, or humans.

Implementation Guidelines

This unit is designed for students in grades 5–8. It is recommended that this unit be taught as an interdisciplinary unit with a social studies unit about the Ancient Maya Civilization. An assessment key as been provided for the lessons. Two lessons are about Mayan mathematics and four lessons are about Mayan architecture. Lesson 5 has been designed as a home project for students to complete while they are working on the rest of the unit in school.

Instructional Materials and Resources

Lesson 3	Computer Internet access
Lesson 6	Computer access: ClarisWorks 2.1, 3.1, or 4.1

Lesson Summary

Lesson 1	Mayan Numbers Identification, conversion, and use of Mayan Numbers. Mayan number chart
Lesson 2	Comparison of Number Systems A comparison and contrast between the Mayan numeral system and the Roman, Egyptian, and Babylonian sysrems.
Lesson 3	Using the Internet Exploration of Mayan mathematics and architecture.
Lesson 4	Mayan Architecture 1: El Castillo Making a paper-folding Maya pyramid and calculating the perimeter, area, and volume of the pyramid.
Lesson 5	Mayan Architecture 2: Replica of a Mayan Ruin Creating a model of a Mayan structure.
Lesson 6	Mayan Architecture 3: Computer Graphics Drawing a Mayan structure on the computer.
Lesson 7 (Extended)	Mayan Head Number Molds
Lesson 8 (Extended)	Mayan T-shirt

Lesson 1: Mayan Numbers

What will students be learning?

STANDARD(S)

Students develop number sense, understand and use appropriate math vocabulary, understand and use numbers and number relationships in problem-solving situations, and communicate the reasoning used in solving these problems. (M1)

Students link concepts and procedures as they develop and use computational techniques, including estimation, mental arithmetic, paper-and-pencil, calculators, computers, and other manipulatives in problem-solving situations and communicate the reasoning used in solving these problems. (M6)

BENCHMARK(S)

Students construct and interpret number meaning through real-world experiences and the use of hands-on materials and relate these meanings to mathematical symbols and numbers.

Students model, explain, and use the four basic operations—addition, subtraction, multiplication, and division—in problem-solving and real world situations.

OBJECTIVE(S)

Students will identify Mayan numbers.

Students will convert a base 10 number to a base 20 number (Mayan) and vice-versa.

Students will use Mayan numbers to add, subtract, multiply, and divide.

SPECIFICS

The Maya used a base 20 number system. They symbolized their numbers using dot and bars; where a dot equaled 1 and a bar equaled 5.

What will be done to help students learn this?

INSTRUCTIONAL STRATEGIES

Task description

Guided practice

Independent practice

Graphic organizer

PRELIMINARY LESSON PREPARATION

To ease understanding of base 20, it is recommended that the teacher review with the students the concept of base 10 and powers of 10.

ACTIVITIES

After the teacher illustrates and describes the Mayan numeric system, practice identifying Mayan numbers on Worksheet 1. Observe how to convert a Mayan number to our number system and vice-versa. Then complete section 2 on Worksheet 1 and all of Worksheet 2. With the teacher, practice adding, subtracting, multiplying, and dividing Mayan numbers. Independently, practice solving math problems that contain Mayan numbers on Worksheet 3.

Lesson 1 (cont.)

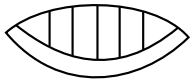
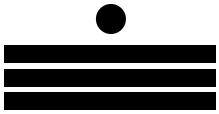
RESOURCES/MATERIALS

Mayan Mathematics Worksheets 1, 2, 3.
overhead transparency sheet of Mayan Number Chart

ASSESSMENT

Use attached key to evaluate Mayan Mathematics Worksheets 1, 2, and 3.

Mayan Number Chart

Number	Mayan Form	Number	Mayan Form
0		10	
1		11	
2		12	
3		13	
4		14	
5		15	
6		16	
7		17	
8		18	
9		19	

Mayan Numbers: Worksheet 1

Name: _____

Section 1

Directions: Using the Mayan Number Chart, identify each of the following numbers:

1.  = _____

2.  = _____

3.  = _____

4.  = _____

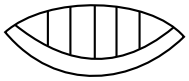
5.  = _____

6.  = _____

7.  = _____

8.  = _____

9.  = _____

10.  = _____

Section 2

Directions: Convert and draw the Mayan numerical symbol for each number:

11. 12 = _____

12. 17 = _____

13. 4 = _____

14. 11 = _____

15. 10 = _____

16. 20 = _____

17. 6 = _____

18. 13 = _____

19. 9 = _____

20. 0 = _____

Mayan Numbers: Worksheet 1 Answer Key

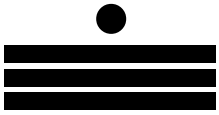
Section 1

1.  = 2

2.  = 7

3.  = 15

4.  = 11

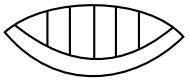
5.  = 16

6.  = 4

7.  = 9

8.  = 5

9.  = 6

10.  = 0

Section 2

11. 12 = 

12. 17 = 

13. 4 = 

14. 11 = 

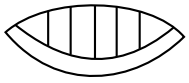
15. 10 = 

16. 20 = 

17. 6 = 

18. 13 = 

19. 9 = 

20. 0 = 

Mayan Numbers: Worksheet 2

Name: _____

Directions: Complete the following charts, using the example as a guide.

Power of 20	Mayan Number	Meaning	Value
8000's		8000×2	16,000
400's		400×4	1,600
20's		20×3	60
1's		1×5	5
		Total =	17,665

Power of 20	Mayan Number	Meaning	Value
8000's		8000×6	
400's		400×16	
20's		20×5	
1's		1×18	
		Total =	

Power of 20	Mayan Number	Meaning	Value
8000's			
400's			
20's			
1's			
		Total =	

Power of 20	Mayan Number	Meaning	Value
8000's			
400's			
20's			
1's			
		Total =	

Power of 20	Mayan Number	Meaning	Value
8000's		8000×4	
400's		400×5	
20's		20×8	
1's		1×16	
		Total =	

Power of 20	Mayan Number	Meaning	Value
8000's			
400's			
20's			
1's			
		Total =	

Mayan Numbers: Worksheet 2 Answer Key

Power of 20	Mayan Number	Meaning	Value
8000's		8000×2	16,000
400's		400×4	1,600
20's		20×3	60
1's		1×5	5
		Total =	17,665

Power of 20	Mayan Number	Meaning	Value
8000's		8000×6	16,000
400's		400×16	6,400
20's		20×5	100
1's		1×18	18
		Total =	54,518

Power of 20	Mayan Number	Meaning	Value
8000's		8000×1	8,000
400's		400×5	2,000
20's		20×10	200
1's		1×15	15
		Total =	10,215

Power of 20	Mayan Number	Meaning	Value
8000's		8000×1	8,000
400's		400×4	1,600
20's		20×10	200
1's		1×15	15
		Total =	9,815

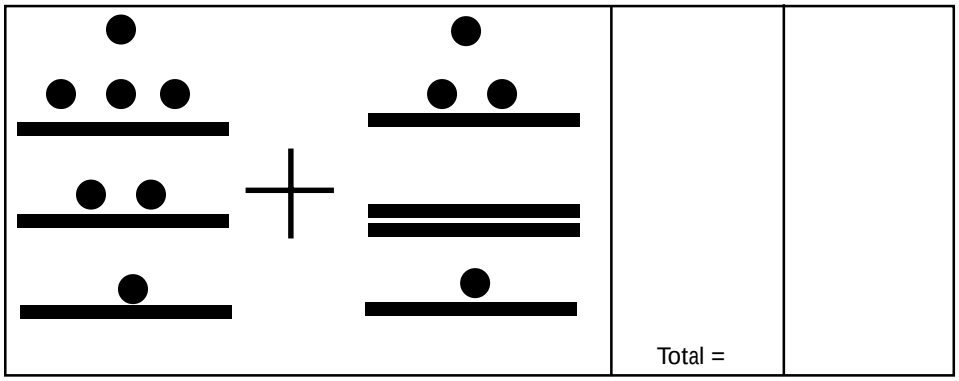
Power of 20	Mayan Number	Meaning	Value
8000's		8000×4	32,000
400's		400×5	2,000
20's		20×8	160
1's		1×16	16
		Total =	34,176

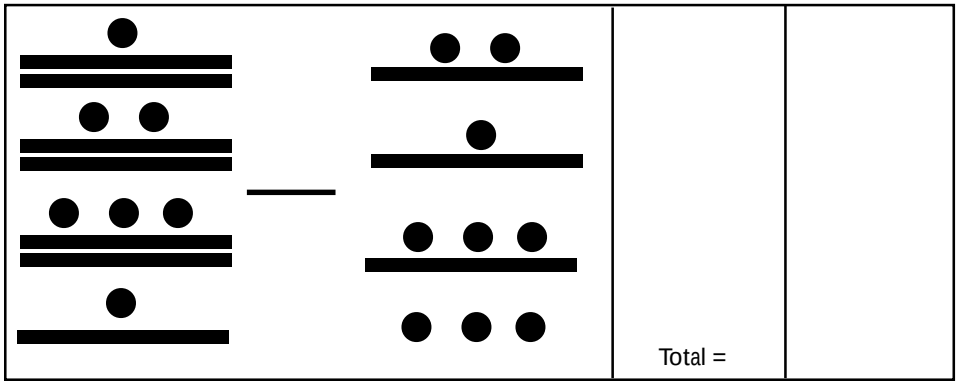
Power of 20	Mayan Number	Meaning	Value
8000's		8000×5	40,000
400's		400×5	2,000
20's		20×10	200
1's		1×2	2
		Total =	42,202

