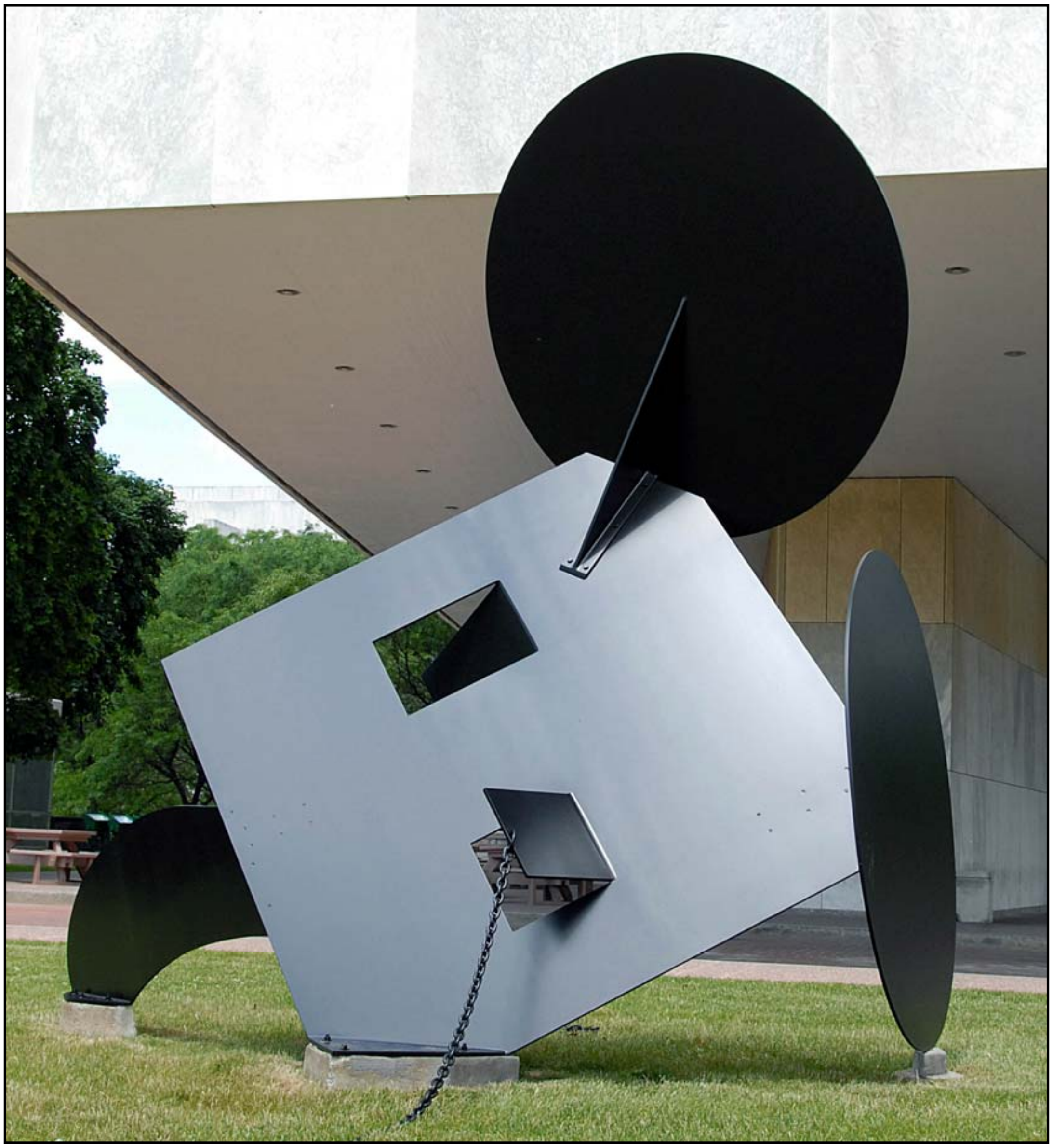


Claes Oldenburg, *Geometric Mouse, Scale A*, 1/6, 1969.

Art & Mathematics

Resource Kit

Empire State Plaza Art Collection

Introduction

Why math and art?

"Nature is relationships in space. Geometry defines relationships in space. Art creates relationships in space." (Universal Patterns -Pythagorean Press)

Consciously or unconsciously, professional artists use mathematical processes all the time. There are at least three phases common to both the math and art process:

1. Representation of some aspects of things abstractly.
2. Manipulation of the abstractions by rules of logic to find new relationships between them.
3. Discovery of whether the new relationships say something useful about the original things (Rutherford & Ahlgren, 1990).

If we want children to learn how to develop mathematical concepts, they need to be exposed to a variety of contexts, in which they can learn to think critically, analyze information, communicate mathematical ideas, create logical arguments, and work as part of a team. Appreciation and creation of works of visual art, from simple expressions of elementary geometry, to complex computer graphics, offer a rich context to learn mathematics at all school levels.

The Math/Art Resource Kit was created to help young people find relationships between Modern Art and Mathematics. This kit will help teachers meet Visual Arts and Mathematics learning standards. In general, students will:

- Explain how ideas, themes, or concepts in the visual artists are expressed in other disciplines (e.g. mathematics).
- Use sculpture and painting to learn mathematical ideas and demonstrate geometric concepts.
- Discover patterns in nature and art.
- Recognize and create a wide variety of patterns.
- Explore and develop relationships among 2 and 3-D geometric shapes.

A few specific mathematic and art concepts covered are:

- Geometric shapes
- Abstraction
- Color theory
- Mapping coordinates
- 3-D shapes
- Surface area
- Optical Illusions
- Circumference

How to use this kit

The Math/Art Resource Kit is designed for use by the classroom teacher, mathematics specialist, or art teacher. It is targeted for a 4^{th} and 5^{th} grade level but can be adapted for older or younger students.

The kit is divided into five **units**. Each unit is sub-divided by **activity** and centers around a piece of art from the Empire State Plaza Art Collection. The units can be done independently from one another, but are designed in progression, with each unit building on the concepts introduced before it. **Questions** for the teacher to ask the students are bulleted by a large purple arrow. **Background Information** can be shared with the class as each teacher determines is appropriate. **Activity Sheets** are included within the units, and are designed to be copied and passed out in class. Basic classroom supplies are needed to complete each activity. Optional **extended activities** may suggest special materials to be provided by the teacher.

The kit contains slide reproductions for classroom viewing, background information on the art and artists, math and art activities, and vocabulary.
The back of this kit also contains a CD with images to be viewed on a computer or digital projector. The images are formatted in MS Power Point and compatible with Windows 2000, Millennium, or XP. Sorry, no Mac format available, yet!

Vocabulary is listed at the beginning of each lesson, and at the teacher's discretion, can be integrated into the lesson so that students begin to use the language of mathematics naturally. A Glossary at the back of the kit lists the definitions of all vocabulary words.

UNIT 1

- Math Objectives:

  Categorizing.
  Identifying.
  Comparing.

- Art Objectives:

  Observation of how shapes are used in designing works of art.
  Understanding the concept of Abstraction.
  Constructing abstract designs.

- Vocabulary:

  Abstract
  Abstraction
  Polygon
  Vertex
  Vertices

Unit 1: Activities

Unit 1: Activity A: The Shape of Things

Procedure:

Students will work in small groups of about 3 to 5 students per group. Give each group a set of sheets containing pictures with objects and images that are based on various geometric shapes. Have each group separate the pictures by cutting them apart.

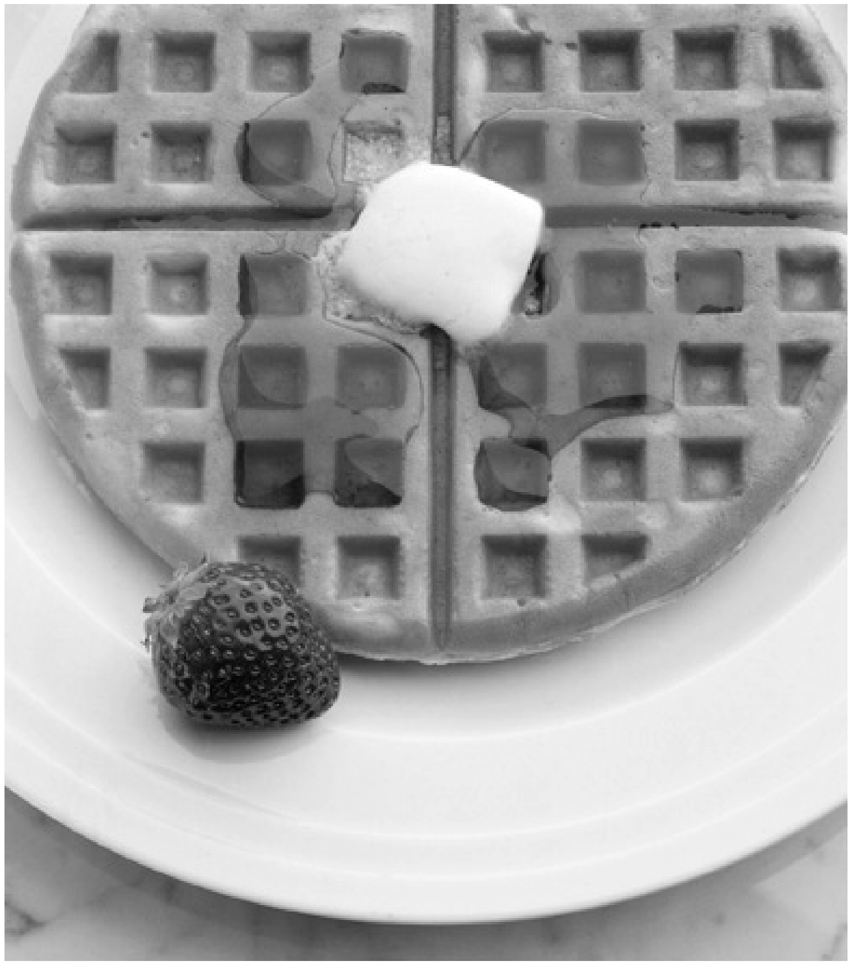
Ask the students to categorize the pictures into as many groups as they feel are necessary, looking for characteristics that they have in common. Allow the students to explore options for their choices in categories but ask them to be able to justify their choices. After the groups have reached their decisions by mutual consensus, share the results.

Note what geometric attributes the students see in the pictures and how they describe them. If they use informal rather than formal math terms, you can use their informal ones as a relevant beginning place to help define the more formal terms. Note how discriminating the students who sort on geometric attributes are in classifying squares, rectangles, triangles, circles, ovals, etc.

Extension:

Have the students do as described for original Activity A. Tell students to sort into 3 groups base on geometric shapes. Compare results. Discuss reasons for their choices of categories and for placing a picture in a category. Note and discuss which shapes in pictures dominate students' choices—which shapes are most compelling as the overall abstraction for a picture. For example, the square may be the most compelling abstraction for the waffle picture even though its overall shape is a circle—depending on whether they concentrate on individual parts of a picture or an overall "look" of a picture.

Unit 1: Activity Sheet A: The Shape of Things

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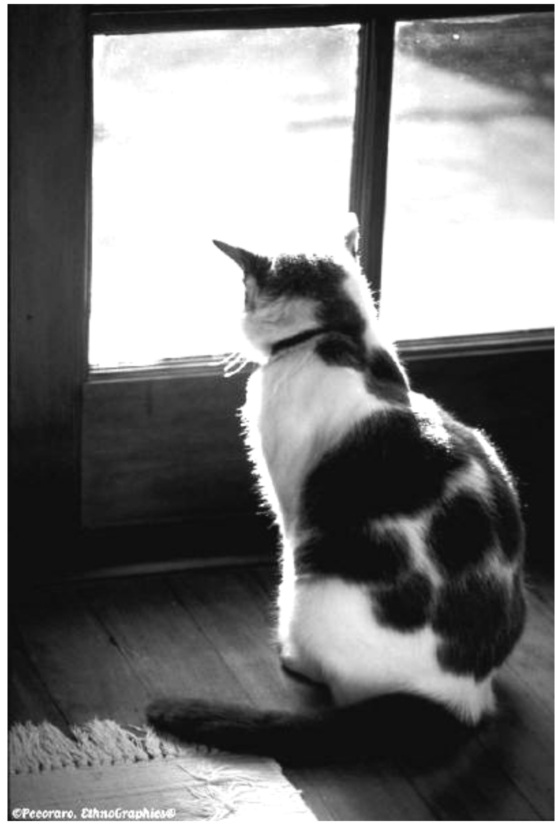

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SIGNAL
AHEAD

Unit 1: Activity B: Looking Activity

Slide 1: Claes Oldenburg
Geometric Mouse, 1968
Painted steel and aluminum

Looking Questions:

Let's begin the process of exploring this sculpture by describing everything that you can see or tell from this slide.

Example:
What is the subject of this sculpture?
Can you guess how big it is?
Of what material does it seem to be made? Etc.

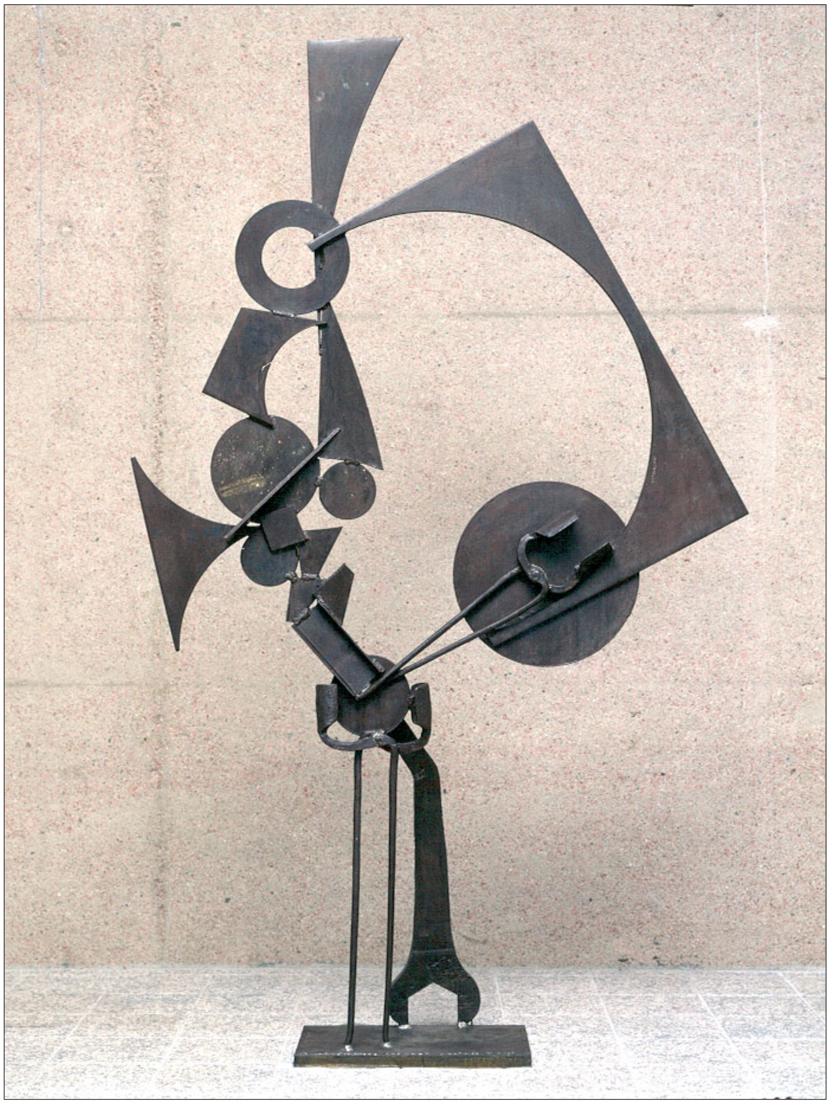
The title of the sculpture is Geometric Mouse. What has the artist done to the image of a mouse to make it "geometric?"

Background Information:
Claes Oldenburg has written:

> Mickey Mouse is one of the most important American symbols. I made Mickey a geometric shape because of this relationship with the early movie camera. The “eyes” operate as shutters, which I have represented as old-fashioned window shades (notice the chains hanging from each of the “eyes” of the sculpture). Such shades never roll up, which accounts for the sleepy look. One side of the “face” shows the mouse’s kindly aspect; the other, his brutal one. The body is included in the face—the tongue doubles as a heart and a foot. (Art and Man, April/May, 1982.)

Oldenburg is will known for his giant-size sculptures depicting everyday objects such as a clothespin, lipstick, light switch, and other items that are not usually the sole subject of a work of art. He also has created “soft” sculptures made of cloth and vinyl of objects such as a bathroom sink, an ice cream cone, and even an automobile engine. Oldenburg challenges us to think about everyday objects in a new way.

Slide 2: David Smith
Volton XVIII, 1963
Painted steel



Compare *Volton XVIII* to *Geometric Mouse*. Is this sculpture "geometric" too? What do you think the subject of the sculpture is? How do you know? What does this sculpture seem to be made of, and how is it put together? (informal objects welded together)

Did you sort any of your images based on abstractions?

Background Information:

In the twentieth century, artists have created works of art based on things they see around them by simplifying or reducing their subjects to basic shapes. This process of simplification is called ABSTRACTION. Sometimes the subject will be distorted so that it no longer looks real. Sometimes, you may not be able to see any resemblance to real things all. *Volton XVIII* is purely abstract in that it does not represent any object. The artist intended to create a subject of just the sculpture itself. This is called **non-representational**, or **non-objective** abstract art, meaning it does not represent any object at all.

David Smith lived and worked in Bolton Landing on Lake George and is considered one of the most important sculptors of this century. Originally trained as a painter, he began working in metal in 1932, enabling him to utilize the welding skills and techniques he developed while working at an automobile plant and later at a locomotive factory. He frequently used "found objects" in his work and integrated them into the total structure of his pieces so that their original function became subordinate to the design of the sculpture itself.

