Let's Investigate!
Plane Geometry

A journey into real-world concepts of Plane Geometry

V1.0

Learn Through Experience

About the Authors

Judy Bippert is a credentialed teacher with a master's degree. She has more than 35 years of experience teaching junior high and college level students, coordinating Gifted Education programs, and supervising student teachers. She is recently retired from being a faculty member at San Diego State University where she taught mathematics methods to pre-service teachers and coordinated Field Experience. She recently made presentations at the National Council of Teachers of Mathematics, the California Mathematics Council, the Greater San Diego Mathematics Council, the Conference for the Advancement of Mathematics Teaching (Texas), and the California Association for the Gifted annual conferences. She has co-authored 11 mathematics simulations with Interact Publications and also contributed to university texts.

Louise Vandling is a credentialed teacher and administrator with a master's degree. She has more than 35 years of experience as an elementary teacher, administrator, district math mentor, staff developer and university math instructor. She is retired from the Vista Unified School District where she was the mathematics specialist for grades 2–5 at Casita Center, a math magnet school in the district. She has co-authored eight nationally published math simulations through Interact Publications and has contributed to Mathematics journals. Currently she consults for districts in mathematics and continues to present at the National Council of Teachers of Mathematics, the California Mathematics Council, the Greater San Diego Mathematics Council, Texas and Arizona math teachers Associations, and the California Association for the Gifted and Association of San Diego Educators for the Gifted annual conferences.

10200 Jefferson Blvd • P.O. Box 802 Culver City, CA 90232
Phone: (800) 359-0961 • www.teachinteract.com
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Welcome to *Let's Investigate!*

One of the most effective learning tools for students is discovering knowledge for themselves. This unit will take you and your students on an adventure investigating plane (two-dimensional) geometric concepts. The unit supports and reinforces classroom instruction or can be used to introduce concepts of geometry before standardized testing. It provides for your students to apply their knowledge and skills to solve real-life situations.

Students will be responsible for their choice of investigations and will sign a contract along with their parent and teacher stating their goal for a grade on the project. Students develop their organizational skills as they plan how they will collect information from their investigations and keep the record of their completed work. They will design a means of sharing their new knowledge with their classmates and the teacher. The difficulty and level of success of the work will determine each student's evaluation (grade/rubric score).

Investigations are based on the hierarchy of levels of Bloom's Taxonomy. They are designed to encourage students to use higher order thinking skills and, in addition, use a variety of learning styles: written, oral, visual and tactile. Each investigation is separate from the others and does not depend on knowledge gained from other investigations in the unit.

Teaching tip
These investigations are ideal for students in homeschool.

Students from grades 3–7 will benefit from this unit. It will provide a variety of experiences with plane (two-dimensional) geometry, reinforce skills and help students needing review.

The best way to learn anything is to discover it by yourself.
—George Polya

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Purpose and Overview

What is *Let's Investigate! Plane Geometry*?

Let's Investigate! Plane Geometry is a collection of activities that enhance instruction of mathematics ideas/content. These tasks provide support for:

- ongoing teaching of geometry;
- review of previously taught material;
- chances to investigate ideas of interest;
- opportunities to make real-world connections in mathematics;
- situations where individual students can make their own choices, work with others and have fun with math while communicating their learning in written, oral or visual form.

The selection of investigations will vary according to the needs of each individual student. Each investigation sets up a situation or poses a problem where students will work with one or more mathematical ideas.

What are Students Learning?

In the current climate toward common core standards, developing an understanding of geometry skills is increasingly important. Specifically, students will be enhancing the following abilities:

Knowledge

- Developing an understanding of the characteristics of two-dimensional geometric shapes
- Evaluating previous information in making decisions
- Understanding the need to make sense of problems and to persevere in solving them
- Understanding coordinate systems
- Connecting math to real-world applications

Skills

- Developing geometric thinking and spatial sense
- Learning about how shapes change and do not change (topology)
- Understanding networks
- Using coordinate systems

- Organizing and writing about mathematical information
- Setting goals and making a contract commitment
- Using appropriate tools strategically to gather data
- Working independently or with others toward a goal
- Using higher order thinking skills
- Using technology as a tool for research and to share learning
- Communicating mathematically
- Using geometric tools (ruler, compass)

Attitudes

- Feeling at ease with analyzing shapes and making predictions
- Developing a positive attitude toward mathematics
- Developing confidence in math abilities
- Having a sense of accomplishment when the contract goals are successfully completed

How are Students Organized?

Students should be allowed to choose to work on their own or with a partner or group of three to complete their contract. Students individually or with their partner(s), make their own decisions about what investigations they want to do and thereby the grade they want to achieve.

How Much Time Do I Require?

The number of investigations and the duration of the unit will depend on the way you choose to use the unit and the needs of your students. There is a variety of ways to approach these investigations. The contract can take up to three or more weeks to complete depending on the number of investigations you decide will be required and the amount of class time used by students to complete the activities. If you decide to allow more days, it's important to build in time to meet with students weekly to assess progress on completion of the contract.

How is Learning Assessed?

Teaching tip
The midway evaluation form will help with assessing progress.