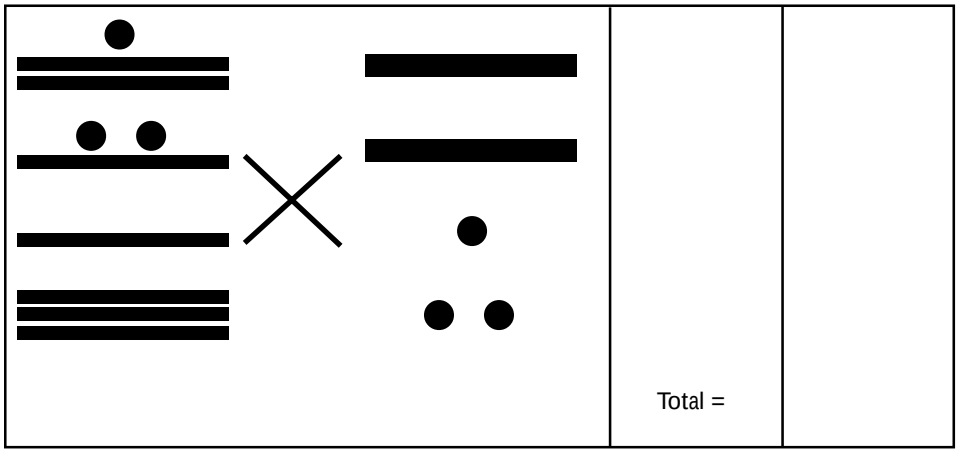
Mayan Numbers: Worksheet 3

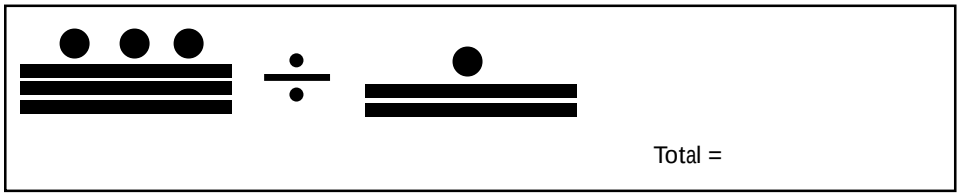
Directions: Using the Mayan numerical system, compute each problem. Be sure the final answer is in Mayan numerical symbols.

Name: _____

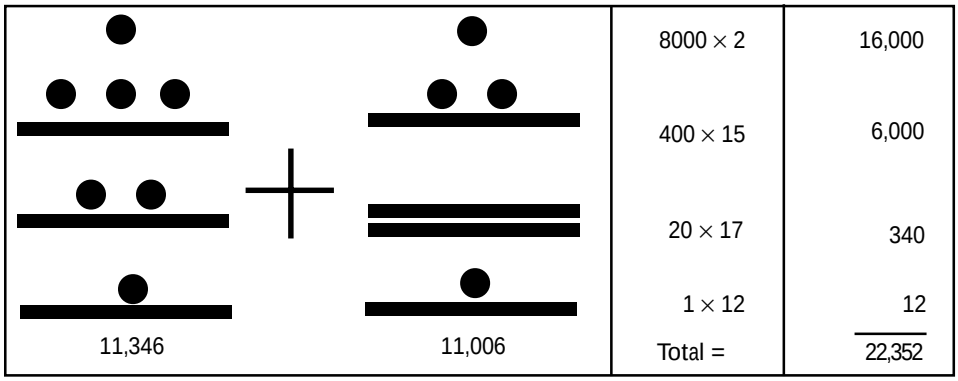






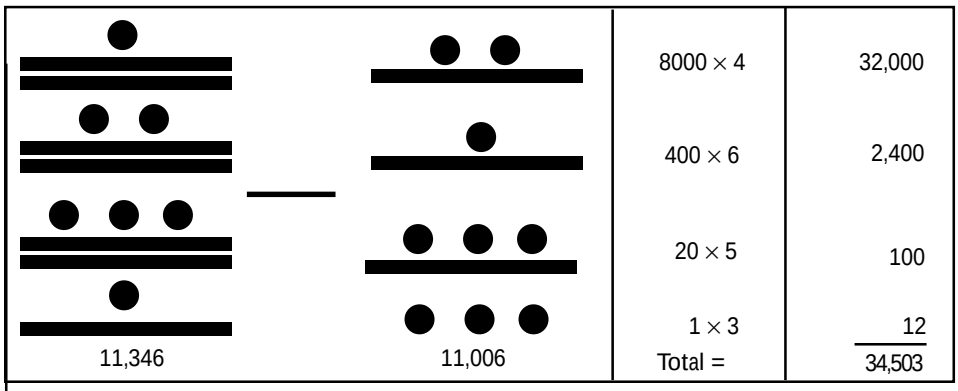


Mayan Numbers: Worksheet 3 Answer Key



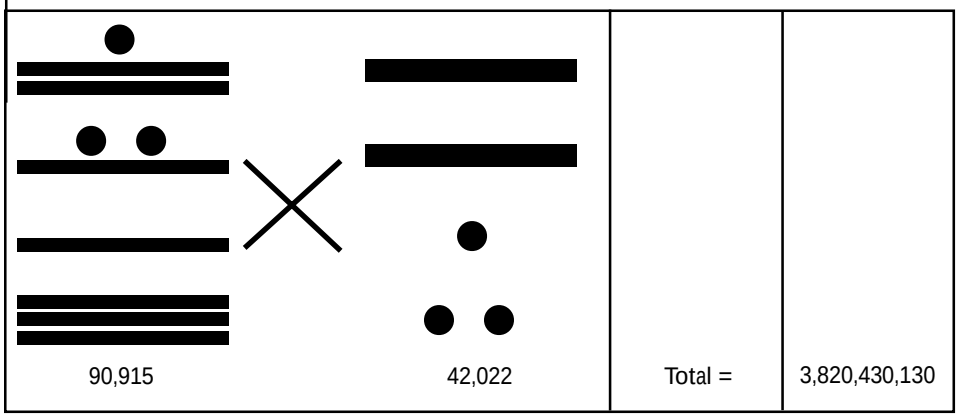
11,346 + 11,006		
	8000×2	16,000
	400×15	6,000
	20×17	340
	1×12	12
	Total =	22,352

Add across each line first. Check your answer by adding the two complete numbers.

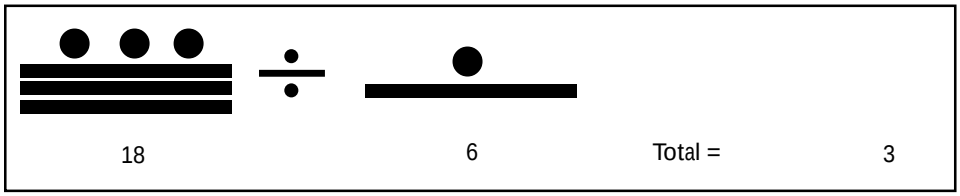


11,346 − 11,006		
	8000×4	32,000
	400×6	2,400
	20×5	100
	1×3	12
	Total =	34,503

Subtract across each line first. Check your answer by subtracting the two complete numbers.



90,915 × 42,022		
	Total =	3,820,430,130



18 ÷ 6		
	Total =	3

Lesson 2: Analysis of Number Systems

What will students be learning?

STANDARD(S)

Students develop number sense, understand and use appropriate math vocabulary, understand and use numbers and number relationships in problem-solving situations, and communicate the reasoning used in solving these problems. (M1)

Students write and speak for a variety of purposes and audiences. (RW2)

BENCHMARK(S)

Students construct and interpret number meanings through real-world experiences and the use of hands-on materials and relate these meanings to mathematical symbols and numbers.

Students prepare written and oral presentations using strategies such as list, outlining, cause / effect relationships, comparison / contrast, problem / solution, and narration.

OBJECTIVE(S)

Students will compare / contrast the Mayan numerical system to other ancient number systems.

Students will prepare a comparison chart for three different ancient number systems.

SPECIFICS

Primitive people used fingers, strings, and pebbles to count. Eventually people found ways to count by arranging numbers. Different number systems had different bases. There were systems of base 5, 10, 12, 20, and even 60. Many of the ancient number systems started with the number 1. However, the Mayan numerical system had a symbol for zero.

What will be done to help students learn this?

INSTRUCTIONAL STRATEGIES

Organizer

Student-directed activity

Summarizing

ACTIVITY

Complete the charts for Roman numbers, Egyptian numbers, and Babylonian numbers on Worksheet 4. Refer to the number charts in an encyclopedia or to the information provided by the teacher. Compare and contrast the ancient number systems of the Romans, Egyptians, and Babylonians with the Mayan number system. Write a summary paragraph of your findings on Worksheet 5.

RESOURCES/MATERIALS

encyclopedia: “N” for number systems

Mayan Number Chart

Worksheets 4 and 5

ASSESSMENT

Use key to grade Worksheets 4 and 5.

Number Systems: Worksheet 4

Name: _____

Directions: Complete the following charts, using the example as a guide.

Roman Number System:

The Romans used letters to symbolize numbers. They used two principles: the additive principle and the subtractive principle. For example, the number VI (6) uses the additive principle. The first symbol, V (5) is greater than the second symbol, I (1), so you add the two symbols. In the number IV (4), the second symbol, V (5) is greater than the first, I (1), so you subtract the first symbol from the second. The Romans used base 10 and started their number system at 1.

Arabic	Roman	Arabic	Roman
1		6	
2		7	
3		8	
4		9	
5		10	

Egyptian Number System:

The Egyptians used a base 10 number system. They represented their numbers with hieroglyphics (picture writing). The Egyptian system started at the number 1 and did not include symbols between 2 and 9. The position of the number did not change the value of the number.