> There is something rather noble about junk – selected junk – junk in one era that performed nobly for common man – to now be perceived by new ownership.
> (David Smith of Bolton Landing, The Hyde Collection, 1975.)

Unit 1: Activity C: Tangram Puzzle

Procedure:

You may want to have your students work independently or in pairs. Students should cut out the Tangram Puzzle outlined in Activity Sheet 1C and follow the directions on Activity Sheet 2C. The Tangram puzzle lets students explore both geometric shapes and the concept of abstraction.

Ask students to discuss what is getting abstracted in the tangram pictures and how this kind of abstraction is like Oldenburg's *Geometric Mouse*. Note how well the students see the abstracted animals and people depicted in the tangram shapes are abstractions for body parts and for the overall shapes of the animals and people.

Extended Activity:

More activities utilizing the Tangram Puzzle can be found in:

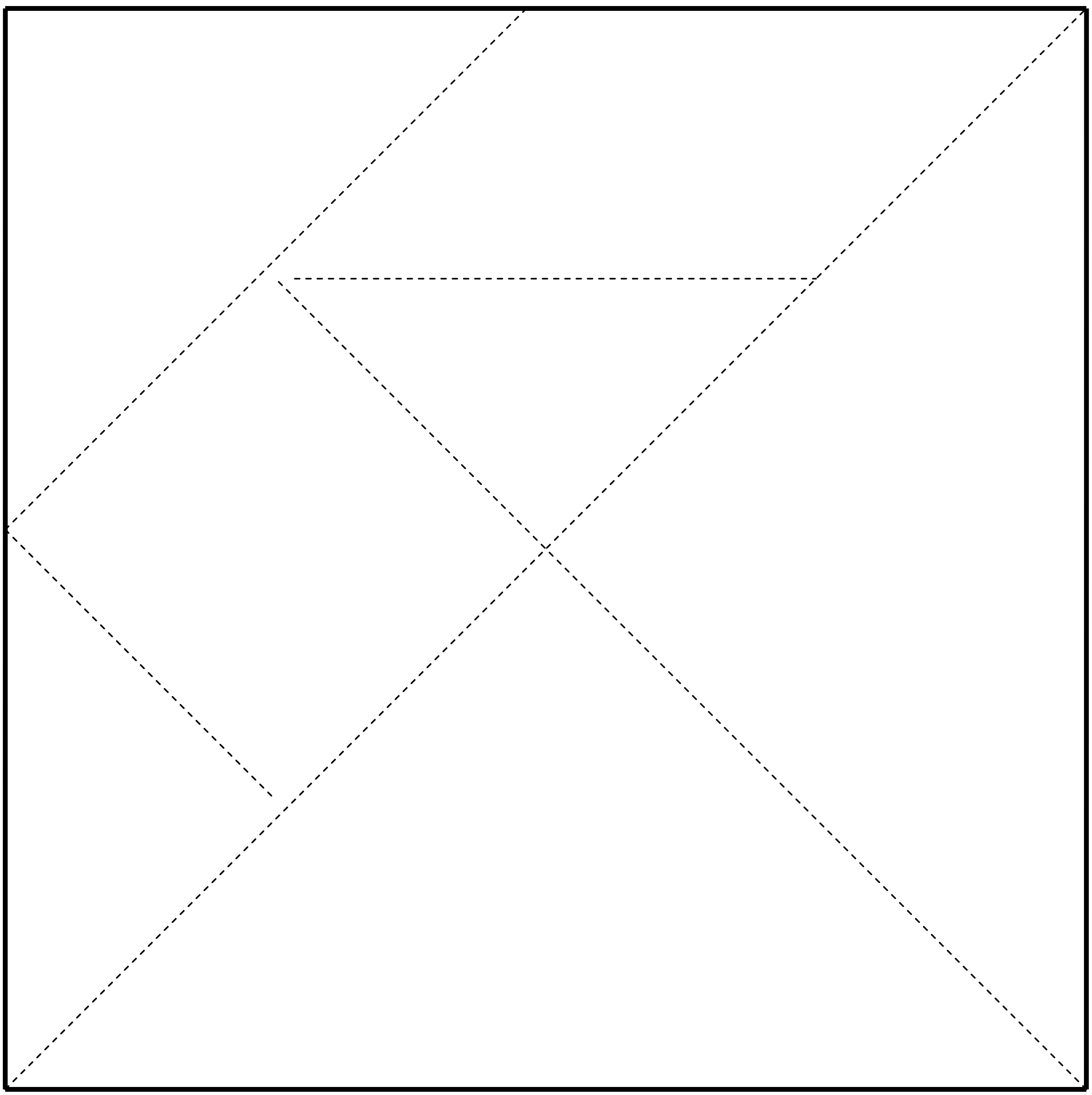
- Seymour, Dale. *Tangramath*. Creative Publications.
- Effers, Joost. Tangram. Penguin Books.

Pattern blocks are also another excellent way to help students extend the concept of abstraction and explore geometric shapes.

- Blinko, Janine and Noel Graham. *Cards for Pattern Blocks: Problem Solving Activities for Young Children*.

Many resources listed in the extended activity guide are available for loan from the Empire State Plaza Art Collection.
(518) 473-7521

Unit 1: Activity Sheet 1C: Tangram Puzzle

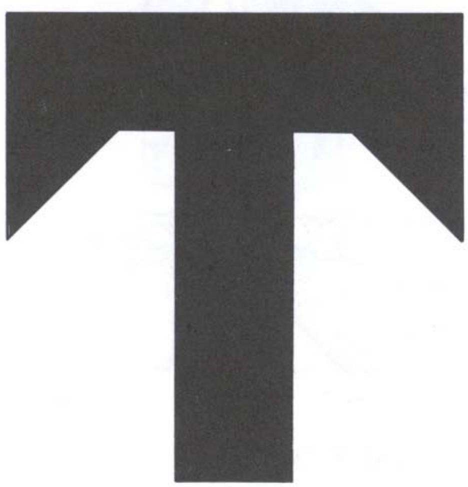


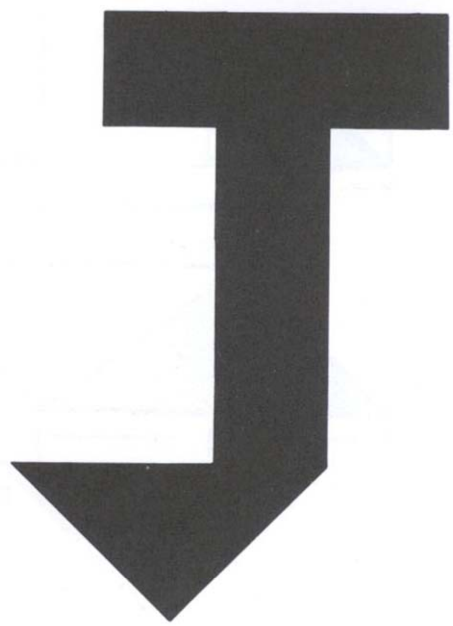
Unit 1: Activity Sheet 2C: Tangram Puzzle

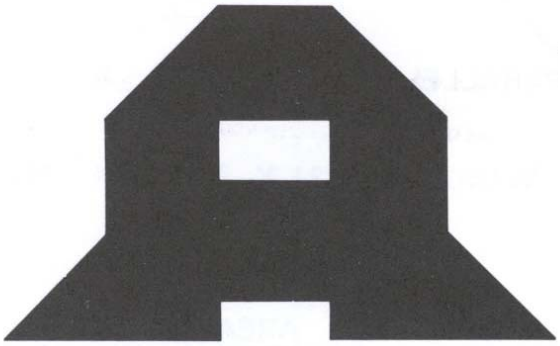
You can create some of your own abstract pictures by playing with the fascinating Tangram. This type of puzzle is from ancient China. Tangrams are very special and are still popular today. With just a few geometric shapes, we can produce many different abstract images, just like *Geometric Mouse* by Claes Oldenburg.

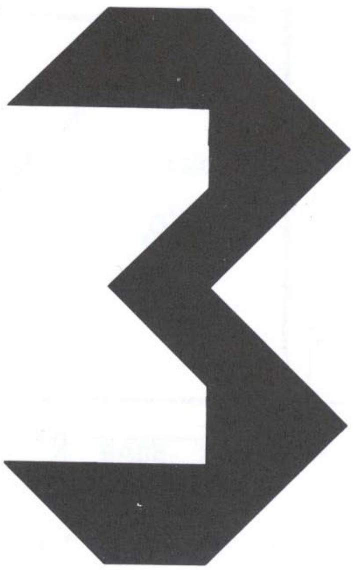
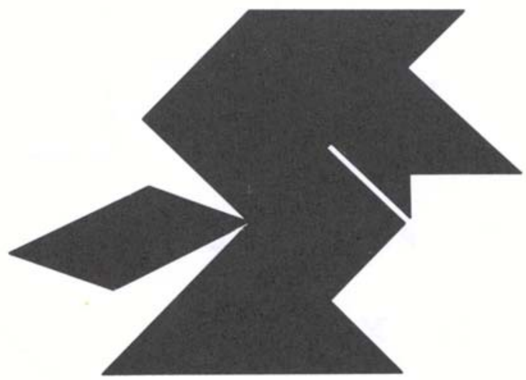
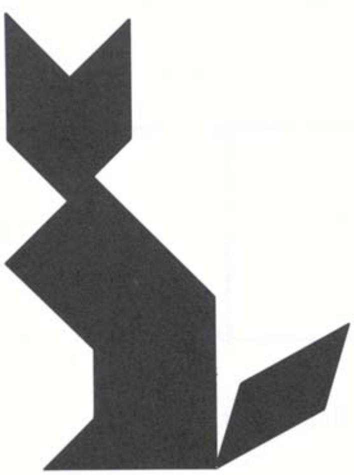
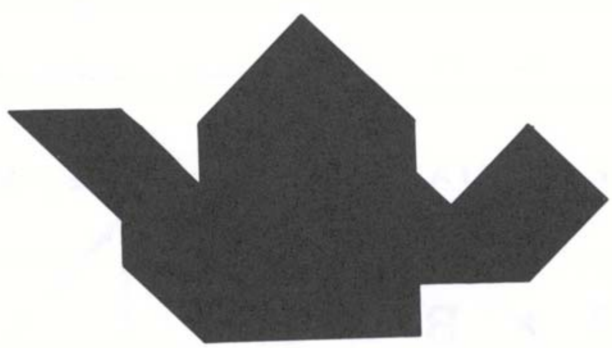
Directions:

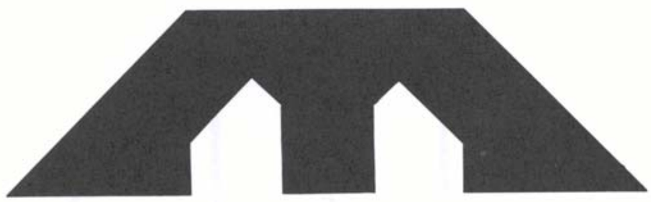
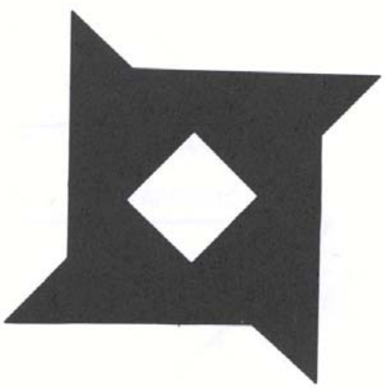
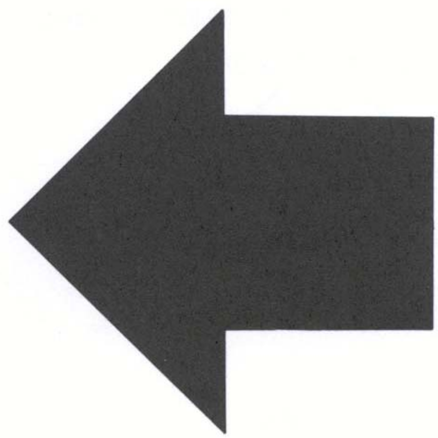
Start by cutting out the Tangram puzzle "game pieces" (you should have 7) and you're ready to play. Then, try to match the figures below—they are just a few of the hundreds of tangram picture puzzles that are possible. There are only two rules to remember—you must use all seven puzzle pieces and they must not overlap one another.
Try making some of your own.








Unit 1: Activity D: Find the Polygons

Procedure:

Introduce the term **polygon**. **Poly** means “many” – **gon** means “side.” (A closed plane figure bounded by straight lines) Students will find the hidden polygons in Activity Sheet 1D. Shapes like triangles, rectangles, and squares are all polygons.

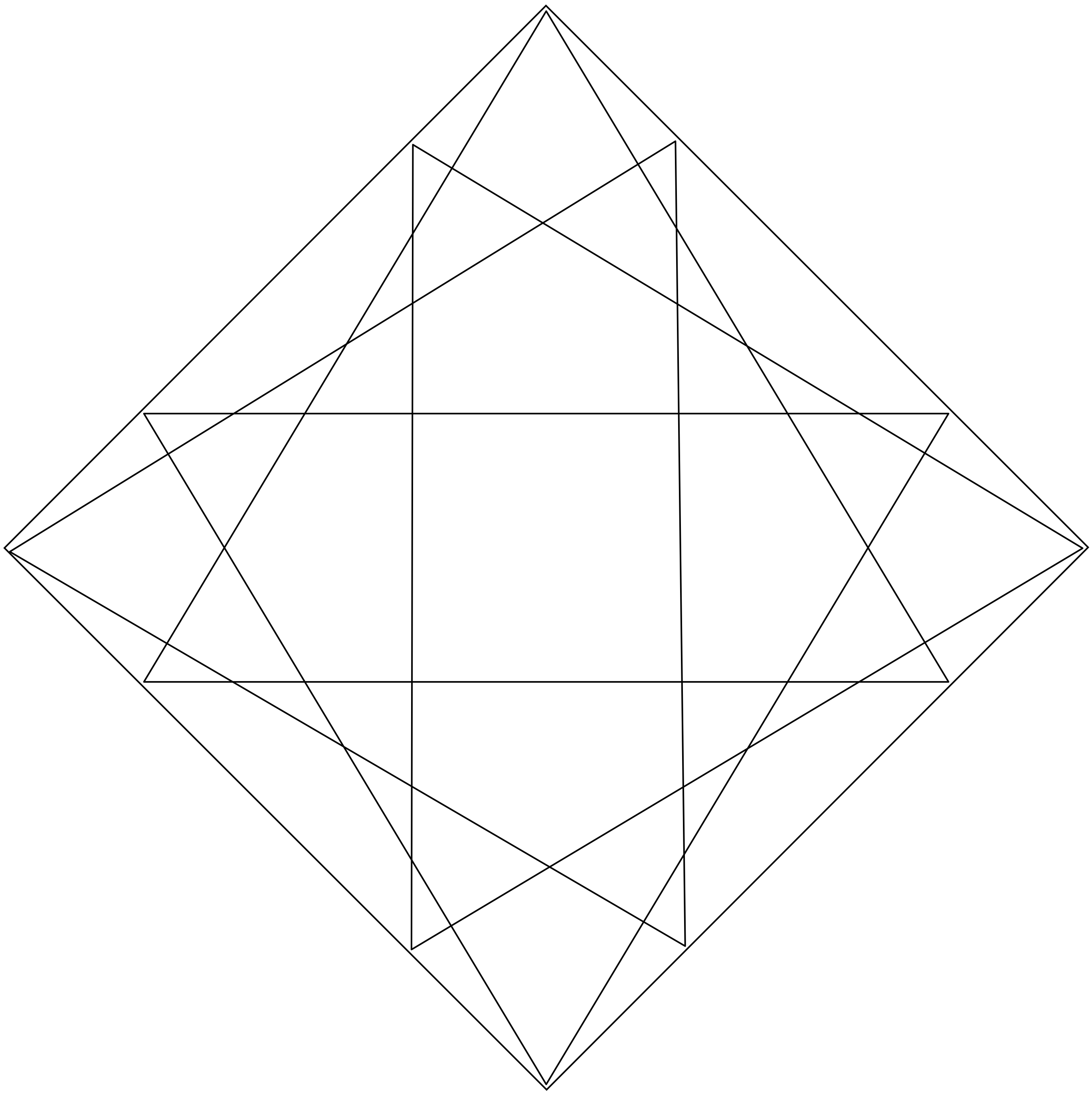
What geometric shape is not a polygon? (A circle: it has no straight lines)

You can change the activity by asking the students to label the figures with all the names that apply or which figures could have more than one name. As a class, agree to call these by the name that tells the most about a figure; the “best” name approach. (e.g. Square tells more than rhombus, which, in turn tells more than parallelogram, yet all of these could describe a square.)