Let's Investigate! Plane Geometry contains a rubric for completion of projects assigning the point value for each category of activities based on the level of thinking (difficulty). The Observation Checklist is available to use for recording student performance during their investigations. Students are expected to reflect on their finished work with the teacher or their classmates in written, oral, or some form of visual presentation.

Why use *Let's Investigate! Plane Geometry*?

The investigations support the nationally recommended Common Core State Standards for Mathematical Practices. These are:

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
3. Construct viable arguments and critique the reasoning of others.
4. Model with mathematics.
5. Use appropriate tools strategically.
6. Attend to precision.
7. Look for and make use of structure.
8. Look for and express regularity in repeated reasoning.

Using this unit promotes your students' discovery of basic geometry concepts to support their understanding. The unit provides a way to use a wide variety of mathematical skills and apply the mathematics students have already learned. Investigations by their very nature promote higher level thinking skills. As students understand and gather information, then transform it by analyzing, evaluating and applying, they are moving toward the life skills they will use in all future careers and for managing family responsibilities.

Differentiation

The *Let's Investigate!* Contract offers a student the opportunity to make choices and to work at their own pace individually or in pairs to solve problems. It accommodates multi-ability levels in that you can modify the contract for students who need more time or have mastered what you are currently teaching and need to go farther. You can select specific investigation choices that you think are most appropriate for students.

Let's Investigate! Plane Geometry is centered on Bloom's levels of thinking and the scoring (grade) is based on the number and levels and the quality of the final products completed by the student. The unit is also designed to incorporate a variety of learning styles including writing, oral communication, visual and tactile experiences.

Homeschool teachers will appreciate the flexibility and various challenges this unit provides.

Motivation

When using *Let's Investigate! Plane Geometry*, students are empowered by choosing their activities, making predictions, collecting data and interpreting their results. They are encouraged to experiment with various shapes, use a compass, examine coordinate systems and discover information using technology. When they share the strategies they have developed when completing activities, it clarifies their thinking, increases the chance that that strategy will be used to solve future problems and helps instill confidence in the students, in their ability to be successful mathematicians.

Flexibility

The number of assignments is based on the teacher's judgment and the amount of time allowed. The number of points can be pre-determined by you to make it optimal for the class level. You can modify the investigation selections by using the material on the CD and selecting only the activities under each heading that you feel are appropriate for your entire class or for individual students.

This unit is composed of three increasingly challenging sections based on Bloom's levels of thinking. You may choose to have all students complete their selection(s) in the first section before going on to section two and so forth. You could also set up centers with the investigations you feel are appropriate for your class beginning with those in the first section.

Ease of use

This unit supports classroom management by offering independent work time for individuals to enrich and extend the classroom instruction in mathematics. You can designate time to work on the contracts in class allowing you to work with individuals or with small groups. Or you can assign investigations (or contracts) as long-term projects to allow students to explore a math concept in greater depth. The investigations also give you an opportunity to expose students to the content of a standard that may not be covered in depth prior to standardized testing. Since the contract work can be organized to be ongoing, you can plan for students to work on it should you need to be out of the classroom.

Students are given the list of suggested investigations and they make their own choices. Even when working in pairs or groups of three, they complete their individual contract, and then submit it to you. The time spent on the investigations can be during regular math time, when other work is finished, or done at home. Your role is primarily as a facilitator— allowing students to discover and develop an intuitive sense of geometric concepts as they work through their selected activities.

Why Study Geometry?

Every day we are exposed to geometric shapes. Learning about geometric properties gives students the ability to become more aware of their environment—to understand it better. Geometry is a fundamental subject relating to many other areas of mathematics such as algebraic thinking through developing patterns and problem solving, involving area and perimeter. As students use models, they learn more about spatial relationships, reasoning and connections.

Bloom's Levels of Thinking

Bloom's Taxonomy has long been used to identify a hierarchy of thinking skills starting from the simplest behavior to the most complex. The cognitive domain of the taxonomy used in this unit involves knowledge and development of intellectual skills. There are six categories of this domain listed in order of difficulty below.

- Knowledge (Remembering)
- Comprehension (Understanding)
- Application (Applying)
- Analysis (Analyzing)
- Synthesis (Creating)
- Evaluation (Evaluating)

Current thought regarding the Bloom's hierarchy places "application" at a higher level. For purposes of this simulation, categories are combined giving three levels of investigation difficulty, as follows:

I	Knowledge and Comprehension
II	Analysis and Synthesis
III	Application and Evaluation

The individual investigations in this unit are each connected with the levels of difficulty. This will enable you to better assist students in choosing contract projects according to their abilities. The difficulty of each investigation will also be reflected in the assessment process.

Components

The Teacher's Guide has everything you will need to run a successful investigations unit—including preparation instructions, daily directions, reproducibles and "notes and solutions" for the investigations.

Organizing for Learning

Take some time before starting the investigations to read the materials thoroughly to understand how the unit works and how best to prepare. Make sure that you have all the materials necessary for the investigations you select.

Decisions to Make

How will you decide on investigation choices?