Arabic	Egyptian	Arabic	Egyptian
1		8	
2		9	
3		10	
4		100	
5		1000	
6		10,000	
7		100,000	

Mayan Number System:

The Maya wrote their numbers from bottom to top. They used a base 20 system. They symbolized their numbers with bars and dots. They also had a symbol which represented zero. The Mayan number chart is in Lesson 1.

Babylonian Number System:

The Babylonian number system used base 60. They used groups of symbols to represent numbers. The first group illustrated the 1's place. The second group illustrated the 60's place, and so on. They used a wedge-like design for their symbol. By 1500 B.C., the Babylonians also developed a base 10 number system.

Arabic	Babylonian	Arabic	Babylonian
1		6	
2		7	
3		8	
4		9	
5		10	

Arabic Number System:

The Arabic number system uses base 10. It is the number system we use today in the modern world. The position of a number determines its value. The Arabic number system was not developed or used by ancient Arabs. In fact, the number system was developed in India. The number system was brought to Persia, where it was translated into Arabic and used by Arabic mathematicians. The Arabs introduced the system to Europe, where it became widely used.

Number Systems: Worksheet 4 Answer Key

Roman Number System:

The Romans used letters to symbolize numbers. They used two principles: the additive principle and the subtractive principle. For example, the number VI (6) uses the additive principle. The first symbol, V (5) is greater than the second symbol, I (1), so you add the two symbols. In the number IV (4), the second symbol, V (5) is greater than the first, I (1), so you subtract the first symbol from the second. The Romans used base 10 and started their number system at 1.

Egyptian Number System:

The Egyptians used a base 10 number system. They represented their numbers with hieroglyphics (picture writing). The Egyptian system started at the number 1 and did not include symbols between 2 and 9. The position of the number did not change the value of the number.

Mayan Number System:

The Maya wrote their numbers from bottom to top. They used a base 20 system. They symbolized their numbers with bars and dots. They also had a symbol which represented zero. The Mayan number chart is in Lesson 1.

Babylonian Number System:

The Babylonian number system used base 60. They used groups of symbols to represent numbers. The first group illustrated the 1's place. The second group illustrated the 60's place, and so on. They used a wedge-like design for their symbol. By 1500 B.C., the Babylonians also developed a base 10 number system.

Arabic Number System:

The Arabic number system uses base 10. It is the number system we use today in the modern world. The position of a number determines its value. The Arabic number system was not developed or used by ancient Arabs. In fact, the number system was developed in India. The number system was brought to Persia, where it was translated into Arabic and used by Arabic mathematicians. The Arabs introduced the system to Europe, where it became widely used.

Arabic	Roman	Arabic	Roman
1	I	6	VI
2	II	7	VII
3	III	8	VIII
4	IV	9	IX
5	V	10	X

Arabic	Egyptian	Arabic	Egyptian
1		8	
2		9	
3		10	
4		100	
5		1000	
6		10,000	
7		100,000	

Arabic	Babylonian	Arabic	Babylonian
1		6	
2		7	
3		8	
4		9	
5		10	

Number Comparison: Worksheet 5

Name: _____

Directions: Use the number charts on Worksheet 4 and the Mayan number chart to complete this page.

1. Compare and contrast the Roman number system and the Mayan number system.

Likenesses:
Differences:

2. Compare and contrast the Egyptian number system and the Mayan number system.

Likenesses:
Differences:

3. Compare and contrast the Babylonian number system and the Mayan number system.

Likenesses:
Differences:

Number Comparison: Worksheet 5 Answer Key

1. Compare and contrast the Roman number system and the Mayan number system.

Likenesses: Numbers 1–4 are symbolized with a single symbol. Numbers greater than 6 are symbolized with the symbols for 5 and 1.
Differences: Mayan system had a symbol for zero; Roman system did not Roman system had additive and subtractive principles. Roman system used base 10 and Mayan system used base 20.

2. Compare and contrast the Egyptian number system and the Mayan number system.

Likenesses:
Differences: Egyptian system used base 10 and the Mayan system used base 20. Mayan system had a symbol for zero; Egyptian system did not. The position of a numeral was significant in the Mayan system but not in the Egyptian.

3. Compare and contrast the Babylonian number system and the Mayan number system.

Likenesses:
Differences: The Babylonian system used base 60 and the Mayan system used base 20. The Mayan system had a symbol for zero; the Babylonian system did not.

Lesson 3: Internet Search

What will students be learning?

STANDARD(S)

Students develop number sense, understand and use appropriate math vocabulary, understand and use numbers and number relationships in problem-solving situations, and communicate the reasoning used in solving these problems. (M1)

Students read to locate, select, evaluate, and make use of relevant information from a variety of media, reference, and technological sources. (RW5)

BENCHMARK(S)

Students construct and interpret number meanings through real-world experiences and the use of hands-on materials and relate these meanings to mathematical symbols and numbers.

Students understand the structure, organization, and use of various media, reference, and technological sources as they select information for their reading, writing, and speaking purposes.

Students paraphrase, summarize, organize, evaluate, and synthesize information.

OBJECTIVE(S)

Students will increase their understanding of the Mayan numerical system and Mayan architecture by using the Internet as a resource.

SPECIFICS

Mathematics: The Mayan number system can be located on the Internet at many different addresses.

Architecture: The Maya built entire cities containing many different types of structures, including temples, pyramids, castles, housing units, markets, and plazas. In fact, the Maya even built courts to play a hand ball game. The Mayan cities were ceremonial cities rather than commerce cities. This can be witnessed in the types of buildings constructed. Students should be able to find many sites on the Internet that contain colorful pictures of these architectural structures.

What will be done to help students learn this?

INSTRUCTIONAL STRATEGIES

Student-directed activity

Reading comprehension

PRELIMINARY LESSON PREPARATION

Obtain signed Internet permission slips before allowing students to use the Internet. Review process of how to retrieve information on the Internet with students.

ACTIVITY

Search for “Maya” by using a search engine. Record any URLs that refer to Mayan numbers and / or architecture. Summarize your findings on Worksheet 6.

Lesson 3 (cont.)

RESOURCES/MATERIALS

Internet permission forms

Internet access

Summary sheet (WS 6)

URLs:

http://www.okcommerce.com/terra/cultures/mayan/mayan1.html
History of Mayan Culture

http://www.kn.pacbell.com/wired/fil/pages/huntmayancivi.html
Digging for the Ancient Maya

http://www.astro.uva.nl/michielb/maya/links.html

http://www.civilization.ca/membrs/civiliz/maya/mmc01eng.html

ASSESSMENT

Summary sheet (Worksheet 6) demonstrates thorough research.

Internet Search: Worksheet 6

Name: _____

Directions: Please list ten URLs you have found that relate to Mayan mathematics or Mayan architecture.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

Directions: Summarize, in your own words, information gathered about Mayan mathematics or Mayan architecture from Internet sites.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Lesson 4: Mayan Architecture 1—El Castillo

What will students be learning?

STANDARD(S)

Students develop spatial sense and use geometric concepts, properties, and relationships in problem-solving situations and communicate the reasoning used in solving these problems. (M4)

Students use a variety of tools and techniques to measure, apply the result in problem-solving situations, and communicate the reasoning used in solving these problems. (M5)

Students link concepts and procedures as they develop and use computational techniques, including estimation, mental arithmetic, paper-and-pencil, calculators, computer, and other manipulatives in problem-solving situations and communicate the reasoning used in solving these problems. (M6)

BENCHMARK(S)

Students recognize, draw, construct, describe, and analyze geometric shapes in one, two, and three dimensions.

Students understand and apply the attributes of linear dimensions, capacity, weight, mass, time, temperature, perimeter, area, volume, and angle measurement in problem-solving situations.

Students develop, use, and analyze algorithms and formulas.

OBJECTIVE(S)

Students will construct a replica of a Mayan pyramid.

Students will measure and compute the perimeter, area, and volume of a replica of a Mayan pyramid.

SPECIFICS

The replica is a model of El Castillo, a four-stairway pyramid at Chichén Itzá. The Maya are believed to have celebrated a manifestation of the god Kukulcan, the feathered serpent at this pyramid. During the spring and fall equinoxes, a serpent appears to slither down El Castillo. In fact, Maya still celebrate this occurrence today.

Formulas needed to complete the lab sheet are:

Perimeter of a rectangle / square = Two Lengths + Two Widths (2L + 2W)

Area of a rectangle / square = Length x Width ($A=L \times W$)

Volume of a rectangle / square = Length x Width x Height ($A=L \times W \times H$)

What will be done to help students learn this?

INSTRUCTIONAL STRATEGIES

Teacher modeling

Hands-on activity

Independent practice

Lesson 4 (cont.)

PRELIMINARY LESSON PREPARATION

Teacher should construct a model of El Castillo for the students to use as a guide. When copying patterns on a photocopier, be careful not to cut off borders or change sizes of patterns. Piece 1 is the entire page, and might confuse students when they go to measure and cut. Also, the teacher should review with the students how to use a ruler and calculate area, perimeter, and volume. Complete the perimeter and area section on Worksheet 7 first, while the patterns are flat. Wait until the pieces are put together to calculate the volume, so that the students can see the actual height. Please note that area was calculated of the pieces flat, not as the surface area of rectangular prisms.

ACTIVITY

Before beginning the paper-folding activity, complete table 1 and 2 on Worksheet 7. Then, construct the replica of El Castillo by following the guidelines. After completing the pyramid, complete the third table on Worksheet 7.

MATERIALS

colored pencils / markers

rulers

glue

El Castillo Lab: Worksheet 7

pyramid pieces

El Castillo Temple Guideline Sheet

ASSESSMENT

Score lab sheet (Worksheet 7) by using the key. Score the pyramid by visual observation.