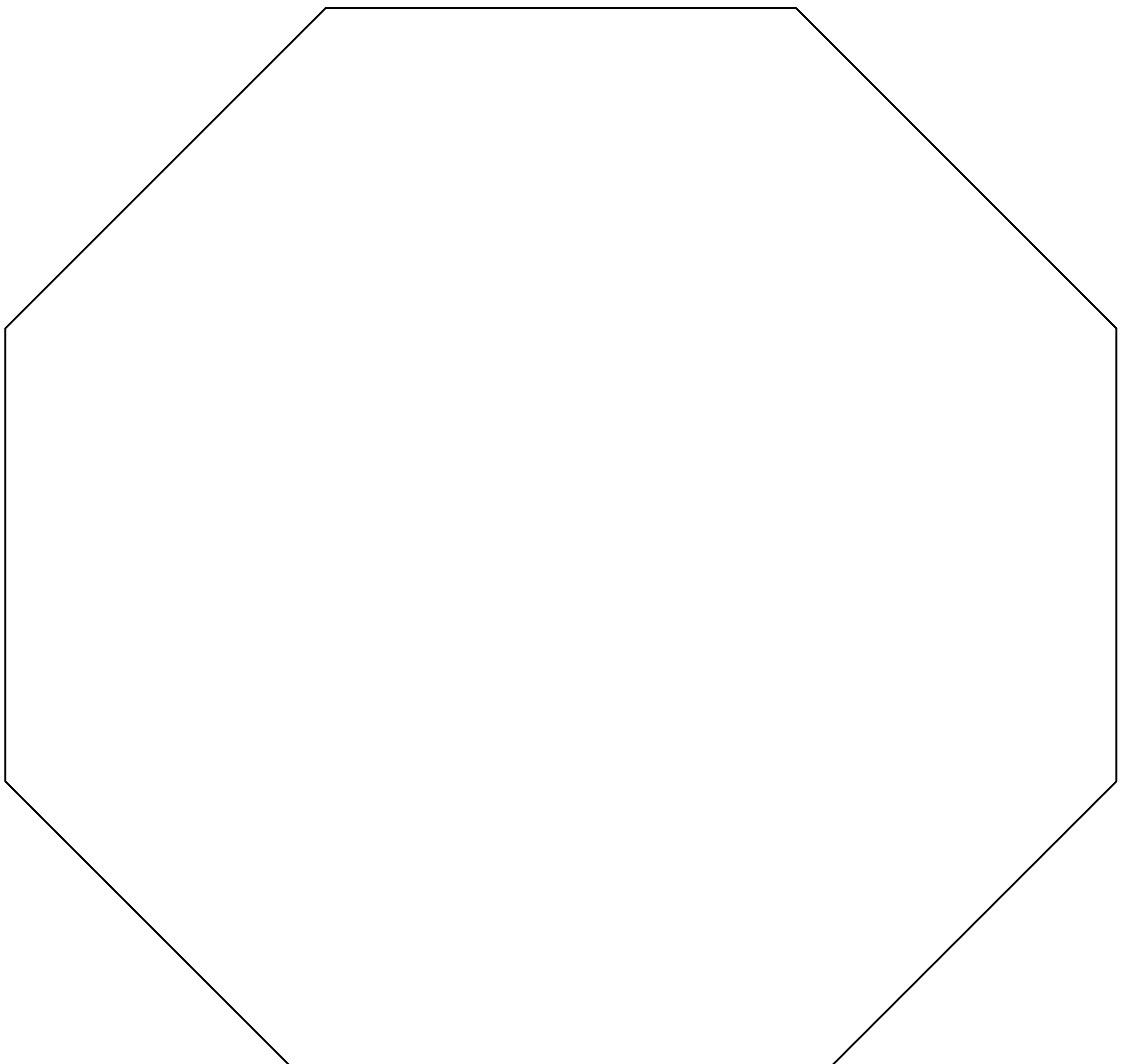
Define the term vertex for students—the point where two straight lines intersect). Have students locate the 4 outer vertices on Activity Sheet 1D. Then, using Activity Sheet 2D, have students create a polygon design in the octagon by connecting its vertices. Take the designs a step further by adding color!

Use Activity Sheet 3D to help reinforce polygon shapes.

Unit 1 Activity Sheet 1D: Find the Polygons



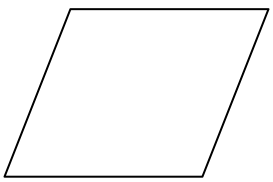
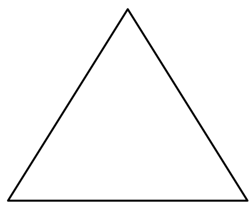
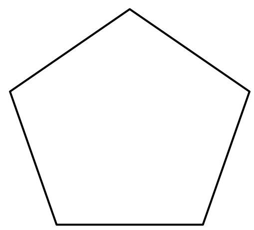
Unit 1: Activity Sheet 2D: Find the Polygons

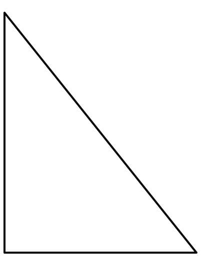
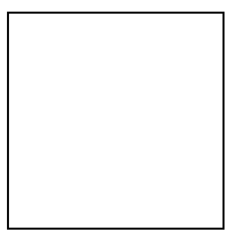
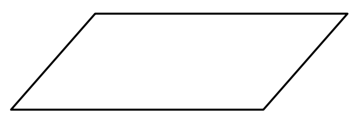


Unit 1: Activity Sheet 3D: Find the Polygons

Match the shapes or polygons to the names listed below, then try to find where they are hiding in the grid on the following page. Mark their outline with a marker or pencil.

Square
Equilateral Triangle
Right Triangle
Parallelogram
Pentagon
Rhombus

UNIT 2

- **Math Objectives:**

  Identifying angles.
  Exploring the concepts of similar & congruent.
  Graphing using coordinates.

- **Art Objectives:**

  Building visual perception skills.
  Identifying complementary colors & exploring their optical effects.
  Designing a picture using coordinates.

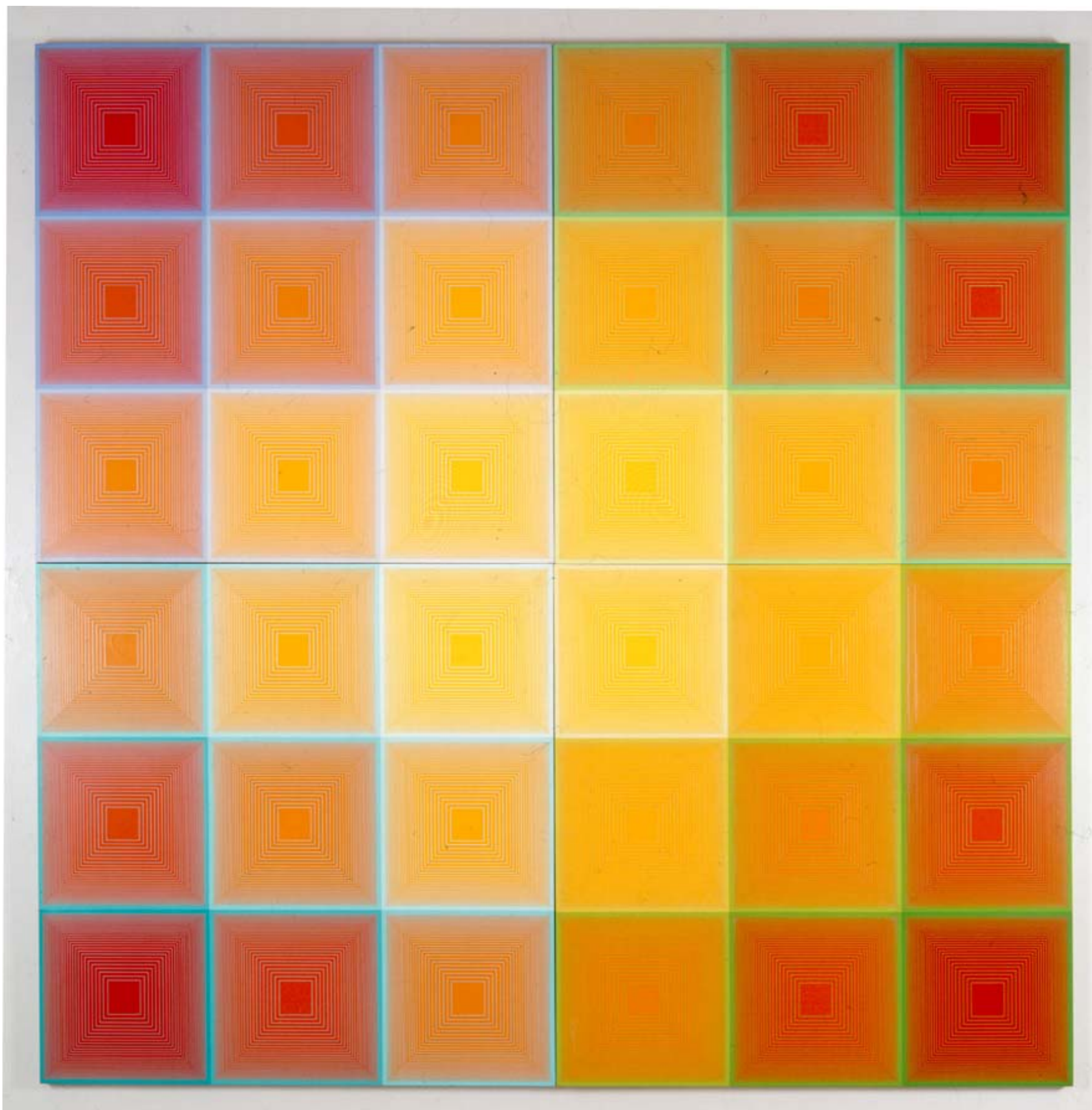
- **Vocabulary:**

  Point
  Bisect
  Diagonal
  Congruent
  Similar
  Coordinates
  Origin
  Axis

Unit 2: Activities

Unit 2: Activity A: Looking Activity

Slide 3: Richard Anuszkiewicz, *Grand Spectra*, 1968



Looking Questions:

Richard Anuszkiewicz has used squares to build a very complex picture in a very simple way. What part of the painting attracts your attention? Why do you think it does?

What colors has the artist used? Notice the colors the artist has used on the outside corners of the painting.

Teaching Tool: Color Wheel (Inside Pocket)

Find the colors that Anuszkiewicz used on the color wheel. Notice how some of the colors on opposite sides of the wheel. Artists know that using opposite colors make the colors stand out more.

Look again at *Grand Spectra*. Notice how those opposite, or complimentary colors make the corners stand out.

Ask the students to describe what they see mathematically. Can you see any diagonal "lines"? How are these diagonals created?

(The diagonals are created by the corner vertices of the concentric squares.)

What do they notice about the spacing between successively small squares?

(As the squares get smaller, there is a greater space between them.)

Hand out to each student a copy of Activity sheet 1A or look closely at the slide of *Grand Spectra*. Ask students if they see the pattern of **congruent** squares composed of parts of each set of same-centered squares in the slide. Pass around Activity Sheet 2A (below) with the diagonals added to the top of the image to illustrate the congruent squares. This sheet also points out the diagonals implied by the squares, however, it does not fill in every diagonal. Instruct students to fill in the missing diagonals.

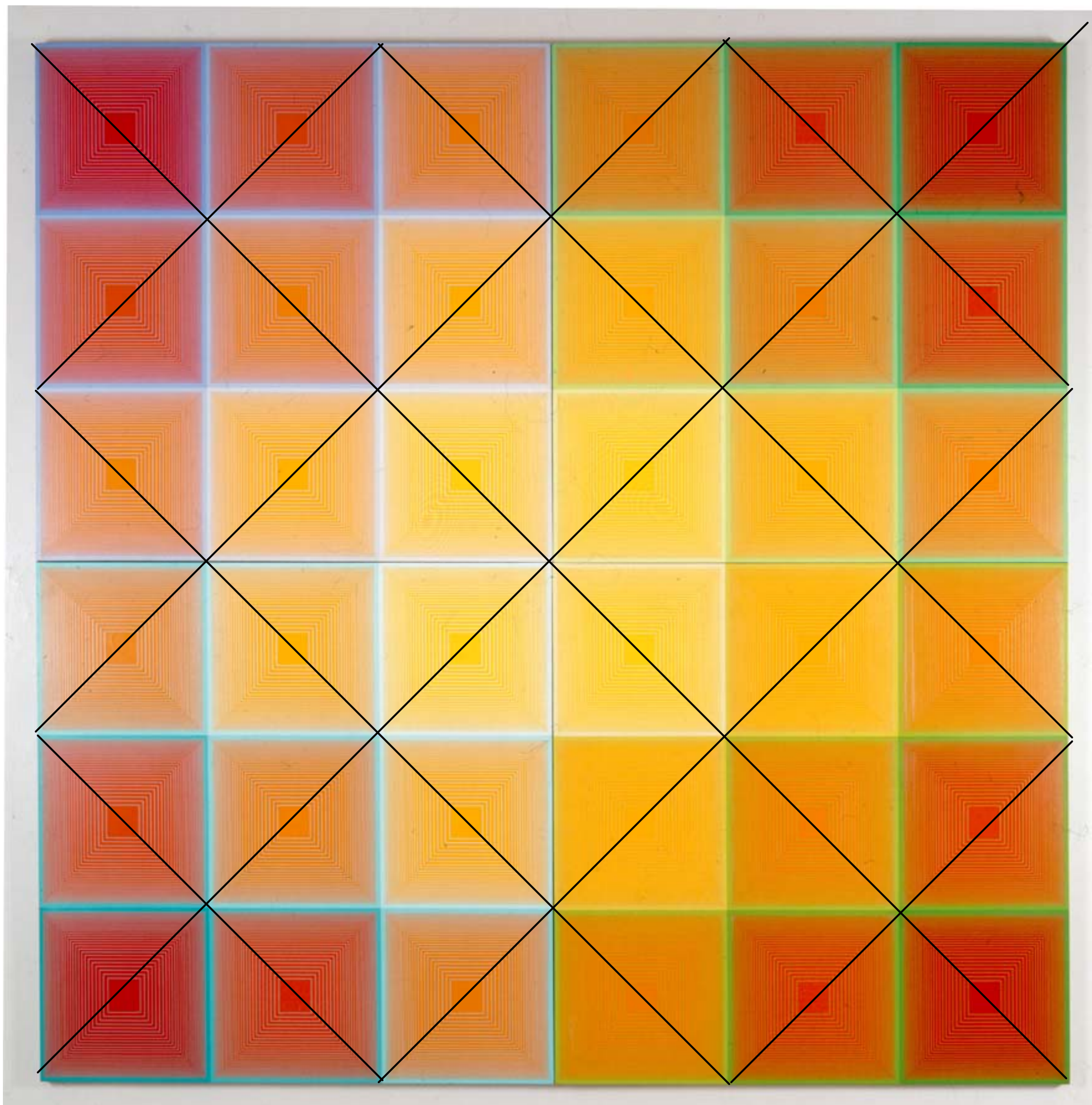
Background Information:

Richard Anuszkiewicz is often referred to as the father of Op Art. Although he rejects this title, his works do share certain characteristics with Op Art, a movement in art that explores the optical effects of color, line and shape. His paintings stimulate visual perception through repeated geometric shapes, interactive complementary colors, and mathematical structuring principles.

Grand Spectra's composition is based on repeated squares. Each square unit contains numerous outlines of squares in decreasing size and also forms part of the larger square; in turn, this larger square constitutes only one of four square panels that make up the entire painting. Color also encourages the eye to move in various directions. Brilliant reds framed by blue and green mark each corner, attracting attention to the perimeter of the work. At the same time, vision is directed toward a central point at which the numerous shades of yellow become uniform.

In 1963 Anuszkiewicz started using architectural charting tapes to fabricate his paintings. After applying three coats of gesso (a primer), sanding between coats, and adding fine coats of a single color to the canvas surface, he uses these tapes to create a design over which a second color is painted. When dry, the tapes are removed, revealing the first pattern. This process is repeated as often as necessary to produce the final design.

Unit 2: Activity Sheet 2A: Looking Activity



Unit 2: Activity B: The Anatomy of a Square

Procedure:

Pass out to each student Activity Sheet B. Have each student cut out the square. Ask them to think of different ways to describe a square. Record the students' descriptions on a blackboard or large sheet of paper for later reference.

After you have recorded all the descriptions that they can think of, ask your students the following questions:

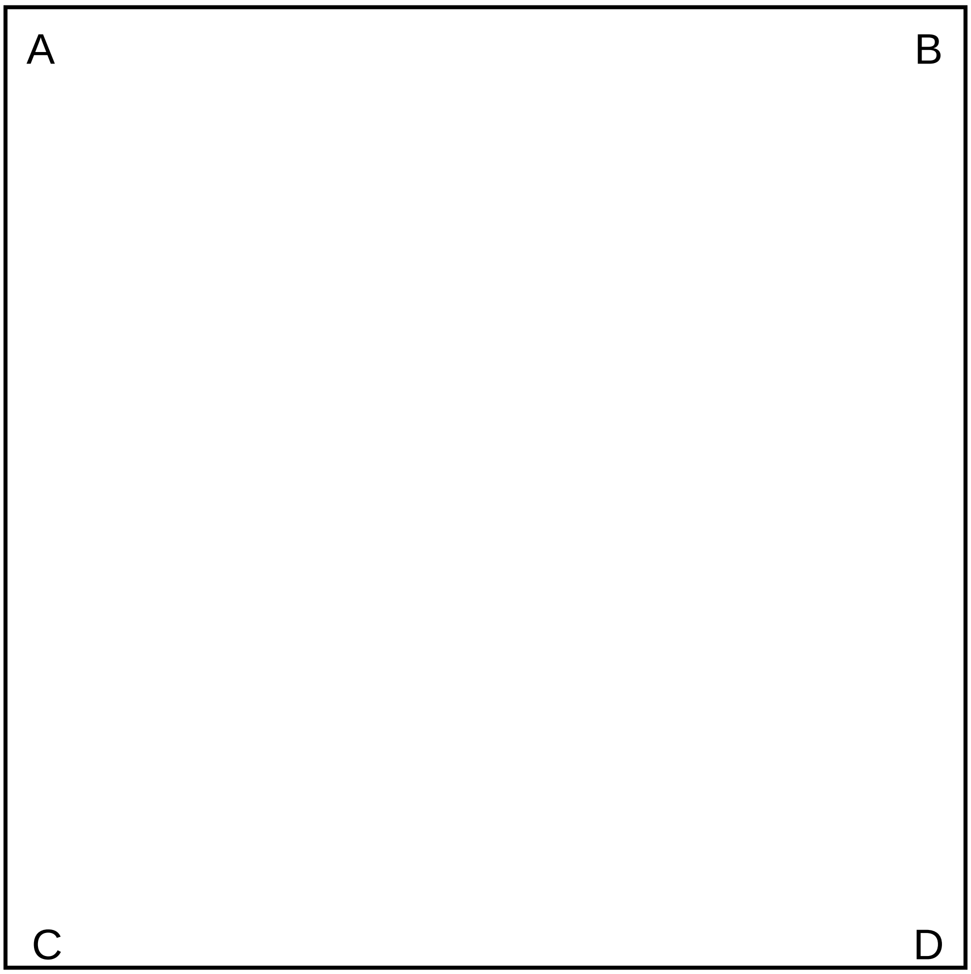
- How can you find the center point of the square?
  (Have students fold the square so that B and D meet. Then open the square back up.)
- What does the fold line do to the square?
  (Cuts it in half or **bisects** it. **Bi** means two. Or, makes it into two triangles.)
- Find the diagonal on your square. How can you make another diagonal?
  (Fold the square so that A and C meet.)
- Open up the square. How many triangles are there now?
  (8 triangles: four small, four large)
- Are the triangles the same shape?
  (Introduce the term **congruent**.)
  The four small triangles are congruent.
  The four large triangles are congruent.
  A small triangle to a large one is **similar**.
- Are angles A, B, C, and D the same?
- Are the angles formed by the two diagonals the same?