Consider your students skills. Then examine the investigations in this Teacher's Guide and select those you think appropriate. The tasks do not need to be completed in any particular order because they do not conceptually build on each other. If you want your students to choose from the list as presented, simply make a copy for students' use. If you want to modify the list, you can use the material on the CD and select the investigations you feel are appropriate for your class or individual students. Limit the choices based on the level of your students, the amount of time allowed and the content you want them to learn. Lower grade students should have fewer choices and do a minimum of one investigation from each section. Students from higher grades should do a minimum of two from each section. It is up to you to make decisions about the appropriate investigations for each individual.

How will you group students?

Some students work better when paired with another or in groups of three while some prefer to work on their own. If students choose to work with others, each student is responsible for recording their individual contributions and signing their individual contracts. The record of how much of the work was each student's share will help you evaluate the work.

How will you organize the classroom?

This unit can be used as a whole class unit, assigned as extra credit or homework, or as individualized projects done when students have extra time in class. Students need to have items such as rulers, scissors, scratch paper, compasses, color tiles, and rulers available for the investigations. If they are to work on their own, the time in math class could be independent work time but most of the work could be done on the student's own unassigned time. The unit could also be set up as a learning center. Some of the investigations call for manipulatives such as tangrams or pattern blocks. There are black line masters included to make paper copies if you do not have the actual pieces.

Teaching tip

You may want to create a class record bulletin board to facilitate checking individuals' progress. For example, you can have individual students put their names on an ice cream cone, and color a scoop and put it on their cones as they complete an investigation. This will give you a quick visual of where your students are at any time during the unit. Or for older students, you could make a class chart showing student names, possible investigations, and completed investigations.

How will you schedule the unit?

As independent work, this unit can be scheduled at any time during the school year. The investigations also give you an opportunity to expose students to the content of a standard that commonly comes at the end of the book or that you know will not be covered in depth prior to standardized testing. The investigations will normally take from one week to three weeks depending on how much class time you allow for students to work on them or the schedule you set for out of class work.

How can students use technological resources to support their investigations?

Students can put together a PowerPoint® presentation or use a SmartBoard™ to illustrate their findings. A digital camera can be helpful in recording investigations and sharing findings with the class. Many of the investigations can be enhanced through activities found online at sites such as NCTM Illuminations, The Math Forum, and IXL.com.

Assessment

Assessment Standards

Based on your individual and state requirements, establish your own level of what meets standards for your grade level. Meeting standards depends on the ability of students to understand and articulate geometrically and the ability to communicate their understanding of the concepts. If a student has written-language difficulties, have the student orally explain her or his thinking. Students who do not meet standards on any part of the assessment should be required to redo that section. Sometimes students need more instruction and a second chance to demonstrate what they know.

Teaching tip

When completing their performance assessments, tell your students you will be focusing on "student work." This means their work is not limited to written work. It includes their demonstrated skills, oral exchanges, processes, strategies, and any other evidence that proves that they have learned the targeted content or skill and can apply what they know.

Performance Assessment

Evaluate work completed by students by using the scoring rubric provided, or devise one of your own. The rubric should be discussed and/or developed with the whole class so they all know what is expected in a finished product as well as the number of points needed for a certain grade. It will be helpful to use the bullets in the investigations to check for completion.

Rubric

Always review each level of the rubric before beginning work so students will understand how they will be graded. After the first evaluation, students generally attend to their tasks better and work to improve their rubric scores for the next evaluation.

Teaching tip

You may wish to adjust the number of minimum points each student should receive from the various investigations based on the level of your students and the time allowed for completion of the contract.

Suggested Contract Points

Lower grade students would need to complete a minimum of 3 investigations—one from each category—with a rubric score of "meets" or "exceeds" expectations. This gives a student a minimum of 18 points, which entitles him/her to a grade of C. A total of 20 points on investigations with "meets" or "exceeds" rubric score earns a B. A student earning 22 or more points on investigations with "meets" or "exceeds" rubric scores earns an A.

Scoring Rubric for Geometry Investigations

Expectations		Section I Knowledge and Comprehension	Section II Analysis and Synthesis	Section III Application and Evaluation	Goal
Exceeds expectations: Fully accomplishes the purpose of the task; demonstrates clear understanding of probability and statistics concepts; recorded work communicates thinking clearly, using some combination of written, symbolic or visual means.	Complete. Clear and well communicated	4	8	12	
Meets expectations: Substantially completes the purpose of the task; displays essential grasp of the concepts; recorded work communicates a large part of the thinking.	Complete	3	6	9	
Approaching expectations: Partially accomplishes the task with limited grasp of probability and statistics concepts; recorded work may be incomplete, misdirected, or not clearly presented; strategies may be ineffectual or not appropriate.	Mostly complete—with some understanding	2	4	6	
Falls far below expectations: Little or no progress toward accomplishing the task; approach may lead away from task completion; shows little evidence of appropriate reasoning.	Incomplete—with little understanding	1	2	3	

Preparation

Gather additional materials:

- Scissors
- Markers
- Pencils
- Rulers
- Compasses (for Investigation #5)
- Scratch paper
- Sets of Tangrams
- Square 1-inch tiles
- Pattern blocks

Teaching tip

You could put together some materials kits for students to check out for at-home investigations. These can be plastic zip bags and the contents depend on student's choices. Keep a piece of paper with a brief bag inventory so that students can keep track of materials.