El Castillo Lab: Worksheet 7

Name: _____

Directions: Calculate the perimeter, area, and volume of El Castillo, by measuring the dimensions of the two-dimensional pieces on following pages and using the formulas indicated.

1. Perimeter is the sum of the distance around a geometric figure: for a rectangle, $P = 2L + 2W$.

Piece	Length	Width	$P = 2L + 2W$
1.			
2.			
3.			
4.			

Total perimeter =

2. Area is the amount of space inside a flat geometric figure: for a rectangle, $A = L \times W$.

Piece	Length	Width	$A = L \times W$
1.			
2.			
3.			
4.			

Total area =

3. Volume is the amount of space inside a three-dimensional geometric figure: $V = L \times W \times H$.

Piece	Length	Width	Height	$V = L \times W \times H$
1.				
2.				
3.				
4.				
5.				

Total volume =

El Castillo Lab: Worksheet 7 Answer Key

1. Perimeter is the sum of the distance around a geometric figure: for a rectangle, P = 2L + 2W.

Piece	Length	Width	P = 2L + 2W
1.	8.5 inches	11 inches	39 inches
2.	7.5 inches	10 inches	35 inches
3.	6.5 inches	9 inches	31 inches
4.	5.5 inches	8 inches	27 inches
		Total perimeter =	**132 inches**

2. Area is the amount of space inside a flat geometric figure: for a rectangle, A = L × W.

Piece	Length	Width	A = L × W
1.	8.5 inches	11 inches	93.5 $inches^2$
2.	7.5 inches	10 inches	75 $inches^2$
3.	6.5 inches	9 inches	58.5 $inches^2$
4.	5.5 inches	8 inches	44 $inches^2$
		Total area =	**271 $inches^2$**

3. Volume is the amount of space inside a three-dimensional geometric figure: V = L × W × H.

Piece	Length	Width	Height	V = L × W × H
1.	6.5 inches	4.0 inches	1 inch	26.00 $inches^3$
2.	5.5 inches	3.5 inches	1 inch	19.25 $inches^3$
3.	4.5 inches	3.0 inches	1 inch	13.50 $inches^3$
4.	3.5 inches	2.5 inches	1 inch	8.75 $inches^3$
5.	3.0 inches	2.0 inches	2 inches	12.00 $inches^3$
			Total volume =	**79.50 $inches^3$**

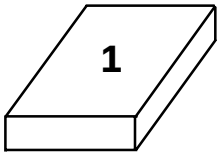
Mayan Architecture:
El Castillo Temple Guideline Sheet

These seven steps are directions for completing the El Castillo Temple.

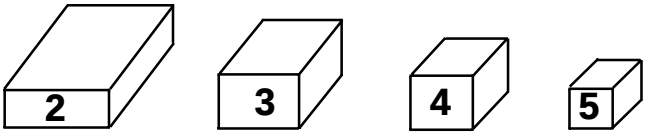
1. Color and decorate all parts of the Mayan Temple.
2. Cut out all sections of the temple.
3. Starting with piece 1, make folds and cuts on marked areas.

Piece 1

4. Using glue, fasten the corners and sides of piece 1 to form a rectangular prism.



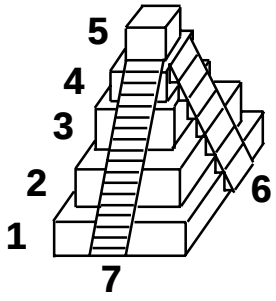
5. Repeat steps 3 and 4 to put together pieces 2, 3, 4, and 5.



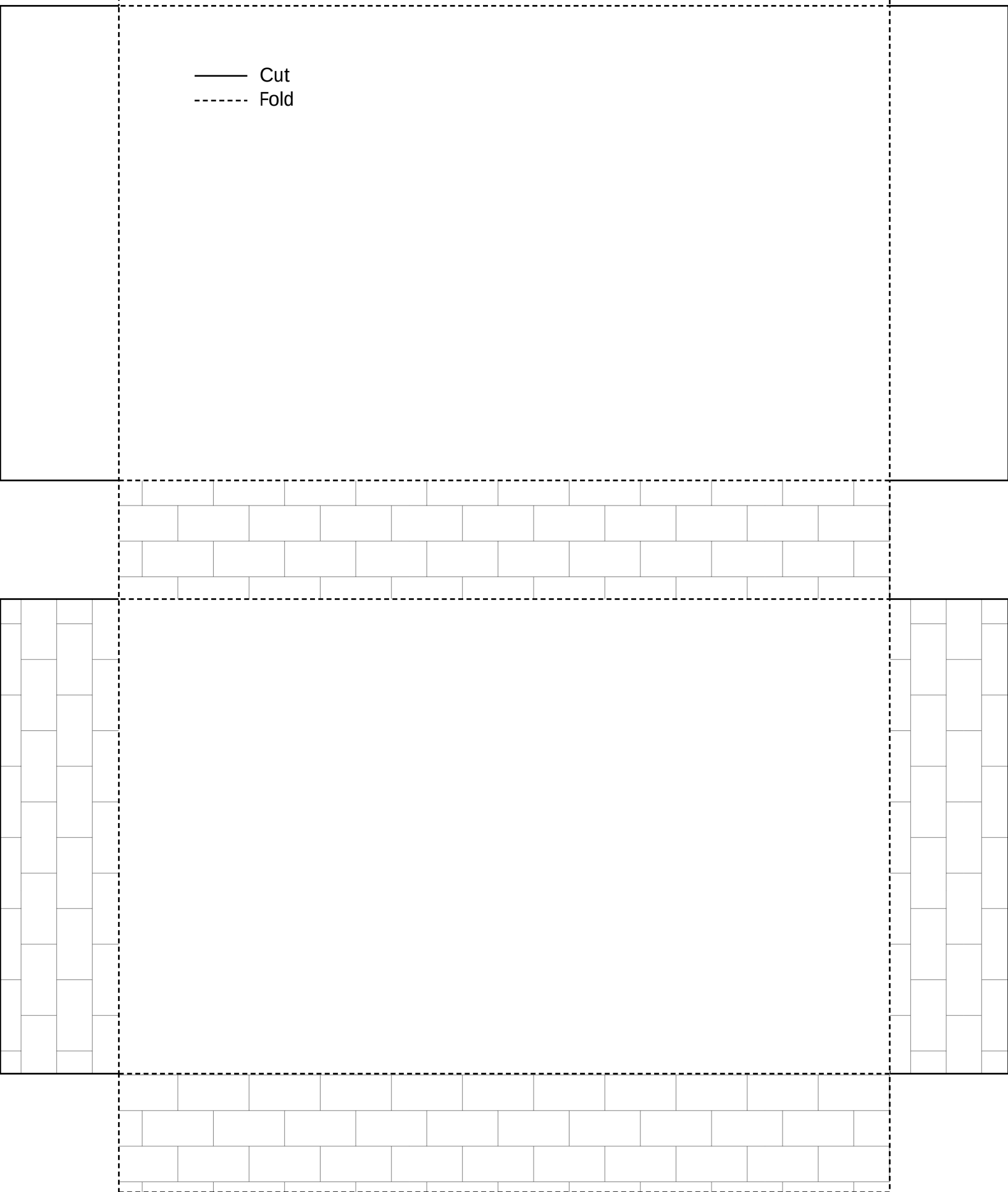
6. To make four staircases, fold pieces 6, 7, 8, and 9 like an accordion.

6

7. To assemble the temple use the following sequence of steps.
   - A. Glue piece 2 centered on top of piece 1.
   - B. Glue piece 3 centered on top of piece 2.
   - C. Glue piece 4 centered on top of piece 3.
   - D. Glue piece 5 centered on top of piece 4.
   - E. Glue the 4 staircases on each side of the pyramid.