Extension:

Copy two or three additional Activity Sheets B so that students can carefully cut one apart to get the small triangles and cut another apart to get the large triangles. Then they can compare directly to check for congruence. They can also compare directly to "see" similarity—a) Corresponding angles have the same measure; b) all the legs of the triangle have changed length in the same way (which for similarity has to be by multiplication of division factor).

This activity can be used in conjunction with Activity A. Is every square similar to every other square? (Yes. This idea is important in later grades, as it is an attribute of regular polygons. Every equilateral triangle is similar to every other equilateral triangle. Every regular pentagon is similar to every other regular pentagon. This is not true of non-regular polygons; not every rectangle is similar to every other rectangle.

Unit 2: Activity Sheet B: Anatomy of a Square



Unit 2: Activity C: Learning About Coordinates

Note: Students should be somewhat familiar with the idea of ordered pairs. This activity can be used as part of an introduction to graphing on the coordinate plane.

Procedure:

Continue to show the slide of *Grand Spectra* while students are working on this activity. Begin by reiterating some of the students' earlier observations.

As you and your students have already observed, Grand Spectra is organized into a series of squares. The pattern of repeating squares creates a grid. (See Activity Sheet 1C) A grid is made of parallel horizontal and vertical lines. The point where a horizontal and vertical line intersects is called a coordinate.

Pass each student a copy of Activity Sheet 1C with a grid superimposed on top of *Grand Spectra*. The bottom horizontal line of the grid is labeled as "X" axis. The left vertical line of the grid is labeled as "Y" axis. The X and Y-axes are numbered from 0, the vertex where the lines begin on the bottom left corner, forming a right (90º) angle and extending into space. On this sheet both axes are numbered to six. But, just imagine the two axes extending off the paper and into space. The numbers can be infinite!

On a grid, coordinates are found by using the numbers on the X and Y-axes. This is what a coordinate looks like: (3,3)

The first number within the parenthesis is the number along the X-axis. The second number is the number along the Y-axis. To find the (3,3) coordinate, count to three along the X-axis. From that point, count up to three along the Y-axis. Coordinates are always in order of (x,y). Dot and label the coordinate as (3,3).

➔ What is the location of that coordinate in reference to *Grand Spectra*?

➔ Now, find these coordinates.
(3,0), (2,2), (0,3), (2,4), (3,6), (4,4), (6,3), (4,2)

➔ Once students find all the coordinates, connect the dots. What did they make?

Next, pass to each student a copy of Activity Sheet 2C. Instruct students to find the coordinates for points a-i. Write the coordinate next to the corresponding letter.

Extension:

Activity Sheet 3C allows the lesson to be extended to include the negative coordinates.

Negative coordinates are (-x, -y), (-x, y), (x, -y)

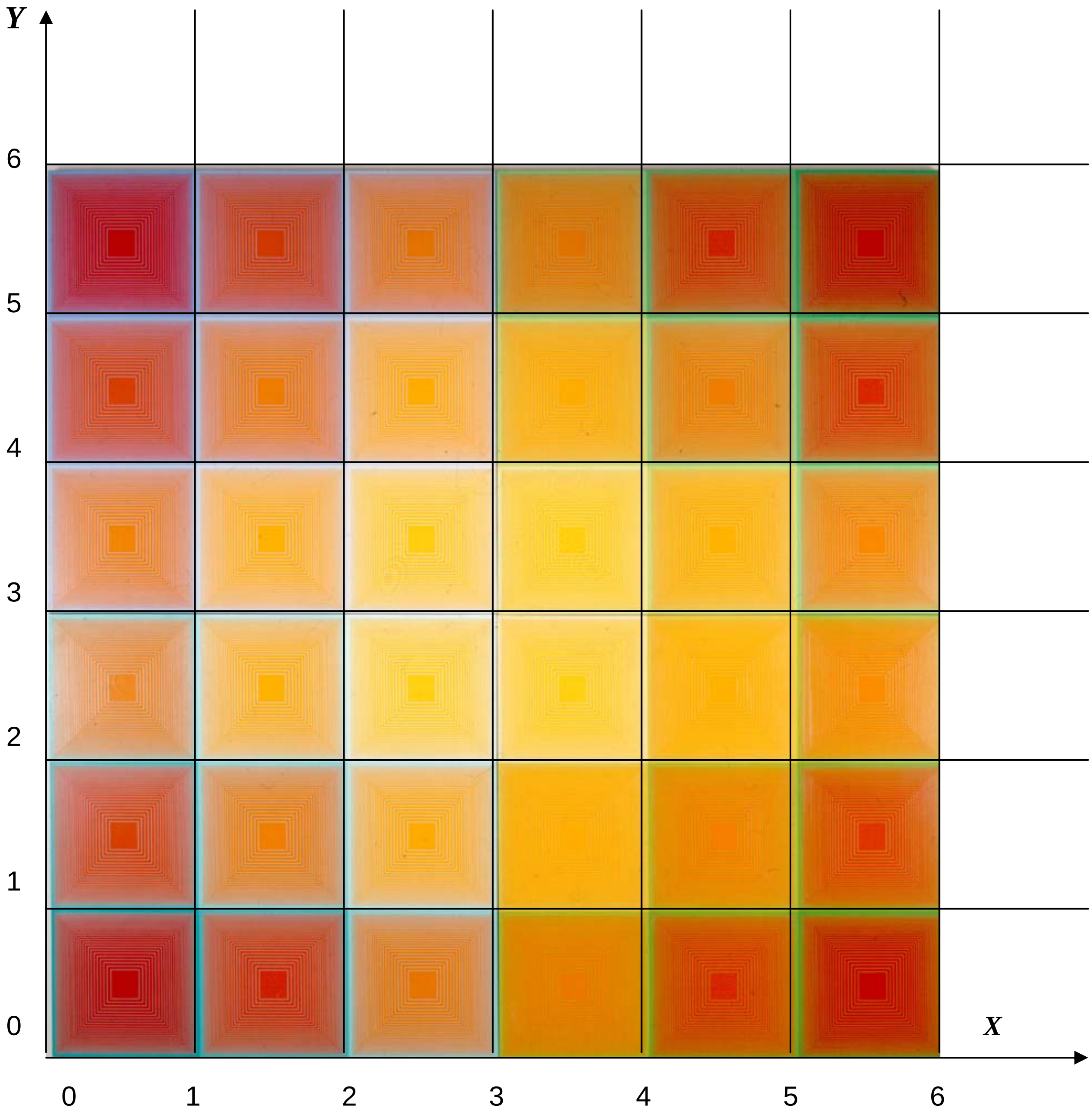
With Grand Spectra aligned within the positive and negative axes, instruct students to find the following coordinates.

(0,3), (1,1), (3,0), (1,-1), (0,-3), (-1,-1), (-3,0), (-1,1)

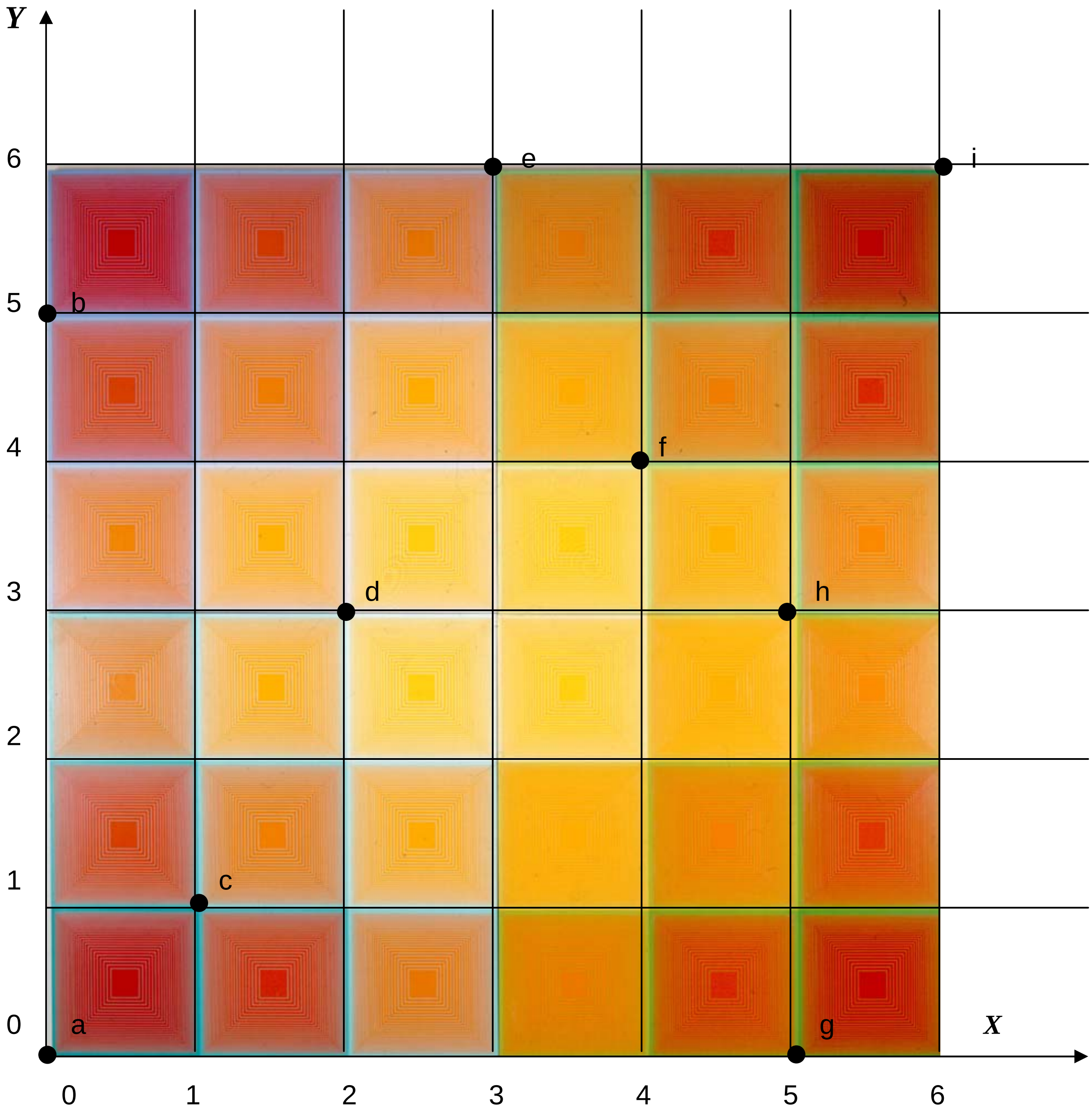
Connect the dots. What did they make?

Pass each student a copy of Activity Sheet 4C. Instruct students to find the coordinates for points a-j. Write the coordinate next to the corresponding letter.

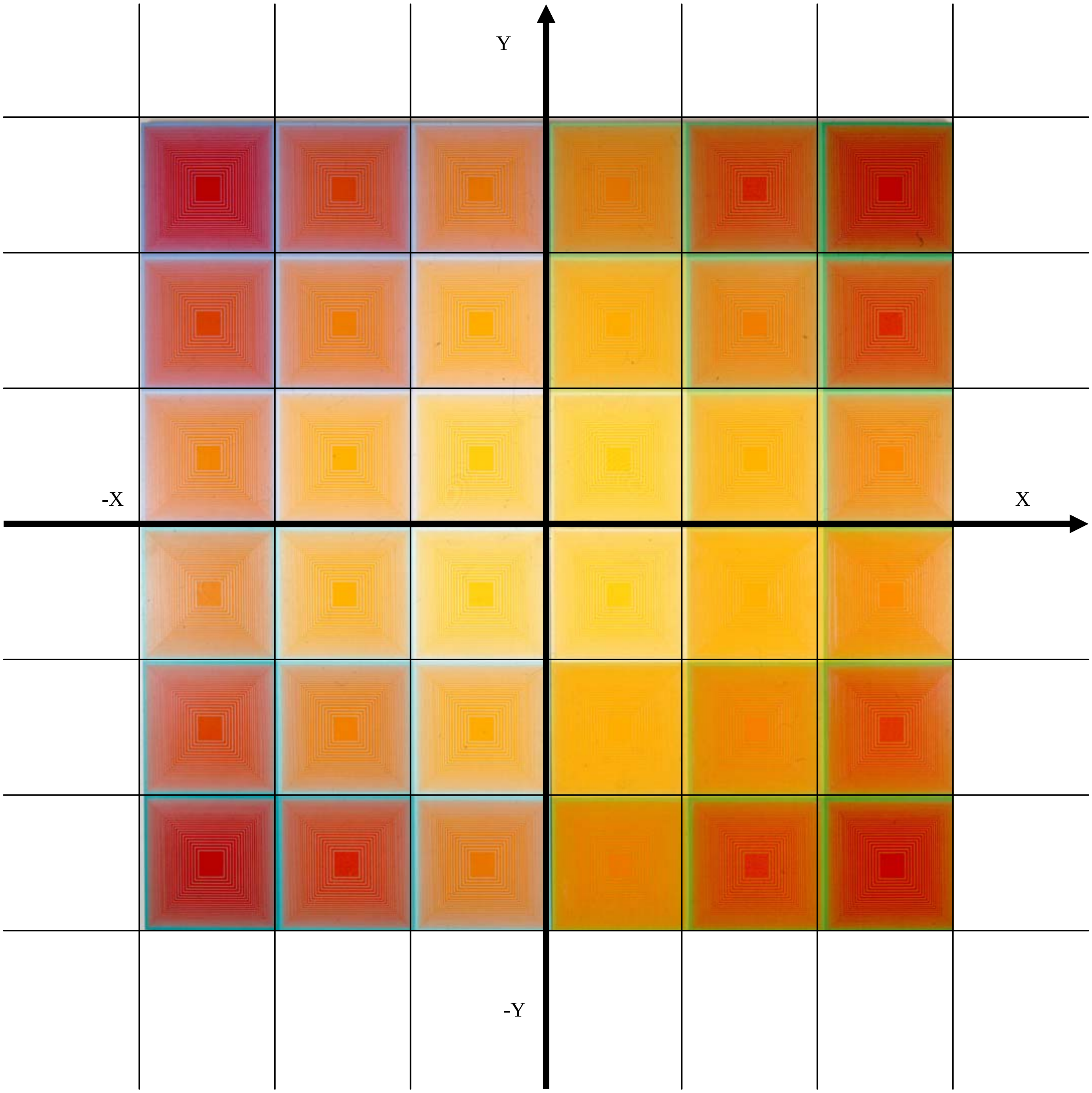
Unit 2: Activity Sheet 1C: Learning About Coordinates



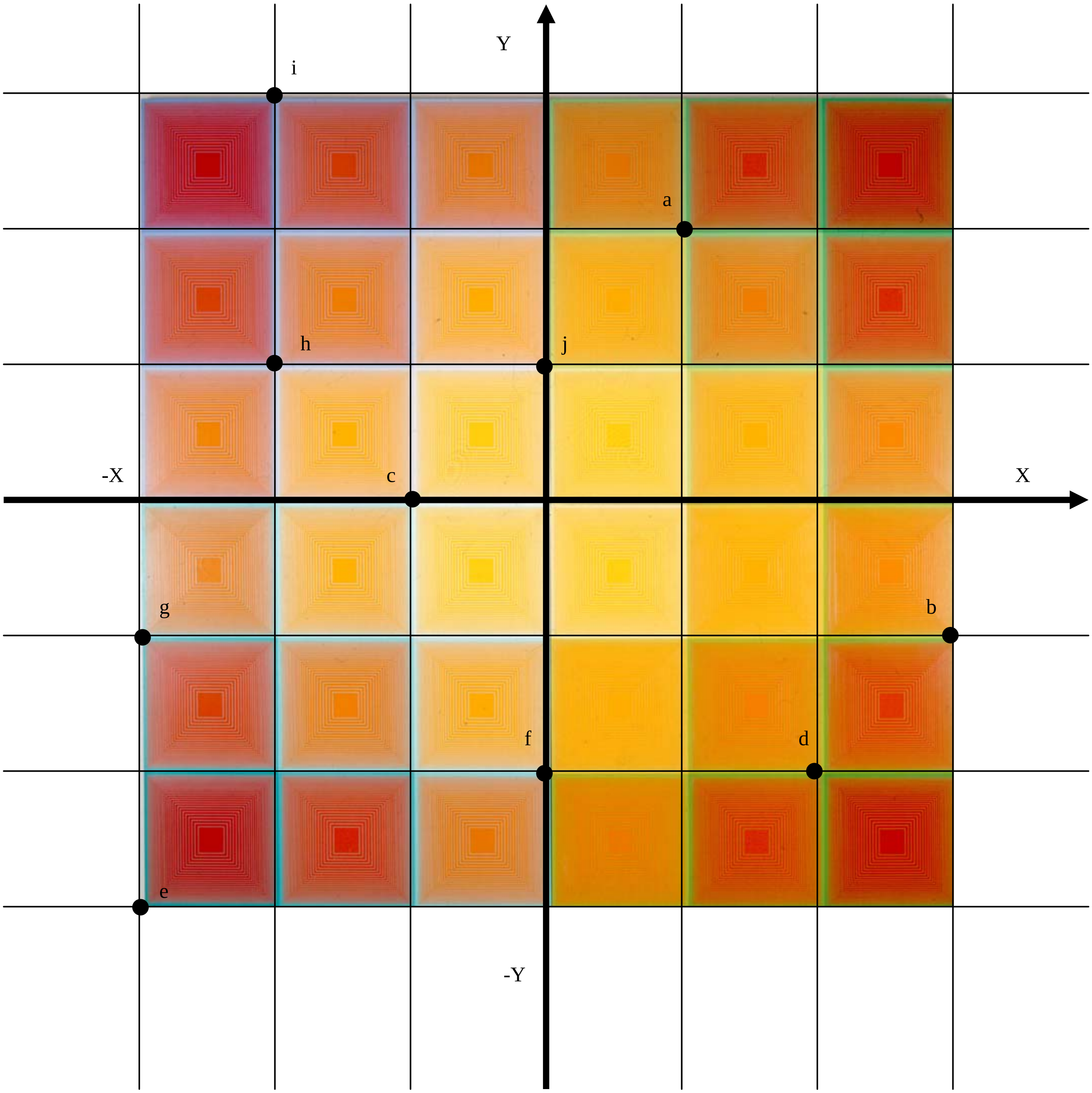
Unit 2: Activity Sheet 2C: Learning About Coordinates



Unit 2: Activity Sheet 3C: Learning About Coordinates



Unit 2: Activity Sheet 4C: Learning About Coordinates



Unit 2: Activity D: Making Your Own Coordinate Art

Procedure:

Once students have an understanding of how coordinates work, then have them make their own coordinate design.