We have included black line masters of the following materials if you do not have them for your students.

- Pattern blocks
- Tangrams
- 1-inch squares
- Coordinate grid paper
- Geoboard dot paper

Teaching tip

It would be helpful to find pictures of city scenes or some other pictures featuring several shapes in nature or architecture to use when you introduce the unit.

An investigation that requires a black line master is noted with a star (*) next to the number.

Identify the **Investigations** in the book (or on the CD) from which your students may choose. Make paper copies or send to them via the Internet.

Make copies of the following reproducibles prior to beginning the simulation:

- Parent Letter
- Individual contracts
- List of investigation selections
- Reflection
- Investigation Reproducibles as needed. (*)
- Observation Checklist
- Midway Report (if needed)

Teaching tip

It is helpful to copy the different levels of questions on different colored paper. This helps both students and teachers to be more aware of what level they are working on.

Daily Directions

Day One

Introducing the unit

Promote student excitement by explaining that they will be investigating an important area of mathematics, geometry. They will be able to work with partners for their investigations.

Read or tell students:

"Today we are going to start a unit where we will explore the nature of "plane" geometry. Plane Geometry is about 2-dimensional shapes, ones that are flat and have length and width but not depth.

What are the names of some of the shapes you know? (*Allow time for students to respond with shapes such as square, rectangle, triangle, and circle. If they say something like a box or cube, be sure to clarify that those are 3D [solid] shapes because they have the third dimension of depth*.)

We find all kinds of shapes all around us every day. (*Show pictures you have gathered*.) Sometimes, you know the name of the shape, but suppose you were talking to someone who didn't know. How could you define the shape so that everyone is on the same level as you?

Look at the pictures. Do you see squares? Triangles? Rectangles? How do you know if a shape is a triangle? Are they all the same?

Geometry is one of the areas of mathematics that has its own specific vocabulary. When studying geometry, we must know and understand this vocabulary. In this unit, we will learn how mathematics defines shapes and concepts such as "what exactly makes a square a square."

Here you may want to illustrate several different polygons with different number of sides and a non-polygon, one with an open side or curved side, or a closed figure with crooked sides. Elicit from students, the response that all polygons are *closed, straight-sided* figures.

"You will be allowed to choose to work alone, with a partner or in a group of three. You and your partner(s) will be responsible for completing the investigations you all choose. If you choose to work on your own, you will make your own choices. You will be expected to complete one (or more) investigation from each of 3 levels of the investigations."

Teaching tip

The vocabulary list in Investigation #1 will be helpful as you introduce this concept if your students don't have a lot of experience with geometry yet.

Teaching tip

This is a good time to get into the differences between right, scalene, equilateral, isosceles triangles and some of the types of quadrilaterals.

Teaching tip

Change the number and levels of investigations required at your discretion.

Teaching tip

You will want to brainstorm how the final products could be presented i.e., oral report, chart, poster, PowerPoint™, SmartBoard™, demonstration, written report, game or a combination of any of these or another idea coming from the students. Time is often limited for these presentations, so student(s) may be expected to present one investigation to the whole class and the rest to a small group of classmates. Every year, consider archiving selected student presentations to make a catalog of exemplars from "exceeds" to "poor" to show students what you expect.

"Once you have decided which investigations you want to do, you will sign the contract with the list of choices and have your parent sign it as well. Each of you is responsible for completing an individual contract even if you are working with others. The contract will list your choices, the completion date, the rubric for your grade and how you plan to present the finished investigation."

Discuss with students how they will manage their time. Explain whether the investigations are to be done in class, at home or both. Also tell them what materials you will provide for them to use. Many students have access to and may use investigation materials they have at home. However, for students who may have few or no materials, always prepare several classroom sets that they can take home. You may find that as a student gets involved in an investigation, s/he may wish to change the plan for presentation or the selected investigation. This is a teacher decision.

Give out the list of investigations to the students as well as the contracts. Go over the different levels, and discuss the investigations. Be sure to tell the students you will be available if they have further questions once they have gone over the list. Give students time to choose their partner(s) if they want one and to go over the list of investigations before they complete their contracts. Have the students make an extra choice in each of the three sections. When you meet with students to sign their contracts you can discuss and determine the appropriate investigations to be included in the contract.

Teaching tip

If you are doing a bulletin board such as the ice cream cones, have students color their cone and put their names on them. These can be put up on the board. If you choose to use a chart, prepare it before the unit so that you can show students how you will be tracking their progress.

Develop/review the scoring rubric on the contract so students will understand the expectations.

Very important for final assessment: When discussing their final products, tell students to be sure to state the problem (investigation) they are working on when they do their final write up as well as describing their findings. Findings should include:

- The design of their investigation
- The outcome of their investigation
- What they discovered about the area of geometry they explored

Teaching tip

It is up to you if you want to allow students to change their choices after the contract is signed. You may want to do it on a case by case basis. Some students may choose an activity that is too difficult for them.