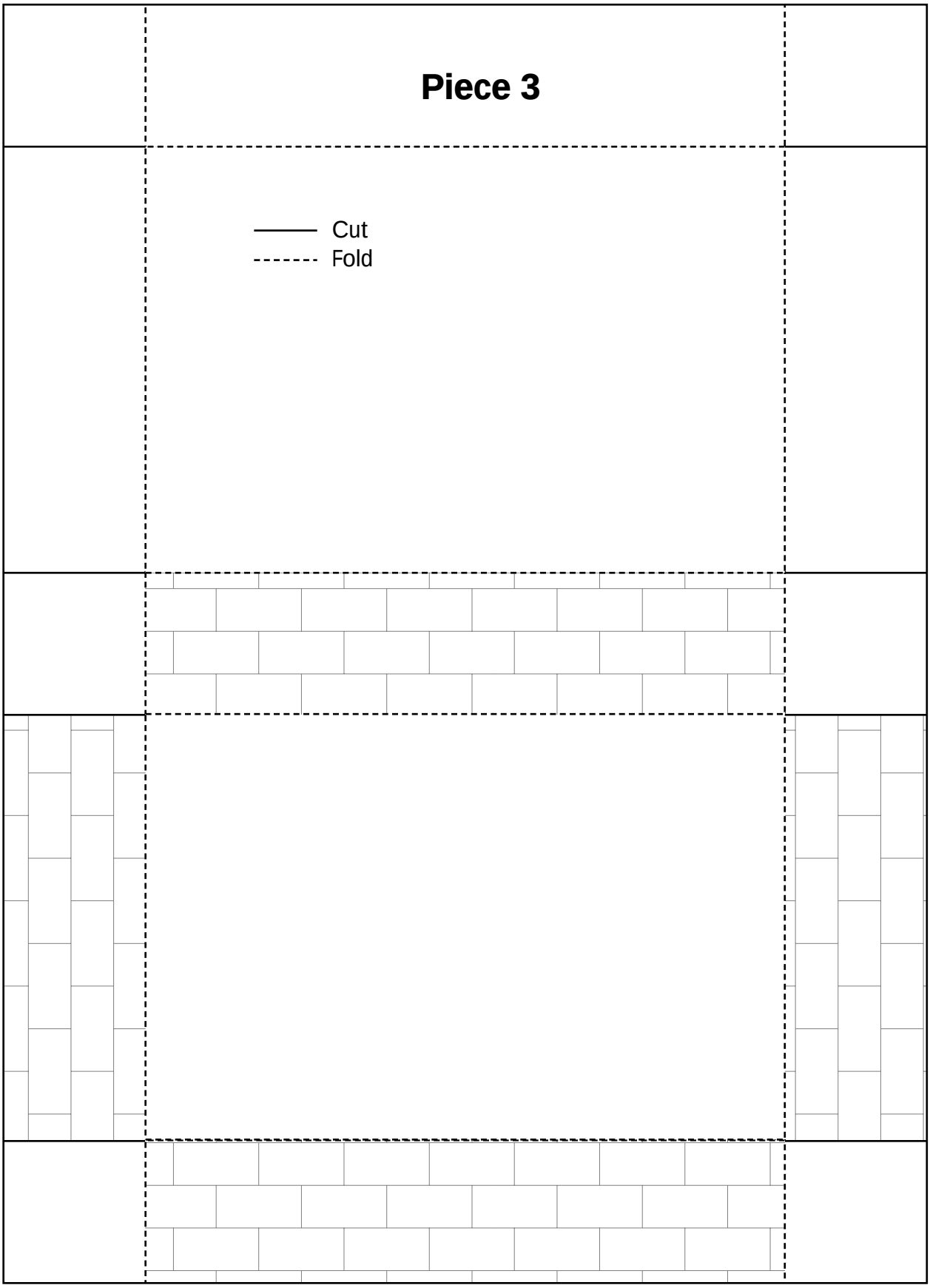


Piece 1



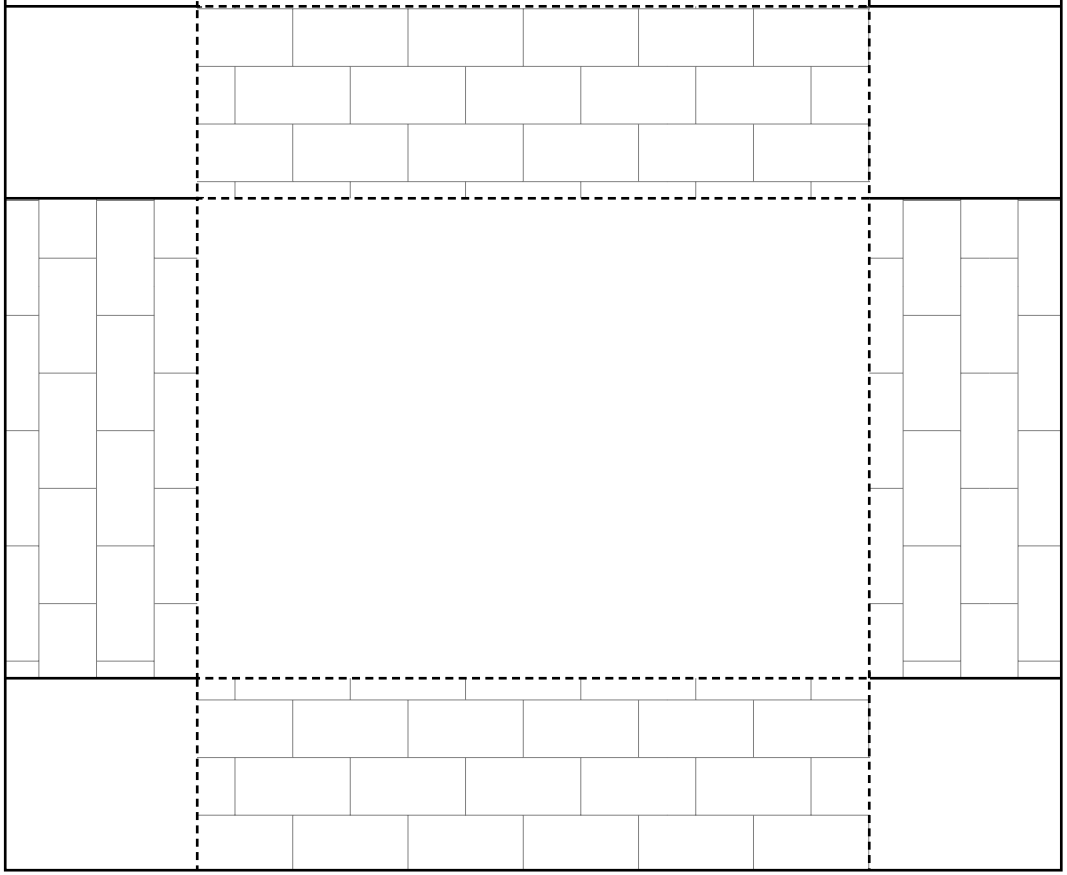
Piece 2

——— Cut
------- Fold

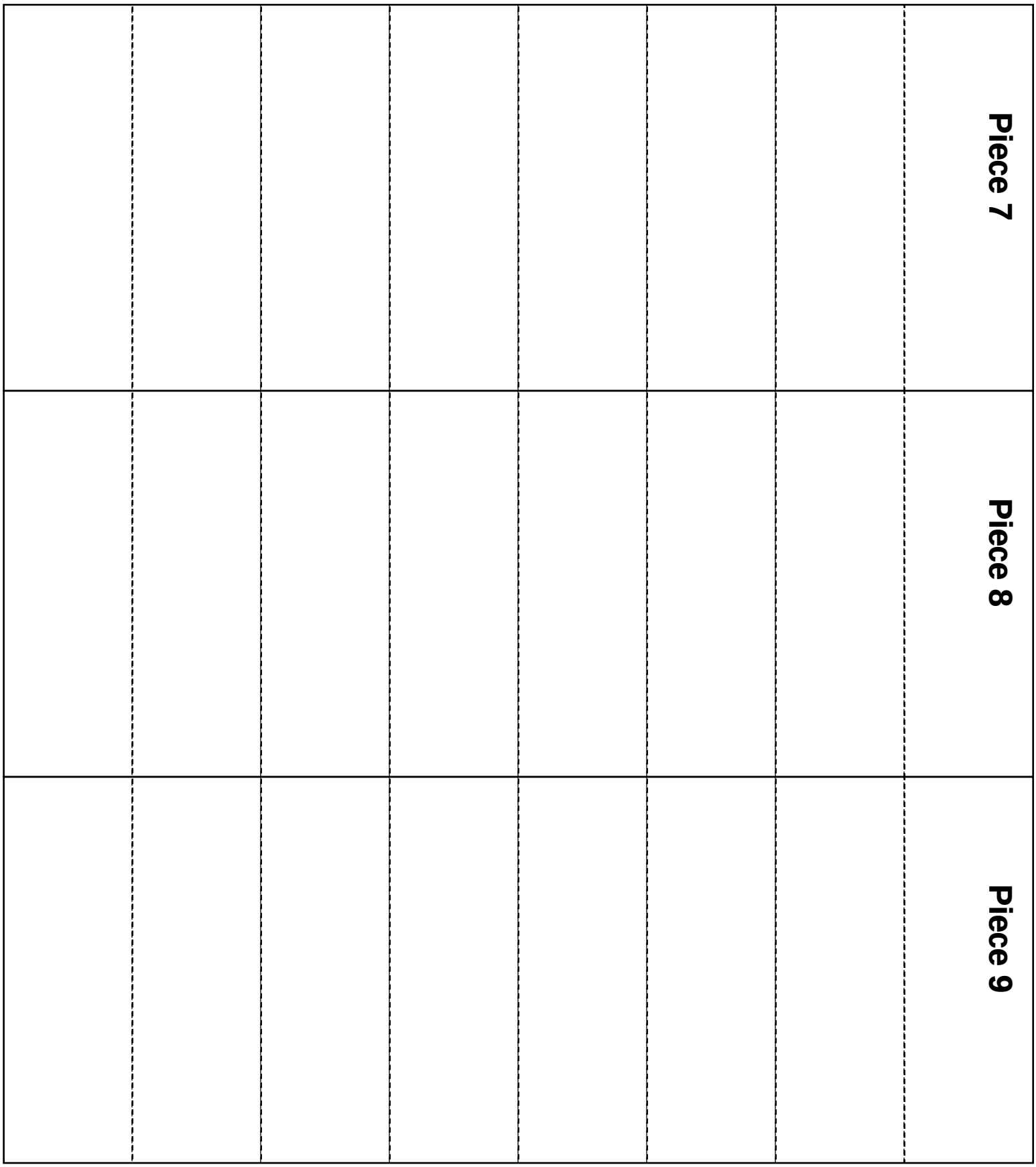

Piece 3
Cut
Fold

Piece 4

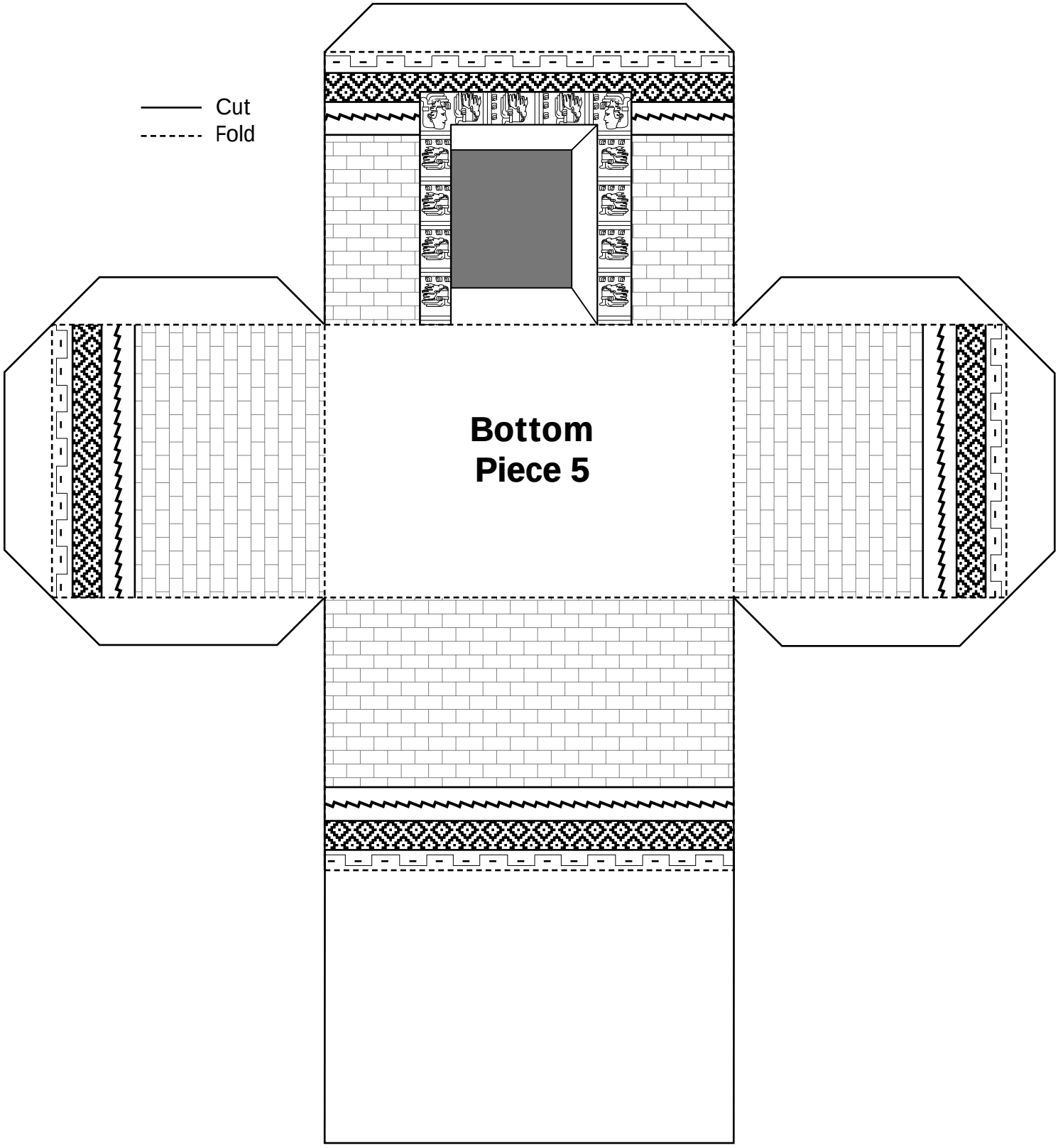
Cut
Fold



Piece 6



——— Cut
------- Fold


Cut
Fold
Bottom
Piece 5

Lesson 5: Mayan Architecture 2—
Replica of a Mayan Ruin

What will students be learning?

STANDARD(S)

Students develop spatial sense and use geometric concepts, properties, and relationships in problem-solving situations and communicate the reasoning used in solving these problems. (M4)

Students use a variety of tools and techniques to measure, apply the results in problem-solving situations, and communicate the reasoning used in solving these problems. (M5)

Students link concepts and procedures as they develop and use computational techniques, including estimation, mental arithmetic, paper-and-pencil, calculators, computers, and other manipulatives in problem-solving situations and communicate the reasoning used in solving these problems. (M6)

Students write and speak for a variety of purposes and audiences. (RW2)

BENCHMARK(S)

Students recognize, draw, construct, describe, and analyze geometric shapes in one, two, and three dimensions.

Students understand and apply the attributes of linear dimensions, capacity, weight, mass, time, temperature, perimeter, area, volume, and angle measurement in problem-solving situations.

Students develop, use, and analyze algorithms and formulas.

Students write and speak for a variety of purposes.

OBJECTIVE(S)

Students will design their own replica of a Mayan ruin (palace, temple, pyramid, plaza, sweathouse, or house).

Students will measure and compute the volume of their ruin.

Students will describe in writing their replica of a Mayan ruin and explain the steps they used to build their ruin.

SPECIFICS

This lesson has been written as a home project to correlate with the work being done in school. It is a wonderful way to get parents/guardians involved with the students academic work. Attached is a detailed explanation of the assignment to be sent home with the students. Recommended time frame for completion: three weeks.

Lesson 5 (cont.)

What will be done to help students learn this?

INSTRUCTIONAL STRATEGIES

Questioning
Student-directed activity
Summarizing
Sequencing
Discussions
Idea diagram

PRELIMINARY LESSON PREPARATION

Have pictures of Mayan ruins available for students to analyze. Below is a list of books that have wonderful illustrations of Mayan architecture. The teacher might consider creating a few examples of ways students could construct their ruin.

ACTIVITY

As a class, read and discuss the directions for the project. Brainstorm ideas for the project. Fill out the project contract and return it to the teacher. Allow 10–15 minutes of each class day to answer any questions or concerns regarding the assignment.

Complete the Idea Diagram and return it within a week of beginning the project.

At home, create a Mayan ruin that correlates with guidelines. (Use the scoring rubric as a guide also.) Calculate and measure the volume of your ruin. Write a detailed explanation of your ruin and the steps that were used to build your model.

RESOURCES/MATERIALS

student contracts
Idea Diagram (Worksheet 8)
Project Guidelines
scoring rubric
books:

Lost Cities of the Maya by Claude Baudez and Sydney Picasso
*The Maya World (*rev. ed.) by Elizabeth P. Benson
Excavations in the Great Plaza, North Terrace, and North Acropolis of Tikal by William Coe
Désiré Charnay: Expeditionary Photographer by Keith F. Davis
Mesoamerica's Ancient Cities by William M. Ferguson and Arthur H. Rohn