Pass out to each student two copies of Activity Sheet D. Begin by labeling the x and y-axis, and numbering each point along the axes.

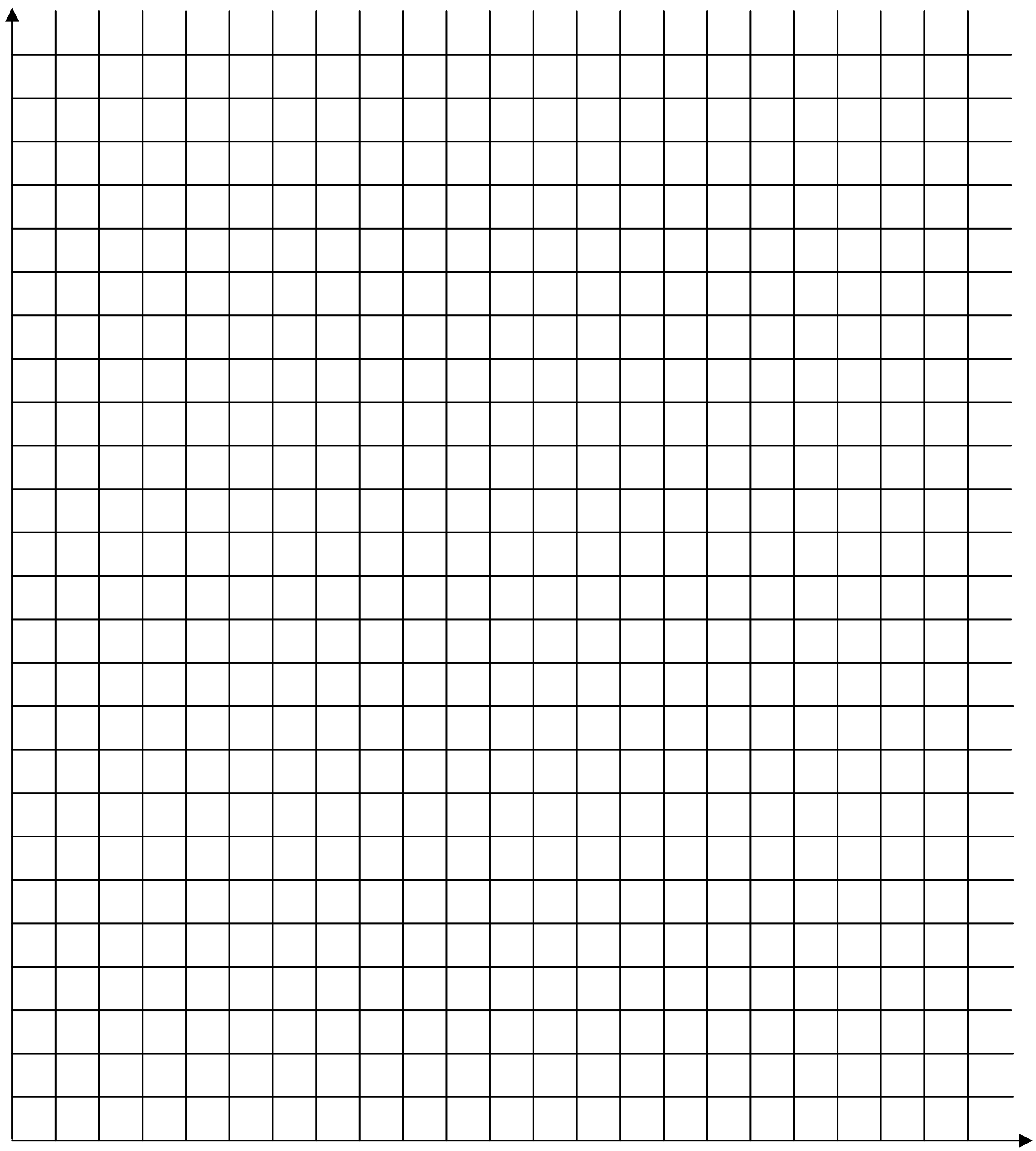
Using one of the sheets, instruct have them create a design by placing coordinates and connecting the points.

Ask students to record the coordinates of their design on a separate sheet of paper.

Once they have recorded the coordinates on a separate sheet, they can exchange it with a fellow classmate.

Without showing them the finished design, students will use the second activity sheet to try to replicate the design of the other students'.

Unit 2: Activity Sheet D: Making Your Own Coordinate Art



UNIT 3

- Math Objectives:

  Exploring the concepts of similar & congruent.
  Calculating surface area.

- Art Objectives:

  Building visual perception skills.
  Constructing polyhedra sculpture maquette.

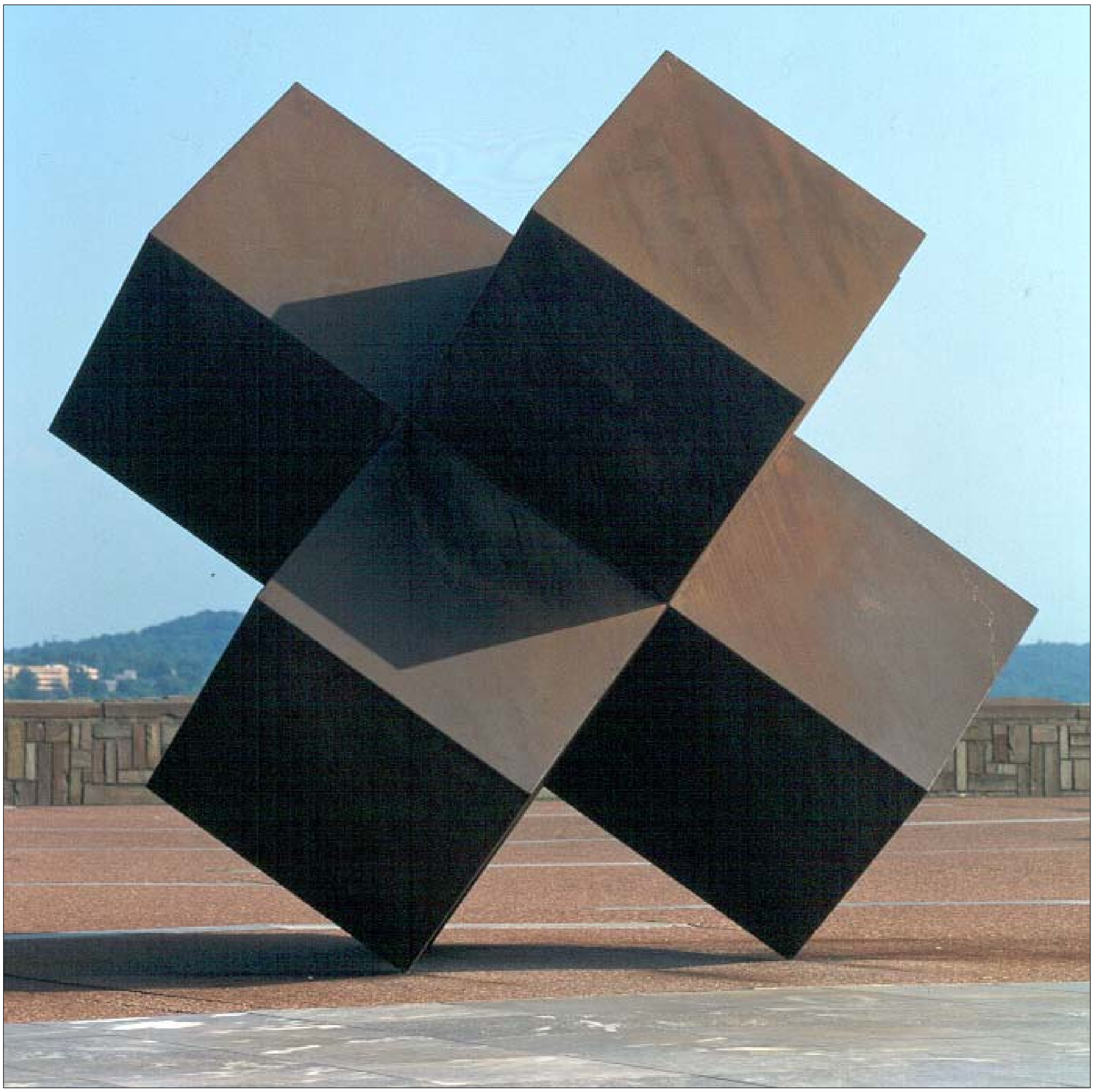
- Vocabulary:

  Face
  Edge
  Vertex
  Area
  Perimeter
  Scale
  Polygon
  Polyhedron
  Polyhedra
  Inscribe
  Cube
  Maquette

Unit 3: Activities

Unit 3: Activity A: Looking Activity

Slide 4: Salem # 7, 1967
Antoni Milkowski
Cor-ten steel
12' x 12' x 12'



Looking Questions:

- What is the basic "unit" that Antoni Milkowski has used to make this sculpture?
  (A cube.)
- What two dimensional shape is the cube made from?
  (A square, a type of polygon.)
- How many squares make one cube?
  (Six—Introduce **polyhedron**; poly "many"; hedron "faces")
- How many cubes has he used in this sculpture?
  (Seven! Six you can see from the outside, one in the center.)
- How many points or vertices are touching the ground?
  (Three!)

This sculpture is 12 feet tall! How would you feel if you were standing next to it?

Background Information:

Antoni Milkowski's early works were composed of found objects. One series of pieces was made from modules built with Con Edison flagstaffs that originally marked excavation sites in the streets and sidewalks of New York City; other works used scraps of steel collected from construction sites. From the beginning of his career, Milkowski produced large outdoor sculptures.

Milkowski often sets the hard, geometric shapes of the sculpture in places where it will contrast with a natural organic setting. *Salem # 7* is named for the location of Milkowski's studio in Salem, New York.

Unit 3: Activity B: Exploring *Salem # 7*

Procedure:
Explain that artists will often create a model or maquette of a sculpture before they create the full-size version. This helps them visualize what it will look like, but also, it helps them to calculate how they will enlarge the sculpture.

Students are going to create their own maquette of *Salem # 7* out of paper. Copy seven sheets per student of Activity Sheet B. The sheet contains the template for a cube. Direct them to cut along the template paste the cube together using the tabs. Each student should have 7 cubes. Before cutting and pasting, students are welcome to color or design the cubes as they like.
You have already learned that Milkowski used seven cubes to create Salem # 7—one in the center that cannot be seen, and six on the exterior. Using one paper cube as the core, students must paste the remaining six, one to each side core cube.
Each side of the cube is 2" x 2".

Using their maquette of *Salem # 7*, have the students answer the questions below.

- How many faces or surfaces do you see on one cube?
  (Six!)
- How can we figure out or calculate the total surface area of one cube?
  Follow the formula: (The area of one side) x 6 = total surface area
- Figure out the surface area of a cube used in your maquette if each side of the cube is 2" x 2".
  (4 square inches x 6 = 24 square inches)
- If the real sculpture is going to be made of cubes with each side 4' x 4', what is the scale of the maquette to the sculpture?
  (1" = 2')
- What will the surface area of one side of the 4' x 4' cube be? Of the entire cube?
  (One side of the cube will be 16 square feet. The entire cube will be (16 square feet x 6 = 96 square feet)
- What is the total surface area of your maquette of *Salem # 7*? Remember, you need the add the areas of only the surfaces that are exposed. It might be helpful to use a pencil to number them.
  (30 faces of the cubes are exposed. If each side of the maquette cube is 4 square inches, and a total of 30 faces are exposed, 4 x 30 = 120 square inches.)
- Figure out the amount of sheet metal you will need to create the real sculpture, using the 1"= 2' conversion. In other words, what will the total surface area of the real sculpture be?
  (16 square feet x 30 = 480 square feet)

Extension:

Using the maquette of Salem # 7, students can also calculate the volume of a single cube, the total maquette, and the real sculpture using the scale conversion. Follow this formula:

Volume = (the length of one edge)^3

So, the volume of a single maquette cube can be calculated as below:

Single Cube Volume = 2" x 2" x 2" = 8 cubic inches

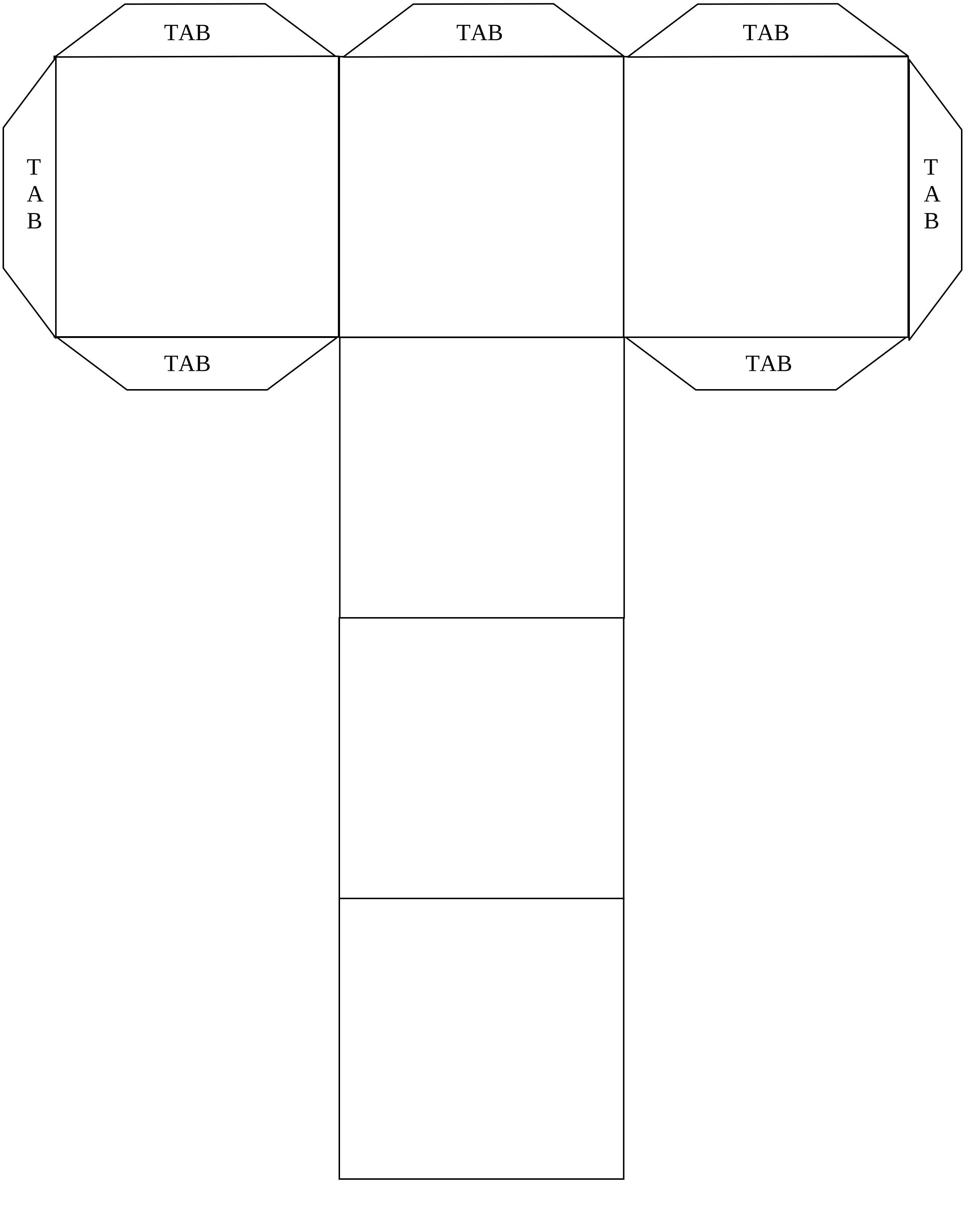
To find the volume of the total maquette, multiply the number of cubes by the volume of a single cube:

Total Maquette volume = 8 cubic inched x 7 = 56 cubic inches.