If you are giving the students more than 2–3 weeks to complete their investigations, tell them you will expect a brief report weekly (included in reproducibles) stating where they are in completing the investigations, how many completed, etc.

Have students take home the list, the contract, and the rubric along with the parent letter (included in reproducibles) to discuss with their parents. Expect the signed contracts back the next day.

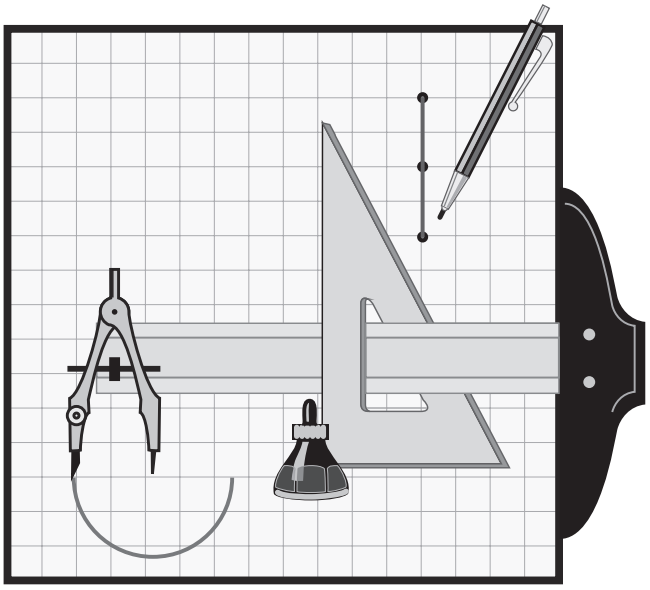
Daily Directions

After Day One

Encourage students to use their extra time in class to work on their investigations. As time permits, check with students about their progress toward completion. Check if they are having any problems or questions. Make sure to carefully monitor students who are not self-starters. Some questions you can use to get them started or monitor their progress are:

- What tools can you use to help with this investigation?
- Do you understand the vocabulary?
- What happened?
- What new information did you learn today?
- How can you write about this or present your findings?

Teaching tip
If you plan for your whole class to complete each section before moving on to the next one, you will want to have presentations at the end of each section.



Daily Directions

Last Day

Schedule a time for students to do an oral presentation of at least **one** of their investigations to the whole class and allow time for them to present their other findings in small groups.

Some questions to help students mentally process their learning and help you evaluate the products are:

- What have you discovered?
- Why do you think you got these results?
- How does this relate to previous information?
- What are the most important things you discovered?
- How might you use this information in a real life application?

You may want to have a place for students to display any posters they have made.

Have students complete the **Reflection**.

Standards

Common Core Mathematics Standards for Grade 5

5.G.1 Use a pair of perpendicular number lines, called Axes, to define a coordinate system, with the intersection of the lines (the origin) arranged to coincide with the 0 on each line and a given point in the plane located by using an ordered pair of numbers, called its coordinates. Understand that the first number indicates how far to travel from the origin in the direction of one axis, and the second number indicates how far to travel in the direction of the second axis, with the convention that the names of the two axes and the coordinates correspond (e.g., x-axis and the x-coordinate, y-axis and y coordinate).

5.G.2 Represent real world and mathematical problems by graphing points in the first quadrant of the coordinate plane, and interpret coordinate values of points in the context of the situation.

5.G.3 Understand that attributes belonging to a category of two-dimensional figures also belong to all subcategories of that category. For example, all rectangles have four right angles and squares are rectangles, so all squares have four right angles.

5.G.4 Classify two-dimensional figures in a hierarchy based on properties.

Common Core Speaking and Listening Standards for Grade 5

SL5.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher led) with diverse partners on grade 5 topics and texts, building on others' ideas and expressing their own clearly.

SL5.5 Include multimedia components (e.g. graphics, sound) and visual displays in presentations when appropriate to enhance the development of main ideas or theories.

Common Core Writing Standards for Grade 5

W5.2 Write informative/explanatory texts to examine a topic and convey ideas and information clearly.

W5.4 Produce clear and coherent writing in which the development and organization are appropriate to task, purpose and audience.

W5.6 Use technology, including the internet, to produce and publish writing as well as to interact and collaborate with others.

W5.7 Conduct short research projects that use several sources to build knowledge through investigation of different aspects of a topic.

W5.10 Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Investigation Notes and Solutions

Section I: Knowledge and Comprehension:

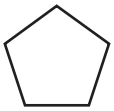
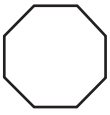
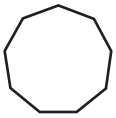
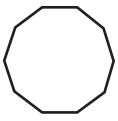
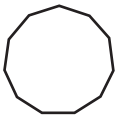
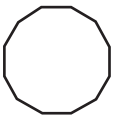
1. These give students many of the vocabulary words that are unique to geometry. Encourage students to use sources on the internet or in math books.