Maya Ruins in Central America in Color by William M. Ferguson and John Q. Royce
Pre-Columbian Architecture of Mesoamerica by Doris Heuyden
A Guide to Ancient Maya Ruins (2nd ed., rev.) by C. Bruce Hunter
The Art and Architecture of Ancient America by George Kubler
An Album of Maya Architecture by Tatiana Proskouriakoff
America's Ancient Cities by Gene S. Stuart

Lesson 5 (cont.)

ASSESSMENT

Complete the scoring rubric for each student.

SCORING RUBRIC:

4. Replica demonstrates creativity along with accuracy. The summary is well written and free of grammatical errors. Exceptional problem-solving skills are evident.
3. Replica is well-constructed but lacks creativity. The summary is readable and contains few grammatical errors. Problem-solving skills are used effectively.
2. Replica is completed but lacks creativity and accuracy. The summary contains many errors that interfere with the reading. Problem-solving is sound, but may be incomplete.
1. Replica is incomplete. The summary is incomplete or contains many grammatical errors. Problem solving is fragmented.

Mayan Architecture 2:
Replica of a Mayan Ruin

Student Contract

Name of Student: _____

I, _____,

have read the guidelines and scoring rubric and understand the project assigned to me.

I agree to complete my Mayan Architecture Project by _____ (due date).

I have explained the Mayan Architecture Project to my parent / guardian(s).

Signature of Student: _____

Signature of Parent / Guardian: _____

Signature of Teacher: _____

Mayan Architecture 2:
Replica of a Mayan Ruin

Dear Parent/Guardian,

Students are currently studying Mayan mathematics and architecture. We have examined the Mayan numerical system, investigated Mayan numbers and Mayan architecture on the Internet, and assembled a folded-paper Mayan pyramid.

While we continue to study Mayan mathematics and architecture, the students will have a homework assignment that will be due on _____. This homework assignment is expected to take three weeks to complete.

Listed below are guidelines and a list of choices. Please read through the guidelines and choices with your student. Your student needs to complete the attached student contract and return it to me tomorrow.

If you have any questions or concerns regarding this homework assignment, please contact me. Also, if none of the following choices are appropriate for your student, please contact me to discuss other options.

Sincerely,

Guidelines

1. Each student must complete the learning contract, idea diagram, and description page, along with a model of a Mayan ruin.
2. The Choice List contains many different ways to create a Mayan ruin.
3. The ruin can be two- or three-dimensional.
4. The model must not be bigger than 1 foot $\times$ 1 foot $\times$ 1 foot.
5. Acceptable materials:

paint	cardboard
colored pencils	tag board
markers	modeling clay
glue	Popsicle sticks
toothpicks	dough (see recipe)
wire	papier-mâché (see recipes)
newspaper	tissue paper
balsa wood	nails
construction paper	dough

6. If you want to use a material or choice that is not listed, please consult the teacher for approval.
7. If you are unable to get any of the materials you need, please consult teacher to discuss options.

Choice List

1. Three-dimensional model of paper, cardboard, tag board, or dough.
2. Three-dimensional model out of papier-maché and wire.
3. Three-dimensional model out of popsicle sticks or toothpicks.
4. Three-dimensional model out of modeling clay.
5. Three-dimensional model out of balsa wood.
6. Two-dimensional drawing on poster board.
7. Two-dimensional painting on poster board.
8. Two-dimensional architecture floor plan.