To find the volume of the real sculpture, first find the volume of a single cube:

Single Cube Volume = 4' x 4' x 4' = 64 cubic feet
Total Sculpture Volume = 64 cubic feet x 7 = 448 cubic feet

Unit 3: Activity Sheet B: Exploring *Salem # 7*



UNIT 4

Math Objectives:

Discovering the underlying grid structure of *New Morning I* by Alvin Loving.
Identifying part to whole relationships.

Art Objectives:

Understanding the concept of isometric depiction of three-dimensional space.
Creating designs based on *New Morning I*.

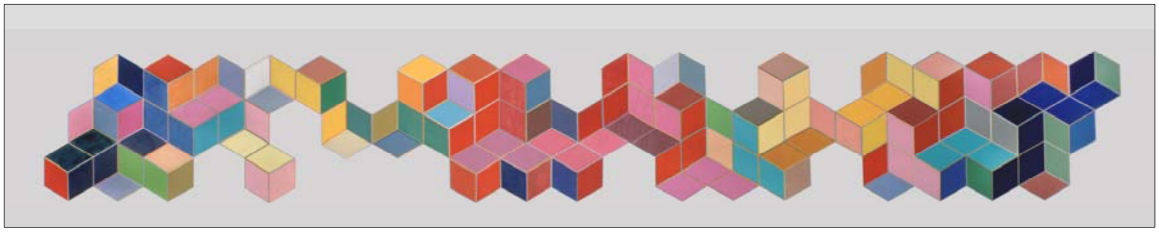
Vocabulary:

Grid
Rhombus
Parallelogram
Optical

Unit 4: Activities

Unit 4: Activity A: Looking Activity

Slide 5: Alvin D. Loving
New Morning I, 1973
Acrylic on canvas



Procedure:

Before projecting the slide, ask for one student to volunteer to be the "describer." The rest of the class must close their eyes, after which the slide can be projected. The class will try to visualize what the volunteer is describing. Encourage the volunteer to try to find as many ways to describe it as possible so that the class can from a mental picture of the painting before they have actually seen it.

After the "describer" has finished, the class can open their eyes.

Looking Questions:

➜ How is the painting different from what you visualized? What could the describer have added or changed to give you a better mental picture?

➜ What is unusual about the outside shape of this painting? What common shapes are most paintings?

(Square or rectangular, but this painting has no definite overall shape—the artist leaves off cubes, making it appear as if in limbo.)

➜ Why do you think the artist "cut out" the outer edge of the painting?

(It adds to the 3-D effect.)

➜ What is the name of the polygon that Alvin Loving uses as the basic unit of this painting?

(rhombus or parallelogram)

➜ What are the characteristics of a rhombus?

(A rhombus has four equal sides, but does not have four equal angles. The angles created by the vertices opposite of one another are equal. One set is acute, and the other is obtuse.)

Background Information:

New Morning I is composed of four sections of canvas pieced together and attached directly to the wall. This reinforcement of flatness, however, increases the tension in the work between the literal surface and the illusion that the parallelograms occupy space in front of and behind the picture plane (the actual surface of the canvas). This paradox is further strengthened by the painting's viewing positions. Standing at t distance, the viewer receives the impact of the overall structure of the painting, the color progressing from a cold tonal austerity at the two ends toward a cluster of warm tones at the center. Standing closer, the viewer perceives the directional variation of the brushstrokes used to paint each parallelogram, and the alternation of mat, shiny, and iridescent surfaces. It is only by shifting positions that the spectator experiences the full range of dynamic repetitions and inversions of this piece.

Alvin Loving's first major solo show was held at the Whitney Museum of American Art in New York in 1970, and his geometric abstractions on shaped canvases received a favorable review. Dore Ashton remarked of Loving's work: "He uses modules of hexagonal shapes which are painted in delicate tones to suggest recessive or projective illusion." (Dore Ashton, "New York Commentary," *Studio International*, April 1970.)

Unit 4: Activity B: Exploring Inside *New Morning I*

Procedure:

After viewing the slide of *New Morning I*, pass out Activity Sheets 1-5. This series of sheets are designed to show the underlying structure, or grid, on which the painting was designed.

Activity Sheet 1B shows a section, or detail, of the painting. Notice the rhombus', when grouped in three's, create the illusion of a cube. However, because this is a flat painting, we are able to see only 3 of 6 sides of an actual cube.

Activity Sheet 2B takes away the color of the cubes, and what we are left with is only an outline of the rhombus'.

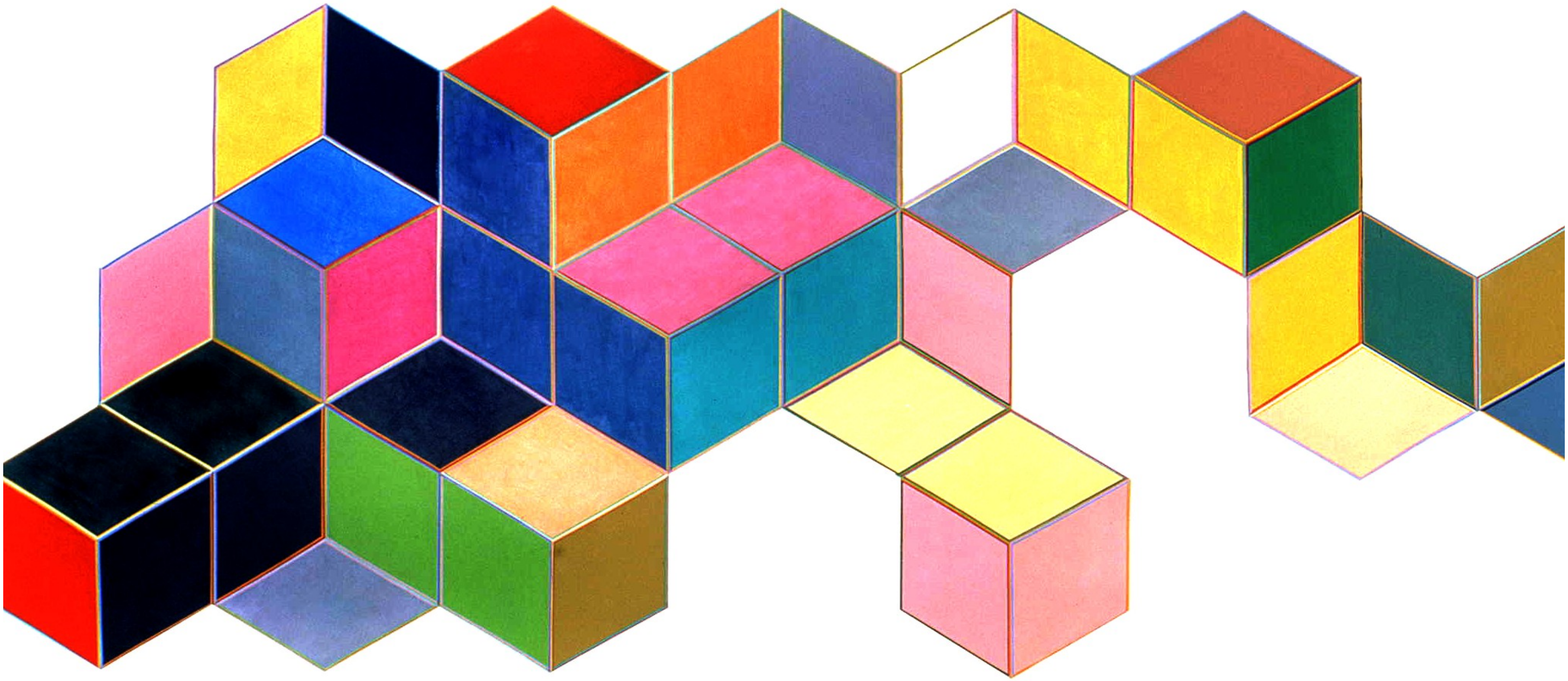
Activity Sheet 3B extends each line created by the rhombus' to the end of the page. There are three types of lines—one straight up and down, one slanting upward from left to right, and one slanting upward from right to left.

- What repeating shape does this pattern of intersecting lines create?
  (a triangle)
- Measure each side of the triangle. What kind of triangle is it?
  (an equilateral triangle)
- Find a vertex where all three of these lines intersect. How many triangles are joined at this single vertex?
  (six)
- What larger polygon do the six triangles, when joined, create?
  (A hexagon)
- Where did the rhombus' go? Are they still there? How many equilateral triangles make a rhombus?
  (The rhombus' are still there, but the extended lines have sliced them in half—it takes two equilateral triangles to create a rhombus.)
- Can you find another, larger equilateral triangle?
  (Yes, looking at the pattern more closely, ask students to find where 4 triangles combine to create a larger one.)

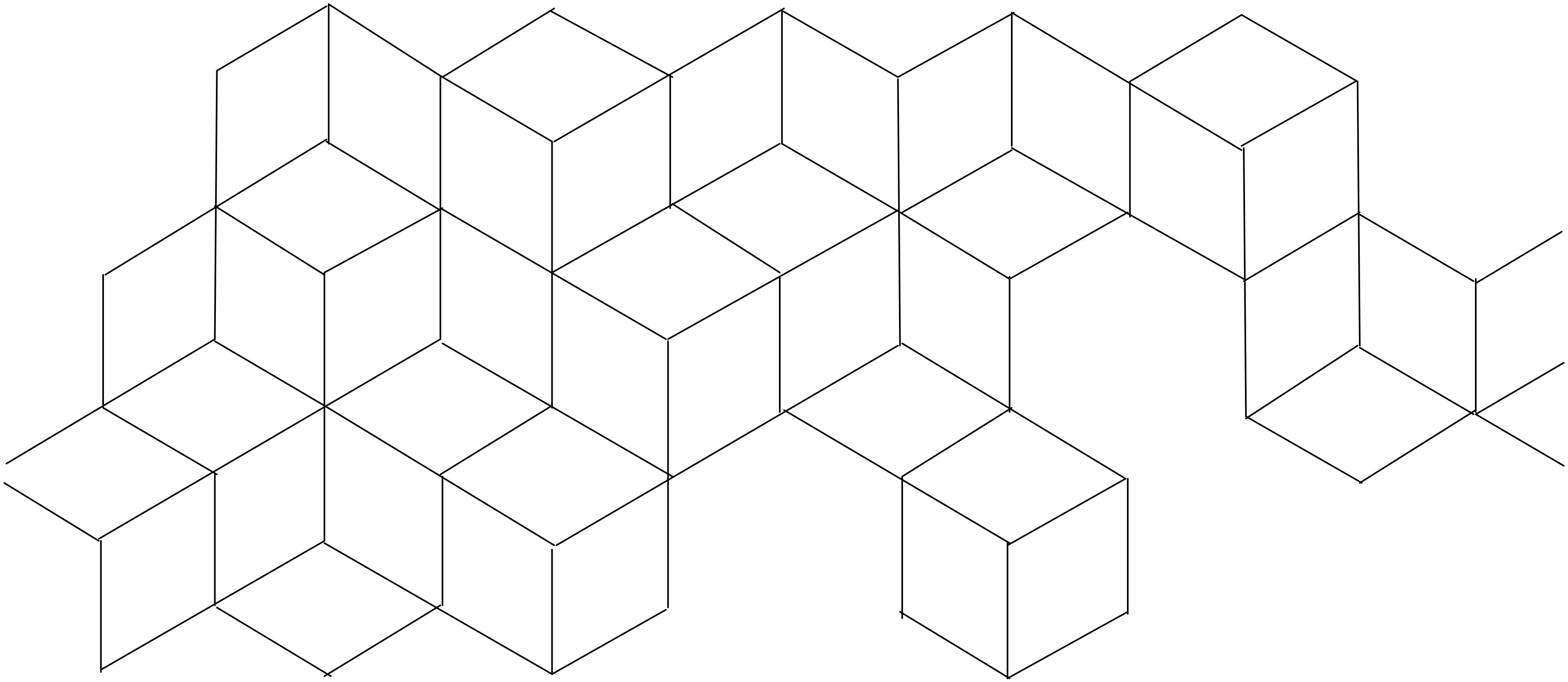
Activity Sheet 4B illustrates the points for all the vertices made in this grid-like pattern.

Activity Sheet 5B takes away the lines and leaves only the points.
Using this sheet of isometric dot paper, ask students to create a rhombus design of their own. They need to begin by making a single cube, and joining them together. This isn't as easy as it looks! If your students have difficulty, have them follow the detailed instructions below on the following page.