• Acute angle	Having fewer than 90 degrees
• Angle	Where two rays join
• Arc	A continuous part of a circle; measured by the degrees formed by the two radii at the endpoints of the arc
• Center point	The point that is equidistant from all points of a circle
• Chevron	A four-sided figure with one concave vertex whose two adjacent sides are congruent with each other, and the two opposite adjacent sides are also congruent with each other; contains only one line of symmetry
• Chord	A segment whose endpoints are on a circle
• Circumference	Distance around a circle
• Compass	Tool used to draw circles and arcs
• Concave	In a polygon, a vertex is a point inside the polygon
• Congruent	Shapes having the exact shape and size
• Convex	None of the vertices in a polygon are contained inside the polygon
• Coordinates	Numbers that correspond to a point on a line
• Degree	Angle measure
• Diagonal	Segment that connects two vertices, but is not a side of a polygon
• Diameter	Chord that passes through the center point of a circle
• Equilateral	All sides have the same length
• Hexagon	Polygon with six sides

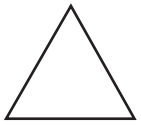
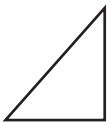
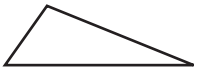
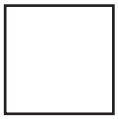
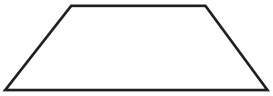
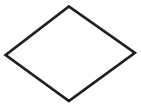
• Isosceles	Refers to a triangle or trapezoid with congruent legs
• Line segment	A line that has two endpoints
• Obtuse angle	Having between 90 and 180 degrees
• Parallel	Always the same distance apart
• Pentagon	A polygon with five sides
• Perpendicular	Intersecting lines forming right angles
• Polygon	Closed, plane figure formed by line segments meeting at their endpoints
• Protractor	A device for measuring degrees in angles
• Quadrilateral	A polygon with four sides
• Radius	A segment from the center point to a point on the circle
• Ray	A line that has one endpoint and goes on indefinitely in one direction
• Rectangle	A quadrilateral with four right angles
• Rhombus	A parallelogram with four congruent sides
• Right angle	Having exactly 90 degrees
• Scalene triangle	A triangle with no congruent sides
• Similar	Shapes having the exact shape, but a different size
• Square	A quadrilateral with four right angles and four congruent sides
• Symmetry	Correspondence of opposite parts in size, shape and position
• Tangent	In a right triangle, it's the side opposite the right angle; in a circle, it's the straight line that touches the circumference
• Trapezoid	A quadrilateral with only one pair of parallel lines
• Triangle	A polygon with 3 sides
• Vertex	Common endpoint of two rays that form an angle

2. Polygons: A polygon is a closed figure with three or more straight sides.

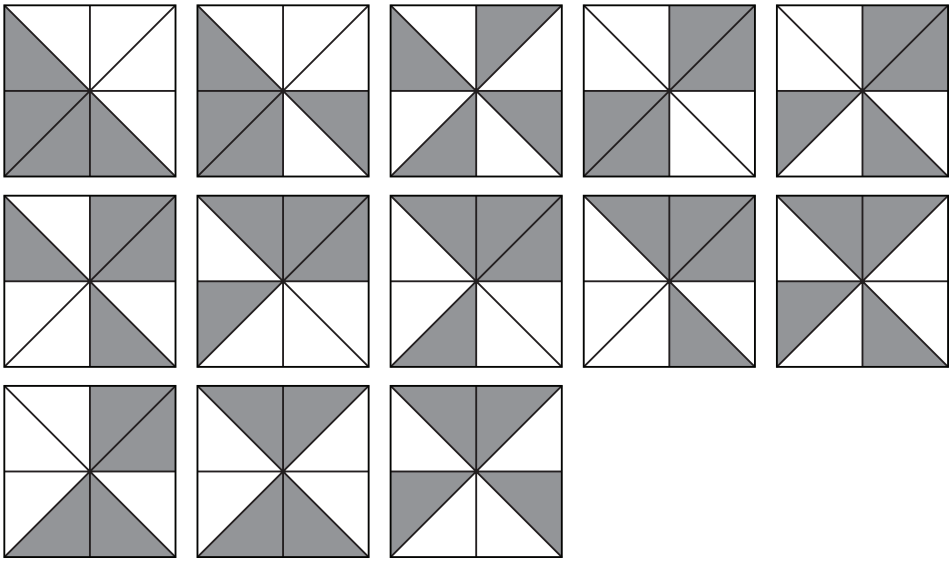
   - A regular polygon has congruent sides and no concave angles. Examples would be an equilateral triangle and a square. The more sides added to a regular polygon, the more it becomes like a circle.
   - An irregular polygon may have sides with different lengths and concave angles.

Name of Polygon	Number of Sides	Sample Illustration
Triangle or Trigon	3	
Quadrilateral or Tetragon	4	
Pentagon	5	
Hexagon	6	
Heptagon	7	
Octagon	8	
Nonagon or Enneagon	9	
Decagon	10	
Hendecagon	11	
Dodecagon	12	

3. Defining Quadrilaterals and Triangles: The sum of the angles of a triangle is always 180°. Sum of the angles of a quadrilateral is 360°.