Two Home Recipes for Papier-mâché

½ cup flour	or	½ cup white glue
¾ cup water		½ cup water

Cut 1-inch-wide strips of newspaper. Dip strips in papier-mâché and run strip between fingers to remove extra mix. Place strips over a structure one at a time. Apply 5 to 6 layers. Allow each layer to dry overnight before adding the next layer.

Dough Recipe

3 cups flour

1¼ cups warm water

1 cup salt

Preheat oven to 250°. Using a rolling pin, roll out the dough about ½ inch thick. Cut dough into pieces for a design. Place pieces on a cookie sheet and bake for one hour and 45 minutes to 2 hours, until golden brown.

Mayan Architecture 2
Idea Diagram

Name _____ Mayan Ruin to be replicated: _____

Choice Number: _____

Materials to be Used:

Methods to be Used:

Description of Model

Lesson 6: Mayan Architecture 3—Computer Graphics

What will students be learning?

STANDARD(S)
Students understand and use appropriate technologies to perform mathematical constructions and computations, simulate mathematical experiences, and to access, process, and communicate information related to the application of mathematics in problem-solving situations. (M7)

BENCHMARK(S)
Students use appropriate traditional and electronic technologies in a variety of formats to extend and enhance mathematical learning and to simulate mathematical models, concepts, and problem-solving situations.

OBJECTIVE(S)
Students will use appropriate technology to create a graphic design of a ancient Mayan temple.

SPECIFICS
Ah Cacaw, the greatest city sovereign of Tikal, began the construction of Temple I and Temple II in Tikal. The temples were very ornamental and of great height. With these two temples, Ah Cacaw set the standard for Mayan architecture. The son and grandson of Ah Cacaw, Yaxkin and Chitam, developed Tikal with temple-pyramids, a palace compound, ball courts, market places, and a sweathouse. It is believed that 40,000 people once inhabited the city of Tikal.

What will be done to help students learn this?

INSTRUCTIONAL STRATEGIES
Student-directed activity
Computer-assisted instruction

PRELIMINARY LESSON PREPARATION
Before giving the assignment to the students, the teacher should complete the assignment, using one of the examples and the tip sheet to make a computer-generated drawing of the temple of Tikal.

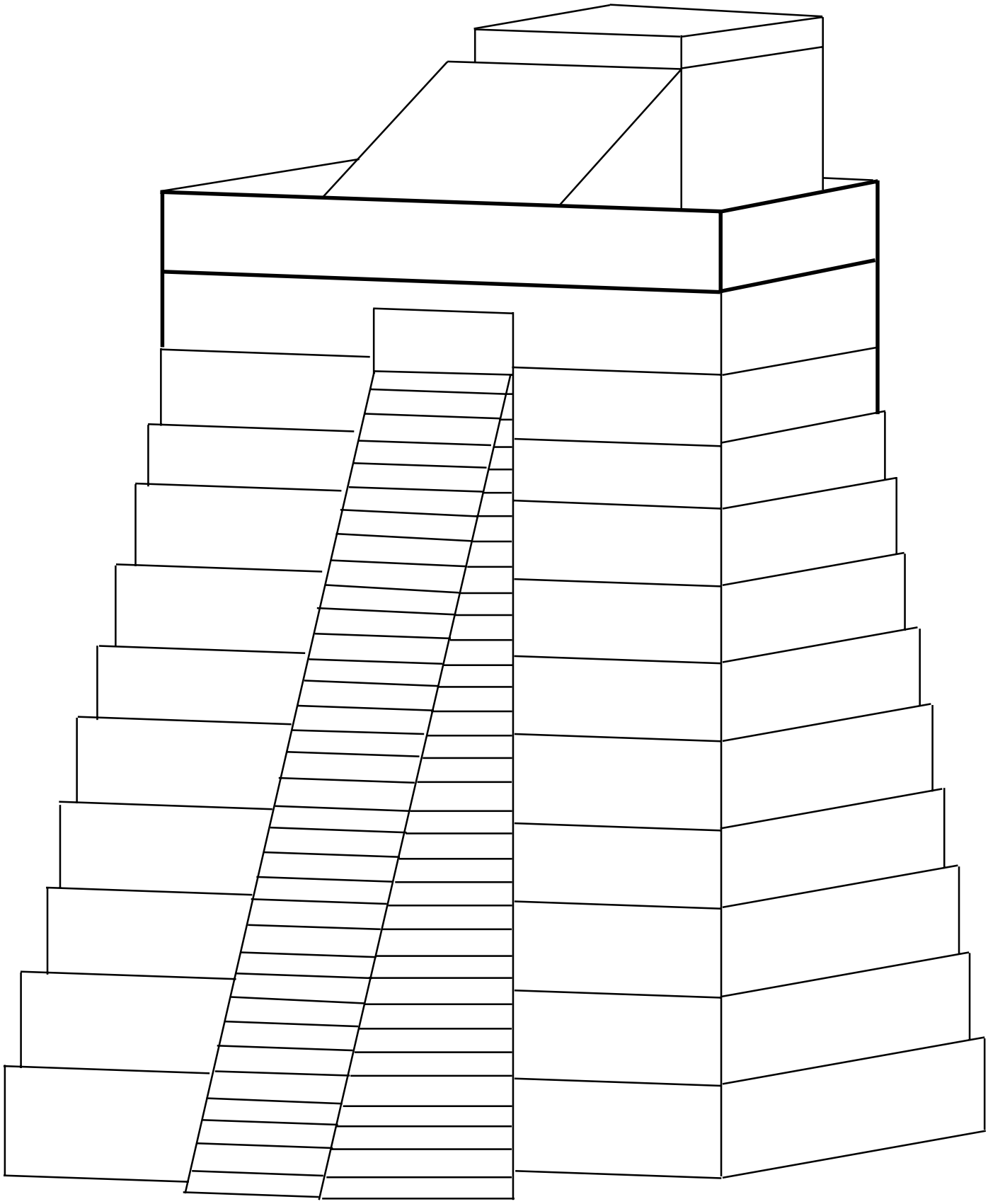
ACTIVITIES
After the teacher explains the directions for the activity, use the tip sheet and examples to make your own temple of Tikal. Create the temple using the software ClarisWorks (Drawing).

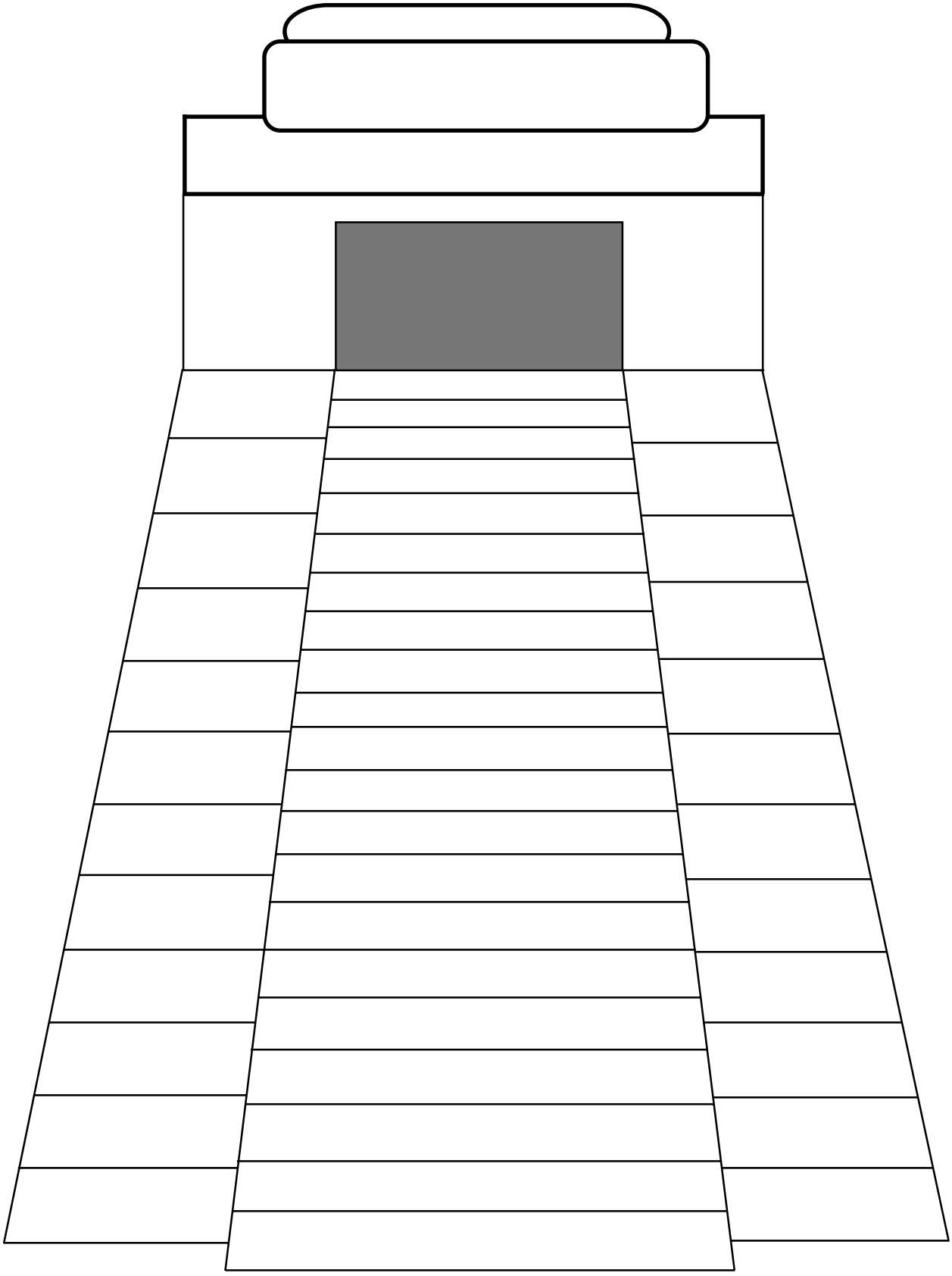
RESOURCES/MATERIALS
instruction (tip) sheet
examples
computer access to ClarisWorks or Word Perfect

ASSESSMENT
Using the examples as guides, evaluate each student's temple.