Unit 4: Activity Sheet 1B: Exploring Inside *New Morning I*

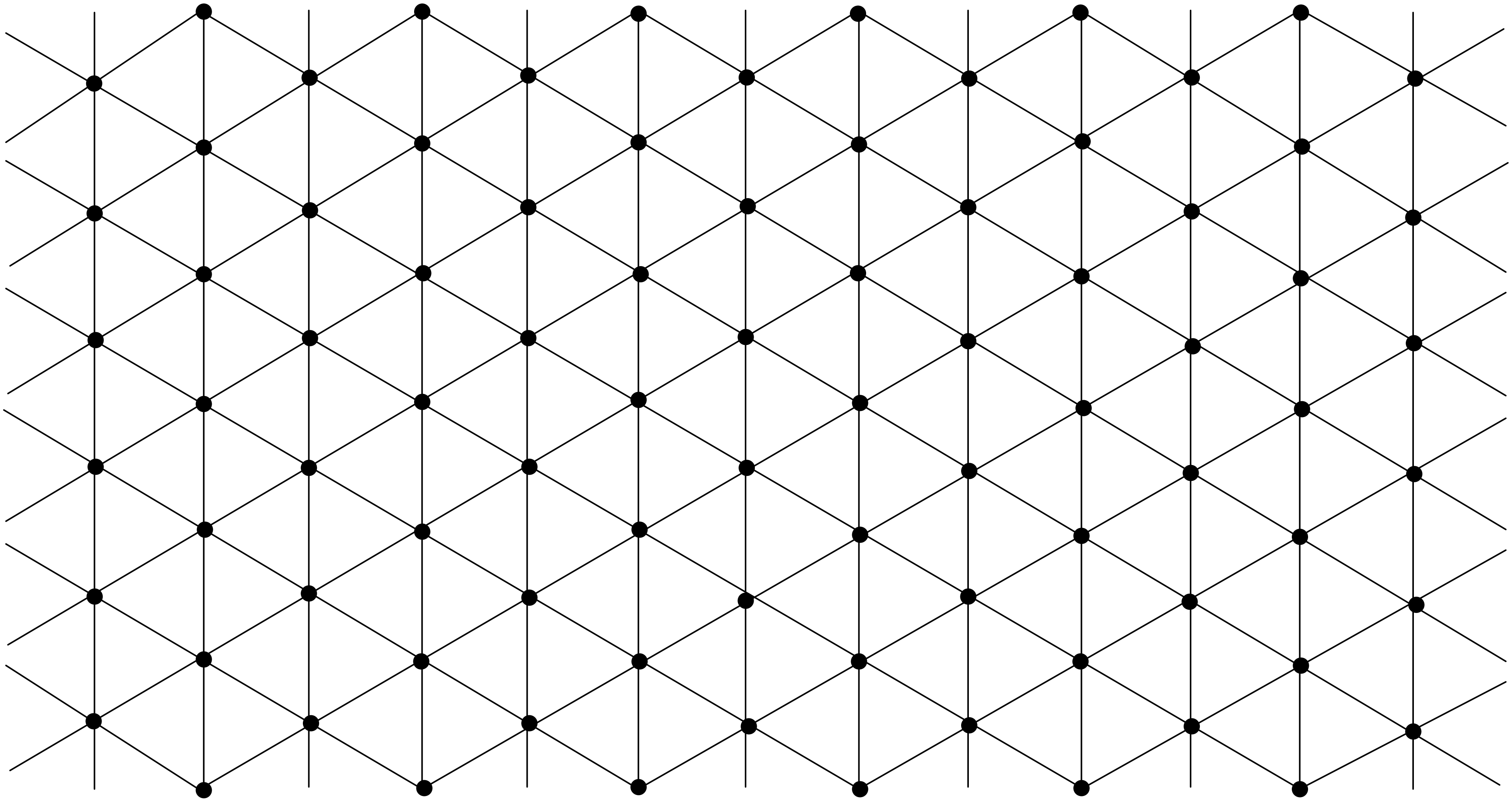


Unit 4: Activity Sheet 2B: Exploring Inside *New Morning I*

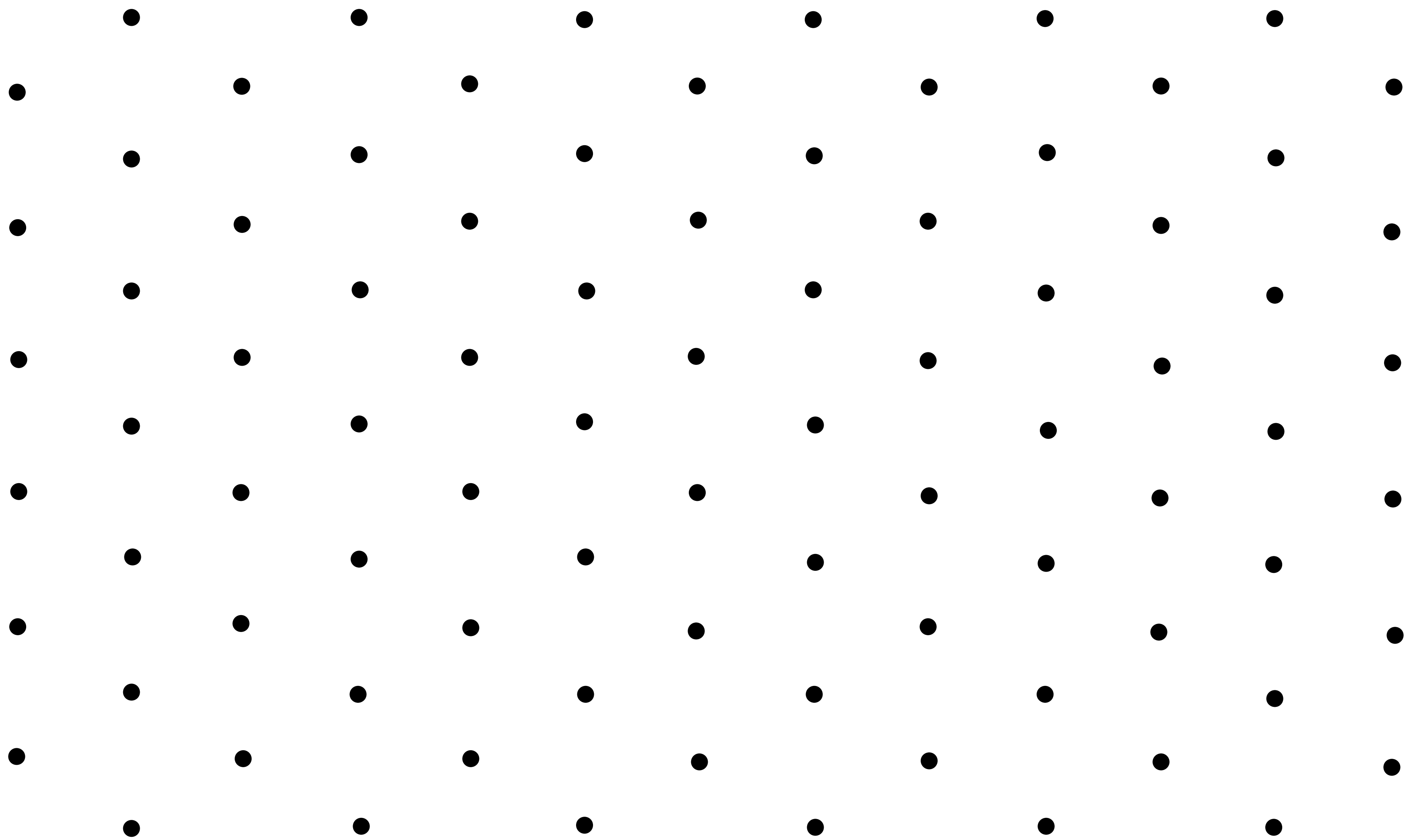


Unit 4: Activity Sheet 3B: Exploring Inside *New Morning I*

Unit 4: Activity Sheet 4B: Exploring Inside *New Morning I*



Unit 4: Activity Sheet 5B: Exploring Inside *New Morning I*



Extension:

Ask students to create one additional cube from the template in Unit Three Activity Sheet B. Explain to the students that what they are holding is an actual three-dimensional cube. What are the similarities and differences between the physical cube they are holding, and the cube that the artist was painting?

Creating a Cube Design Using Isometric Dot Paper (Activity Sheet 5B)

1. Start at any point, follow the directions. Draw lines from a single point in the following directions:

-Up right	U^r
-Up	U
-Up left	U^l
-Down left	D^l
-Down	D
-Down right	D^r

2. Building a hexagon. Start at any point, follow the directions.

U^r
U
U^l
D^l
D
D^r

Make another hexigon the exact same way.

3. Building a cube. Using one of your hexagons, find the dot in the center of the shape. Draw three lines connecting the center to the hexagon to its edge. Follow the directions.

U^r
U^l
D

Build another cube from the second other hexagon. Find the dot in its center and follow the directions.

D^l
D^r
U

What is the difference between the two cubes?
What shape makes up the each of the three sides of the cube?

4. Pick any point and follow the directions. Some of the lines may overlap. What did you build?

U^r U^r U^r U U U D^l D D^l D D^l D U^l U D^r U^l U^r D^r U^l U D^r U^l U^r D^r U^l U D^r U^l U^r D^r

If you were building this using cube blocks, how many cubes would you use?

Unit 4: Activity C: Optical Effects

Procedure:

Using the isometric dot paper, tessellation designs can also be patterned. Check out tessellation poster guide on the insert of this binder for many more interesting activities with tessellations.

Using Activity Sheet C, students must find the pinwheel design hidden in the patterns. Students must color in the "pinwheel" design to reveal the 3-D illusion. Encourage them to experiment with colors to find ones that create the strongest illusion.

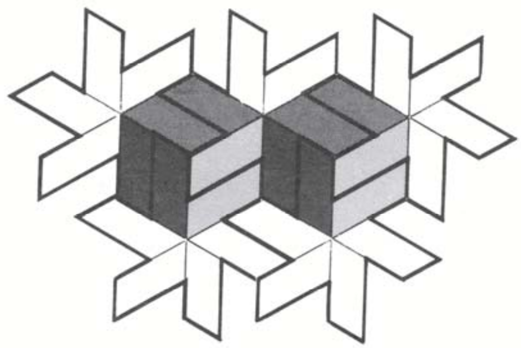
Extension:

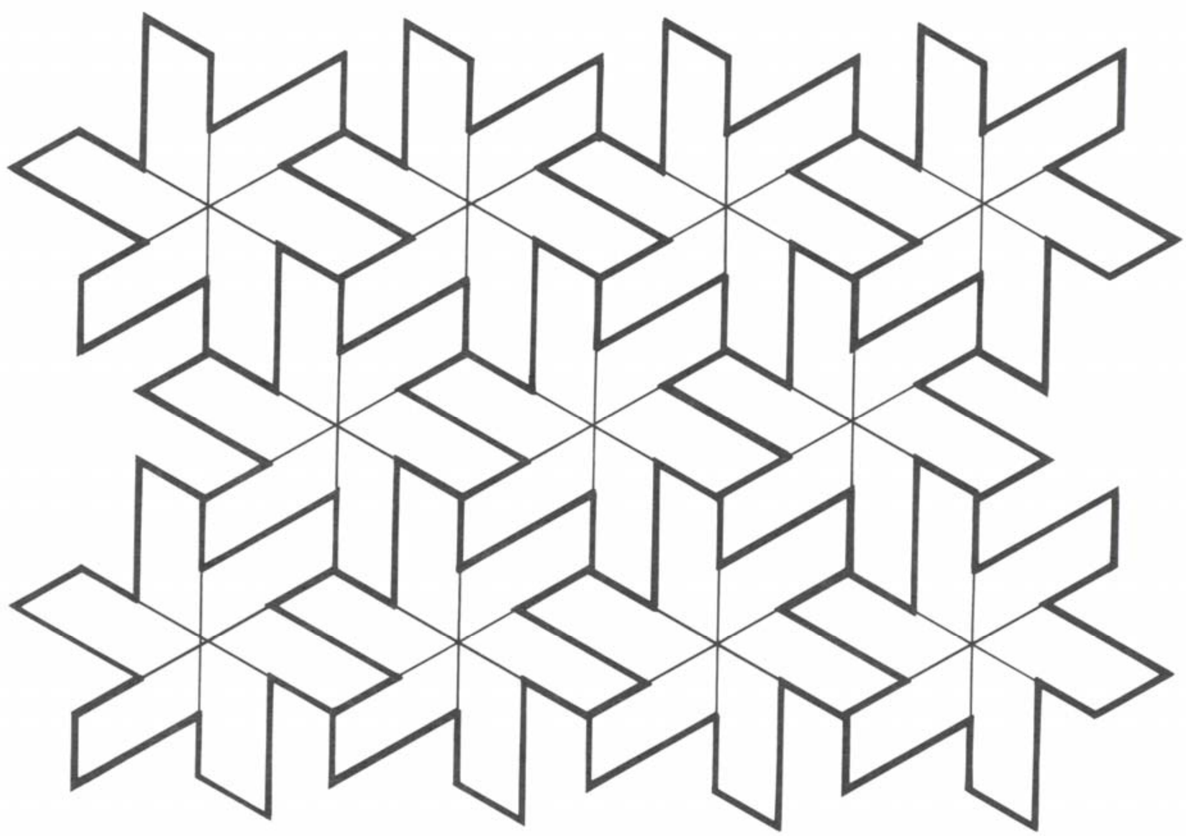
For additional activities regarding optical effects:

Spatial Visualization: Teacher's Guide & Activity Book. Addison-Wesley Publishing Company.

Unit 4: Activity C: Optical Effects

Find the hidden pinwheels using color. Follow the model below.





UNIT 5

- **Math Objectives:**
  Identifying properties of a circle.

- **Art Objectives:**
  Creating constructed designs.

- **Vocabulary:**
  Diameter
  Circumference
  Radius
  Chord
  Sphere

Unit 5: Activities

Unit 5: Activity A: Looking Activity

Slide 6: Naum Gabo
Construction in Space: Spheric Theme, 1969
Stainless and cor-ten steel

Looking Questions:

Describe everything you can about this sculpture. (Include information on shapes, color, texture, materials, etc.)

Does this sculpture have qualities that are geometric or mathematical?

Is there anything about this sculpture that suggests movement?

The title of Naum Gabo's sculpture is *Construction in Space: Spheric Theme*. How dies it look like this sculpture was "constructed?" What is a sphere? How dies this sculpture relate to a sphere?

Slide 10: *Construction in Space: Spheric Theme* (detail)

Look carefully at the pattern of lines at the center of this sculpture. Are any of these lines curved? Follow each line from one end to the other where it connects to the sculpture. (Each line is straight; it is the pattern of lines that creates the curved look.)

Background Information:

Born in Russia, Naum Gabo broke from the Russian avant-garde early in his career, moving several times before he finally settled in the United States in 1946. Gabo employed engineering techniques to produce his first three-dimensional constructions. These now famous first sculptures—were slotted or glued together, resulting in a honeycombed structure open to light and space.

Although Naum Gabo went through many evolutions in his art, much of his mature work relates directly to mathematical models and spherical forms.

Unit 5: Activity B: Anatomy of a Circle

Procedure:

Direct students to cut out the circle on Activity Sheet 1B. Ask them if they can find the center of the circle, (fold in half twice). With a marker, have them highlight one of the folds that runs through the center. Identify this line as the diameter. Highlight another fold, emphasizing that this is also a diameter and they are equal. Each diameter touches the outside edge of the circle that is called the circumference.

How many diameters are there in a circle?
(infinite)

Introduce the term radius. Radius = 1/2 the diameter, (The plural for radius is radii.)

Try these examples: If D = 16 inches, R = _____.
If D = 4 feet, R = _____.

How many radii are there in a circle? (infinite)

Can you draw a straight line that begins and ends on the circumference that is longer than a diameter? (no)

Can you draw one that is not a diameter? (Yes, it is called a chord.)

Is a diameter always a chord? (yes)

Is a chord always a diameter? (no)

Activity Sheet 2B illustrates the various components of a circle. Using that circle as a model, ask students to measure, in centimeters, the following:

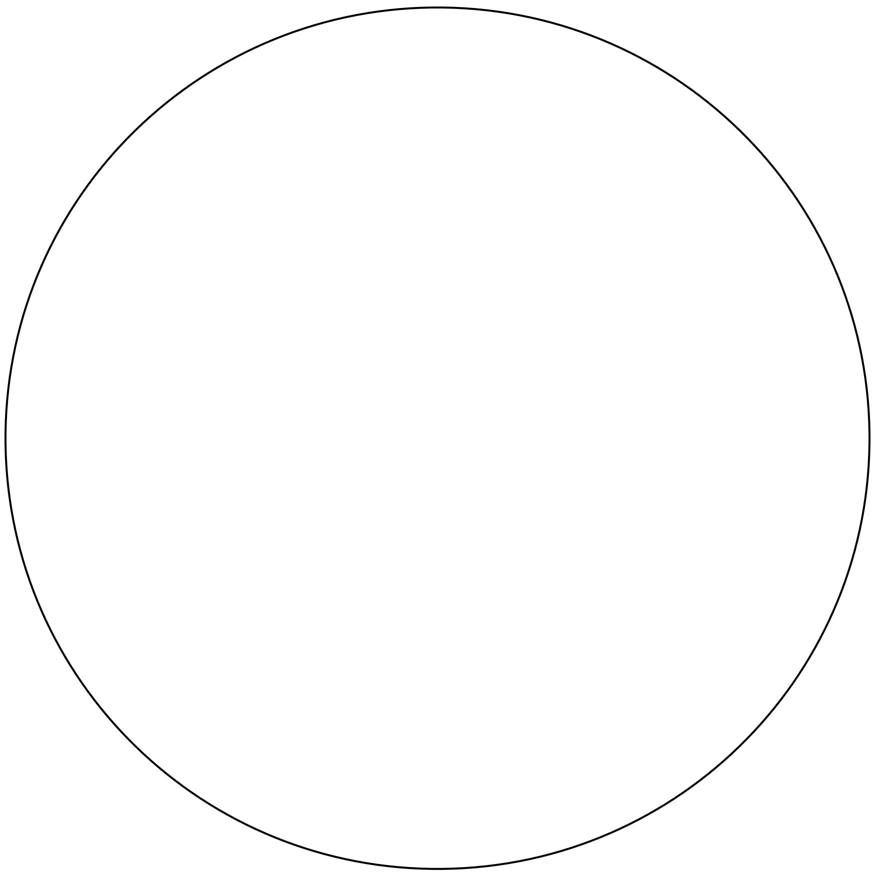
-Diameter =
-Radius =
-Chord A =
-Chord B =

Challenge:

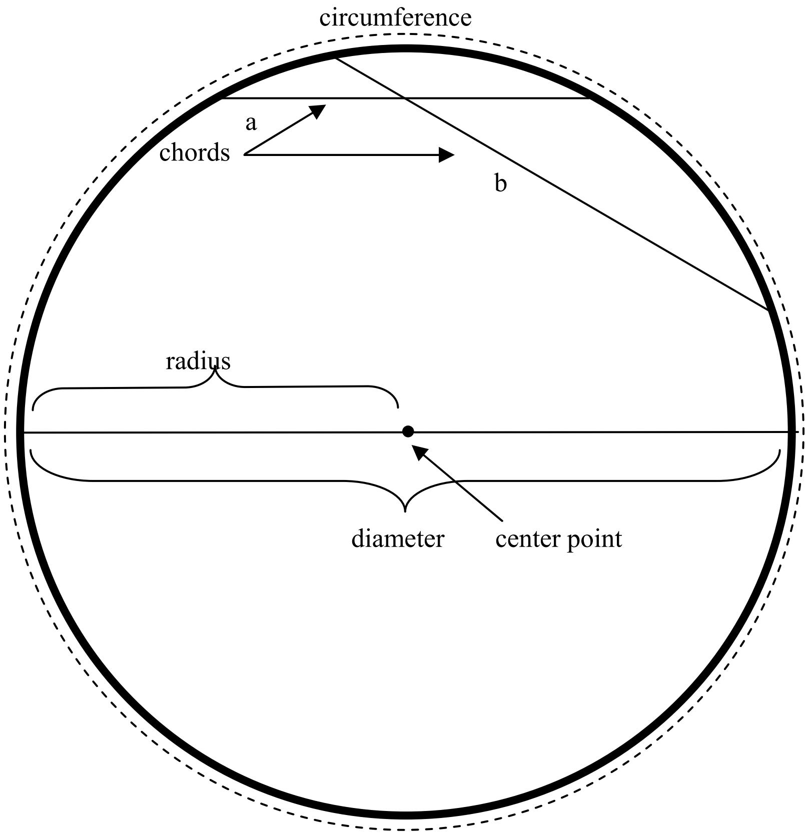
Ask students to figure out the circumference of the circle using the following formula:

$$\text{Circumference} = \pi r^2$$

Unit 5: Activity 1B: Anatomy of a Circle



Unit 5: Activity 2B: Anatomy of a Circle



Unit 5: Activity C: Line Art

Procedure:

Pass out to each student a copy of Activity Sheet 1C. Ask them to connect the points indicated at the bottom of the sheet with a straight line to create a design. After it is complete, ask them if they found another strategy for completing the design.