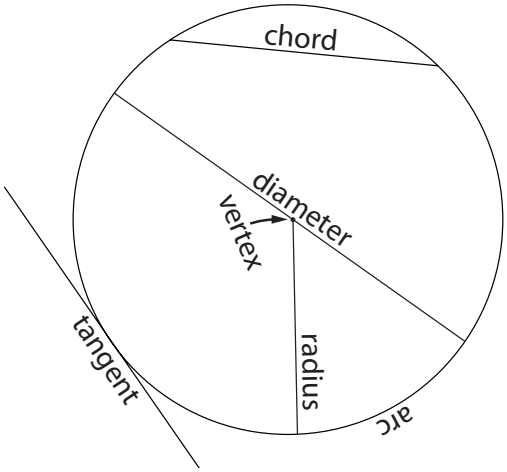
Figure	Sample Illustration
Equilateral Triangle	
Right Triangle	
Isosceles Triangle	
Scalene Triangle	
Square	
Rectangle	
Parallelogram	
Trapezoid	
Rhombus	
Kite	
Chevron	

4. (*) Thinking Spatially: See page 45 for a reproducible of the squares. Here are the possibilities.

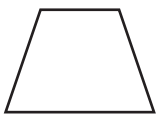


Different ways to color ½ of squares.Total = 13

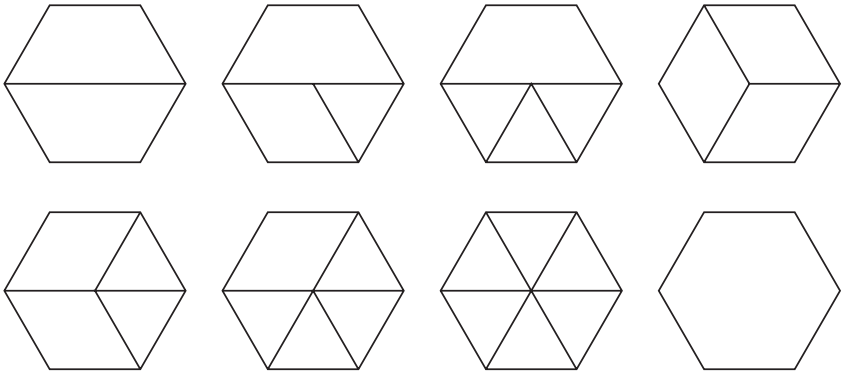
5. This is a chance for student to use compasses and rulers to define parts of a circle. The circumference is the distance around and always the longest. The shortest can vary: radius, arc, or chord. Diameter = 2 radii.



6. Trapezoid and rectangle comparison:

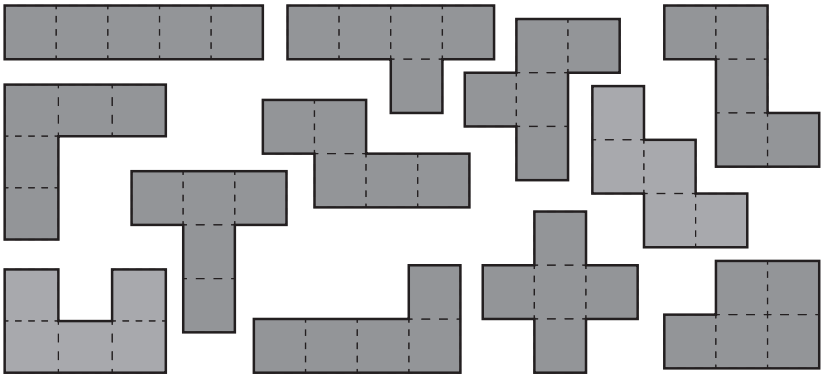
Trapezoid	Rectangle
Quadrilateral; one set of parallel lines; angles need not be equal; diagonals need not cross in the center 	 Quadrilateral; two sets of parallel lines; two sets of congruent lines; four right angles; diagonals cross in the center

7. (*) Using manipulatives will help students use tactile skills to investigate multiple solutions.



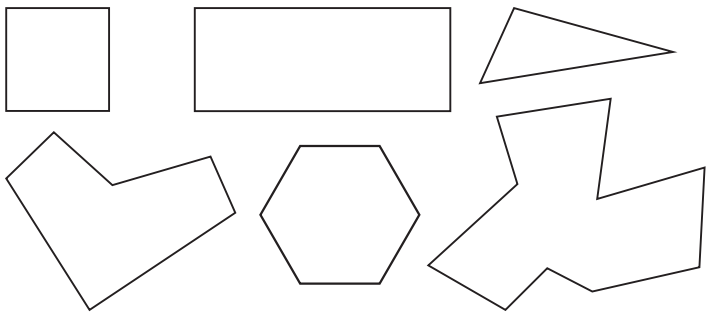
Section II: Analysis and Synthesis:

8. (*) It will help if students have colored square tiles or pieces of paper cut in 1-inch squares. (See page 47 for a reproducible sheet of 1 inch grid paper.) They need to understand that a figure is still the same if it is turned or flipped. Students should make a tesselation of just one pentomino. Each of the 12 pentominoes will tessellate.