Architecture 3: Instruction (Tip) Sheet

1. First open **ClarisWorks-Drawing**.
2. Using the **tool box** on the left-hand side of the screen, click on the **line** with your mouse.
3. Draw lines using your mouse on the grid. (**Click and drag**)
4. Click on the line in the tool box each time to start **a new line**.
5. Using only lines, begin to create a temple. Start at the bottom of your paper.
6. **To move a line**, click on the arrow key in the tool box. Click on the line you wish to move. Your line is highlighted if it has two little black boxes on each end. Now you can move the line with your mouse or cursor keys.
7. **To erase a line**, click on the arrow key in the tool box. Click on the line you wish to erase. Your line is highlighted if it has two little black boxes on each end. Now push the delete button on the keyboard.
8. To draw a **rectangle**, click on the square in the tool box. Then using your mouse draw a rectangle on the grid. (Click and drag diagonally)
9. To write **letters or numbers**, click on the **A** in the tool box. Then draw a text box on the grid. Once you have a text box, you can type inside the box.
10. To **thicken lines**, click on the box that contains three lines on the bottom of the tool box. Then choose a thickness.
11. To **color or shade** in an area, click on the box that has colors or the box next to the color box. Then choose the color or shade you want.





Lesson 7 (Extended): Mayan Head Number Molds

STANDARD(S)
Students know and apply visual materials, tools, techniques, and processes. (A3)

BENCHMARK(S)
Students use elements of art, principles of design, and style to create a work of art.

OBJECTIVE(S)
Students will mold a Maya Head Number out of clay.

SPECIFICS
Students can select one of the Mayan Head Numbers (0–19) to create. Head numbers can be found on the internet at the URL below. For younger students, photocopy and enlarge the number heads to cover an area of 36 square inches (6 × 6) of clay.

ACTIVITY
Choose a head number to mold. Using a rolling pin, roll out clay one inch thick with an area of about 6 inches × 6 inches. Trace the shape of the head number onto the clay with a plastic knife. Bake the clay in an oven or kiln for 1 hour and 45 minutes to 2 hours at 250°. After the clay has been baked, paint the head number.

RESOURCES/MATERIALS
rolling pins
plastic knives
head number patterns
paint
paintbrushes
oven / kiln
25 pounds of white clay or use this recipe:

- 3 cups flour
- 1¼ cups warm water
- 1 cup salt

URL: *http://www.astro.uva.nl/michielb/maya/links.html*

ASSESSMENT
Visually assess quality of mold.

Lesson 8 (Extended): Mayan T-shirt

What will students be learning?

STANDARD(S)
Students know and apply visual materials, tools, techniques, and processes. (A3)

BENCHMARK(S)
Students use elements of art, principles of design, and style to create a work of art.

OBJECTIVE(S)
Students will design a Mayan temple t-shirt.

SPECIFICS
Students can draw a temple by hand or use their computer design from Lesson 6. They may also add a background to the design. Encourage creativity.

What will be done to help students learn this?

ACTIVITY
Place pattern of Mayan temple in between the front and back of the T-shirt. Be sure to put something between the front and back of the shirt to prevent bleeding. Trace the pattern with a permanent marker. Add a background or other elements if desired. Then place white T-shirt over a coffee can. Pull shirt tight and secure with a rubber band. Using a pipette or eyedropper, drop rubbing alcohol onto the design. Keep moving shirt and securing to can, until rubbing alcohol has been applied to the entire design. After the shirt has air-dried, place in the dryer on high to set design.

RESOURCES AND MATERIALS
permanent markers of various colors
pipettes or eyedroppers
rubbing alcohol
white cotton T-shirts
Mayan temple patterns
coffee cans
rubber bands

ASSESSMENT
Visually assess quality of T-shirt.

Unit Assessment

How will students demonstrate proficiency?

PERFORMANCE TASK

Divide class into groups of 3 to 4 students. Each group will design their own ancient Mayan city.

Each group must apply the knowledge from Lessons 1–6 to their cities by designing a city map and oral presentation.

The map must contain the following items:

1. Five different Mayan structures
2. Ten Mayan symbol numbers or head numbers
3. An area measurement
4. A perimeter measurement
5. A city name

After the maps are constructed, the groups will prepare a presentation providing information on their ancient city architectural plan. The presentation should answer the following questions:

1. What was the function of each structure in the city?
2. How were Mayan numbers used in the city?
3. Why was each structure placed where it was?
4. What architectural style was on the structures?
5. How did you solve for area and perimeter of your city?

SCORING RUBRIC:

4. Superior presentation that answers all prompts with well-organized reasoning and creativity. The map contains all components and demonstrates exceptional mathematical problem-solving skills.
3. Effective presentation that answers all prompts, but lacks creativity and organization. The map contains all components and problem-solving strategies are used effectively.
2. Marginal presentation that answers some of the prompts, but needs revisions. The map contains most of the components and mathematical problem-solving is sound, but may be incomplete.
1. Unsatisfactory presentation that shows misunderstandings of prompts. The map has little work done and fragmented evidence of problem-solving process.

Bibliography

Books

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Historical accounts of many ancient civilizations, one of which is Maya. This book is suggested as a reference to the teacher.

Boyer, Carl B. and Uta C. Merzbach. *A History of Mathematics,* rev. ed. New York: John Wiley and Sons, 1989.
A historical review of math history. Good reference book about ancient math systems. Not suggested as a supplementary text.

Editors of Time-Life Books. *The Magnificent Maya.* Alexandria, VA: Time-Life Books, 1993.
A children's book that contains colored illustrations and a lot of information on the Maya. Highly recommended for the classroom.

Eyewitness Book. *Aztec, Inca, and Maya.* London, Dorling Kindersley Limited, 1994.
Wonderful children's picture book. Available in Spanish and English.

Eyewitness Book. *Pyramids.* London, Dorling Kindersley Limited, 1993.
Wonderful children's picture book. Available in Spanish and English.

García, Horacio and Norma Herrera. *Los señores del tiempo.* México, D.F.: Pangea Editores, 1994.
An educational text about the Aztec and Maya written in Spanish.

Haslam, Andrew, and Alexandra Parsons. *Ancient Egypt.* New York: Two-Can Publishing, 1997.
A children's book about ancient Egypt. An excellent text but not needed to complete this unit.

Hellemens, Alexander and Bryan Bunch. *The Timetables of Science.* New York: Simon and Schuster, 1988.

Martell, Hazel. *The Kingfisher Book of the Ancient World: From the Ice Age to the Fall of Rome.* New York: Kingfisher Publishing, 1995.
A children's book that contains a section on the Maya.

Nicholson, Robert. *The Maya.* New York: Chelsea House Publishing, 1994.
Children's book that contains wonderful illustrations and easy-to-read accounts of the Maya.

Schele, Linda and David Freedel. *A Forest of Kings: The Untold Story of the Ancient Maya.* New York: William Marlow Publishing, 1990.
Historical explanations of Maya. Contains good information on Mayan numbers and drawings of ruins. This book is suggested as a reference for the teacher.

Thompson, J. Eric S., *Maya Hieroglyphic Writing.* Norman, OK: University of Oklahoma Press, 1960.
A large text that explains the decoding of Mayan hieroglyphics.

Books with pictures of Mayan Architecture

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Proskouriakoff, Tatiana. *An Album of Maya Architecture.* Norman, OK: University of Oklahoma Press, 1963.

Stuart, Gene S. *America's Ancient Cities.* Washington, DC: National Geographic Society, 1988.

Software and Kits:

A Coloring Book of Incas, Aztecs, and Maya, Santa Barbara, Bellerophon Books, 1998.
Children's activity book that contains Maya illustrations to color. Can be ordered for $4.95 from Bellerophon Books, P.O. Box 21307, Santa Barbara, CA 93101.

Lost Civilizations: An Exploration Kit. Running Press Book Inc.
An educational history kit that contains a book about the Maya along with materials to build a replica of a Maya temple.

Maya Quest: The Mystery Trail. MECC
Ages 10–16. CD-ROM interactive program that tours around ancient Mayan ruins with a bicycle.

Websites

http://www.ok commerce.com/terra/cultures/mayan/mayan1.html
History of Mayan culture.

http://www.kn.pacbell.com/wired/fil/pages/huntmayancivi.html
Digging for the ancient Maya.

http://www.astro.uva.nl/michielb/maya/links.html
Useful general information site on the Maya; contains links to other relevant pages.

http://www.civilization.ca/membrs/civiliz/maya/mmc01eng.html
The Canadian Museum of Civilization's Mayan civilization site. Great for general information on the civilization and culture.

About the Author

Julie Murgel was born in Anaconda, Montana. She received a bachelors degree in elementary education from Carroll College, Helena, Montana. She began studying Spanish classes in high school and continued to study Spanish in college. She is currently pursuing a masters degree in education at Regis University.

Julie has taught in Denver Public Schools for three years as a middle school bilingual mathematics teacher. Prior to teaching in Denver, Julie taught third grade in Las Vegas, Nevada.

Julie's interest are in mathematics, science, and art. She enjoys creating challenging hands-on activities for her math classes. During the summer, Julie enjoys teaching geology.