Extension:

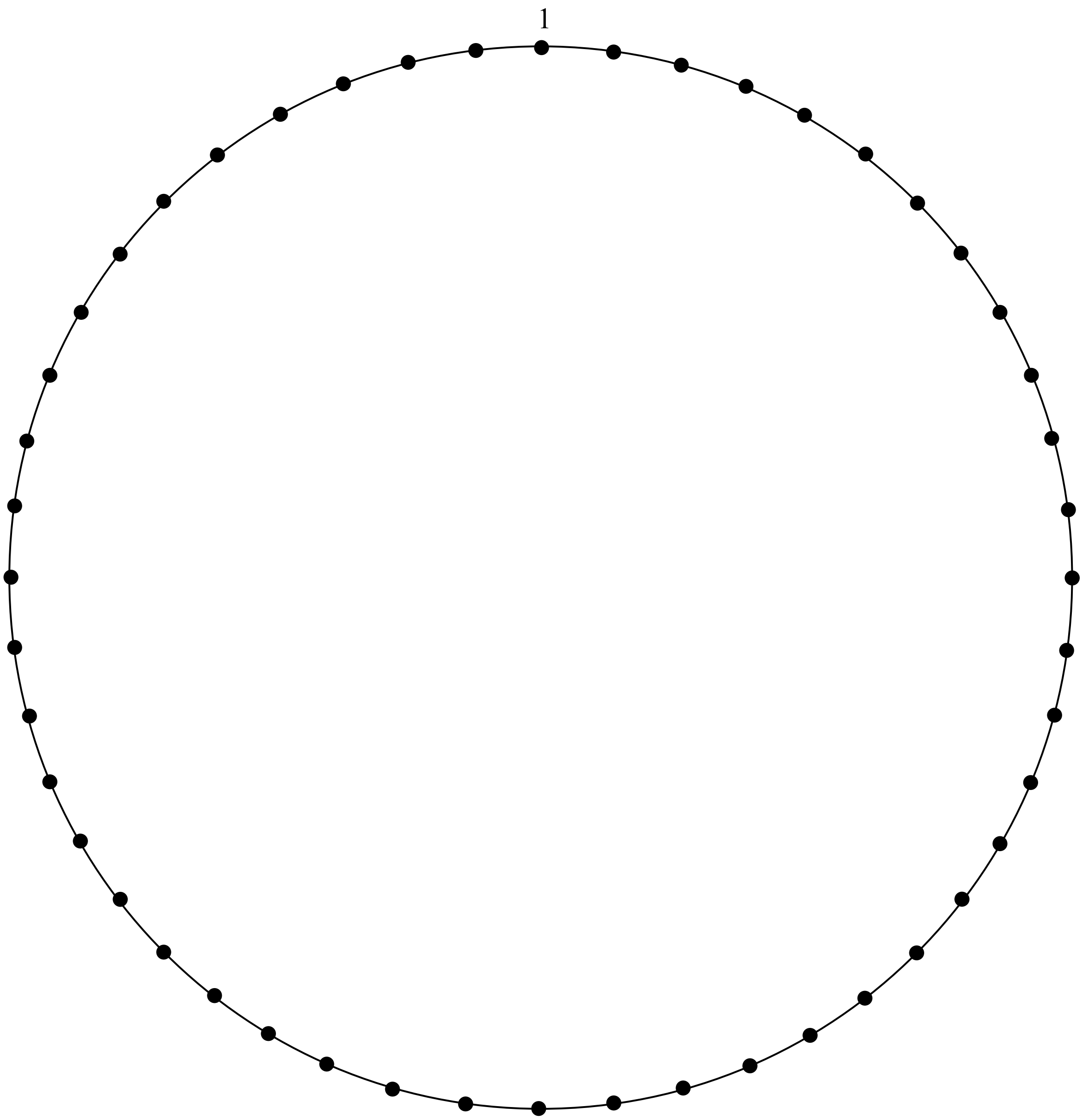
Using Activity Sheet 4C ask the students to think of a "what if…" idea for connecting points on a circle and creating a design. Before starting, have the students predict what the results of their drawing will be. Compare and contrast results with their prediction. For inspiration to the "what if" design, have students look at Activity Sheets 2C & 3C.

Additional Extension:

Have students experiment with creating curved designs with a circular geoboard and/or select activities from the *Geoboard Activity Book* by Judy Kevin, published by the Teaching Resource Center.

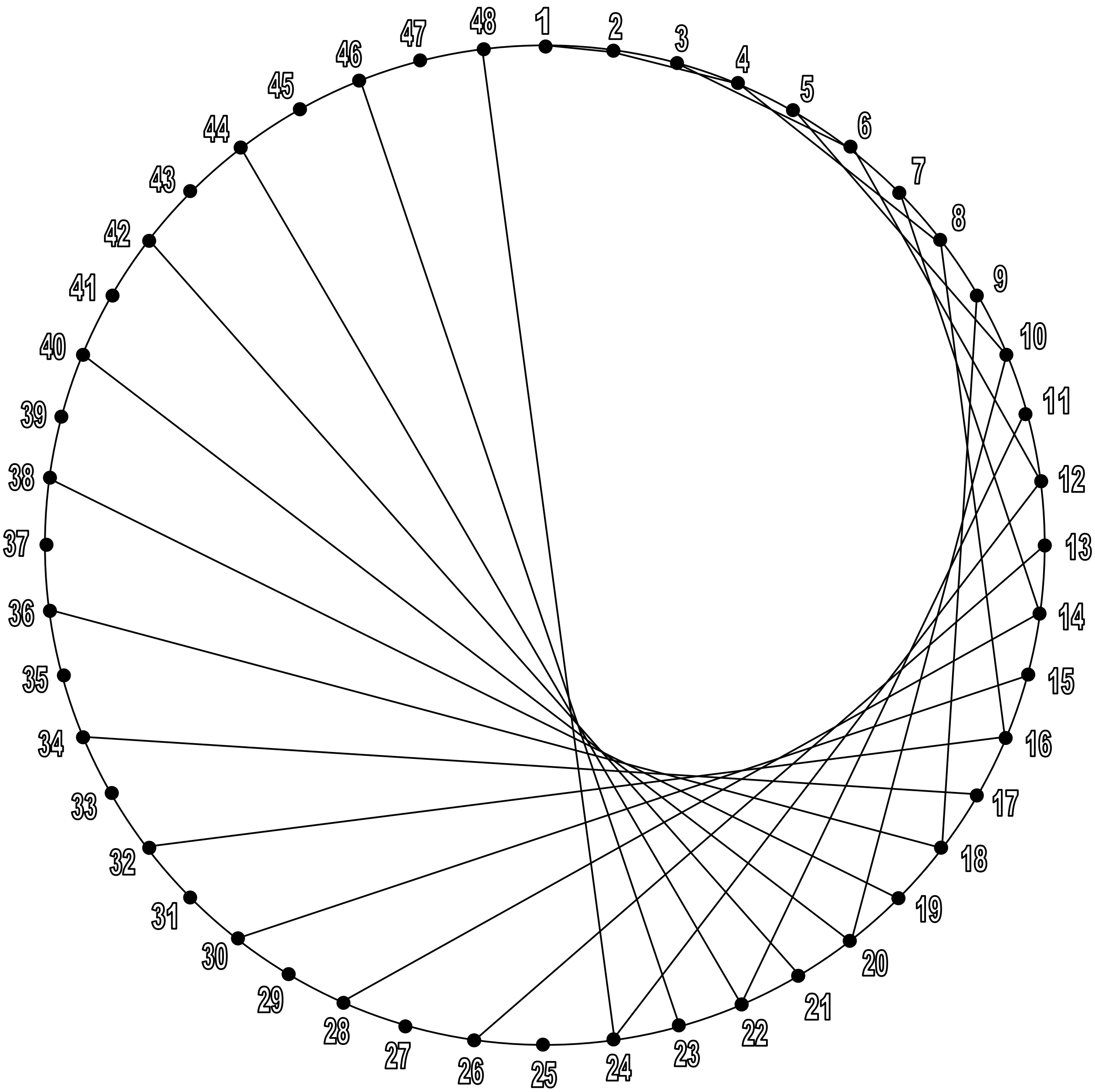
Unit 5: Activity Sheet 1C: Line Art

Number the points on the circle beginning with one.
Use a straight edge to connect the points listed below.



1-20	2-21	3-22	4-23	5-24	6-25	7-26	8-27	9-28	10-29	11-30	12-31
13-32	14-33	15-34	16-35	17-36	18-37	19-38	20-39	21-40	22-41	23-42	24-43
25-44	26-45	27-46	28-47	29-48	30-1	31-2	32-3	33-4	34-5	35-6	36-7
37-8	38-9	39-10	40-11	41-12	42-13	43-14	44-15	45-16	46-17	47-18	48-19

Unit 5: Activity Sheet 2C: Line Art: Example

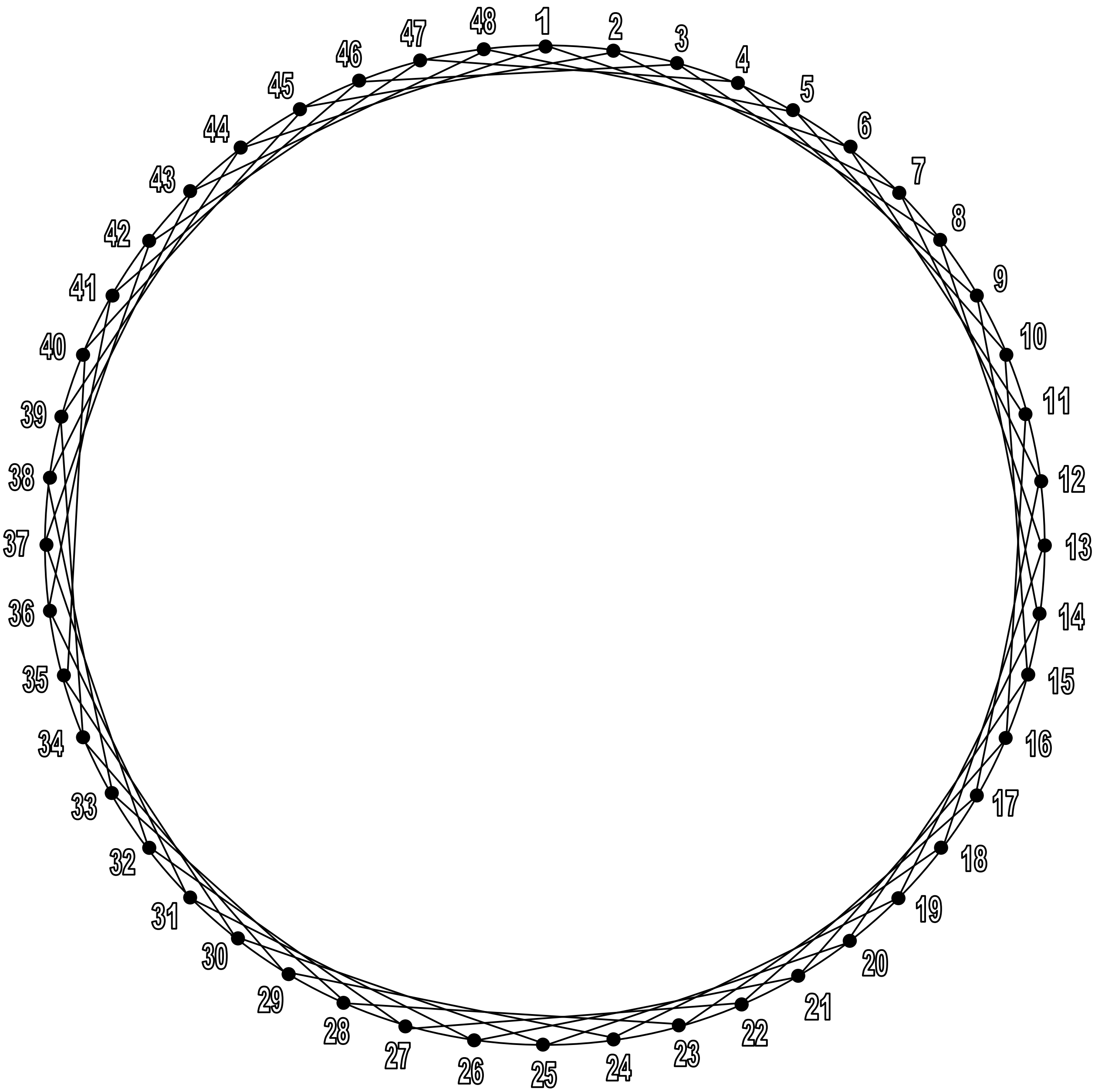


What if: I connect each number to 2 times itself?

Predict: A curve.

Result: A cornucopia curve.

Unit 5: Activity Sheet 3C: Line Art: Example



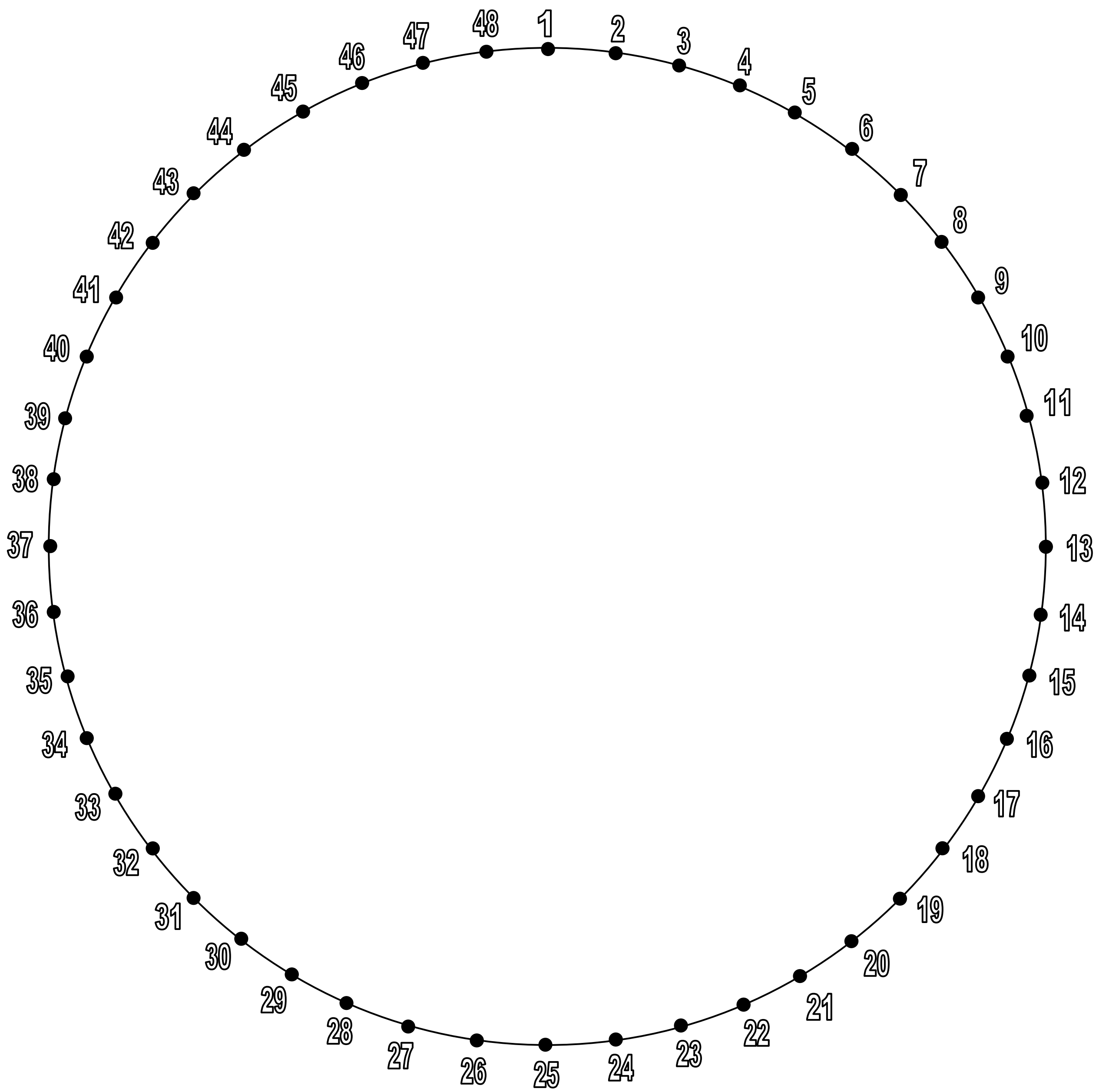
What if: I connect each number to 6 greater?

Predict: Another circle.

Result: A wide ring.

Unit 5: Activity Sheet 4C: Line Art: Challenge

Try designing your own circular design.



What if:
Predict:
Result:

Glossary

Abstract: something that is a general, often ideal, mental idea, picture, or model.

Abstraction: an abstract composition or creation in art, in which line, color, texture and shape are emphasized instead of a realistic object.

Area: a surface included within a set of lines.

Axis: a straight line about which a body or geometric figure rotates; a line of symmetry (a line that divides a figure into 2 parts that match exactly when the figure is folded along the line.)

Bisect: to divide into two equal parts.

Chord: a straight line joining two points on a curve.

Circumference: the perimeter of a circle.

Congruent: being in agreement or correspondence; having the shape and size.

Constructed Sculpture: sculpture made of glass, metal, plastic, and other industrial materials and techniques stressing space rather than solidity.

Coordinates: a set of ordered numbers used to specify the location of a point on a line or graph.

Cube: a 3-D object with six square congruent faces, (six square faces that are the same size.)

Diagonal: joining two nonadjacent vertices of a polygon of polygon or polyhedron figure.

Diameter: the length of a straight-line segment through the center of a circle.

Edge: a line that is the intersection of two planes; line where two faces of a 3-D object meet.

Face: a flat surface of a 3-D object.

Grid: a network of equally spaced horizontal and perpendicular lines, as in a graph.

Inscribe: to draw within a figure so as to touch in as many places as possible.

Maquette: a kind of three-dimensional sculptor's sketch, modeled in clay or wax as a trial run.

Optical: of or relating to vision.

Origin: the intersection of coordinate axes.

Parallelogram: a quadrilateral with opposite sides parallel and equal.

Perimeter: the boundary of a closed plane figure.

Point: a location, place, or position in space.

Polygon: a closed plane figure bounded by straight lines.

Polyhedra: plural of polyhedron.

Polyhedron: a solid formed by plane faces.

Radius: a line segment extending from the center of a circle or sphere to any point on the circle of the surface of the sphere.

Rhombus: an equilateral parallelogram or a quadrilateral with four equal sides.

Scale: a ration between two sets of dimensions.

Similar: not differing in shape but only in size or position.

Sphere: a globular body, ball.

Tetrahedron: a polyhedron of four faces.

Vertex: the point where two lines intersect.

Vertices: the plural of vertex.

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