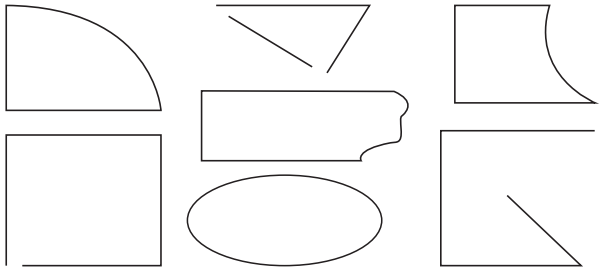


9. The important points here are that a polygon must be a closed multi-straight-sided figure. Often students will believe that a polygon needs to be regular (all congruent sides or they miss an unclosed side. Here are some examples. Notice some of the angles are concave.

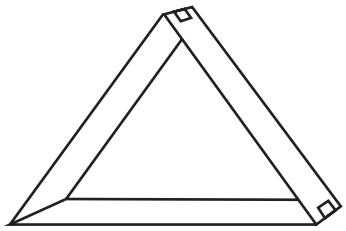
   These are polygons:



These are *not* polygons:



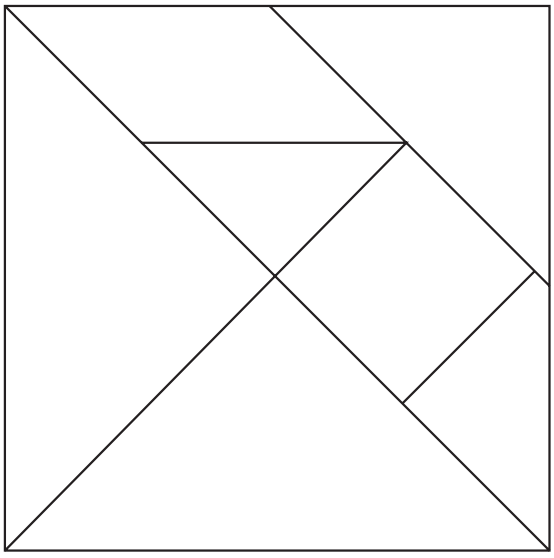
10. This investigation leads students to understanding that the two smaller sides of the triangle need to add up to a greater length than the longest side. A chart will help them organize their thinking. The sum of the angles of all triangles is 180°.



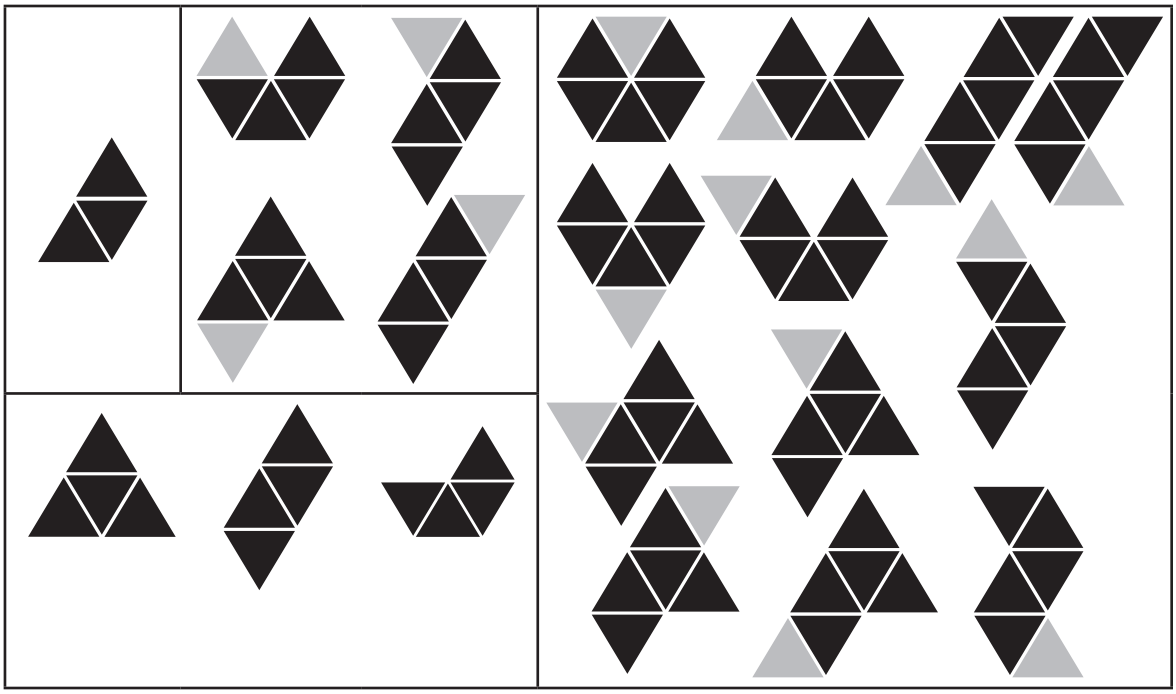
Sample chart:

These strips make a triangle	These strips do not make a triangle
1", 1", 1" 2", 2", 2"	1", 1", 2"

11. (*) Solutions will vary. This one will be a good indicator about what students know and understand about polygons. Instructions for making tangrams are on page 49.



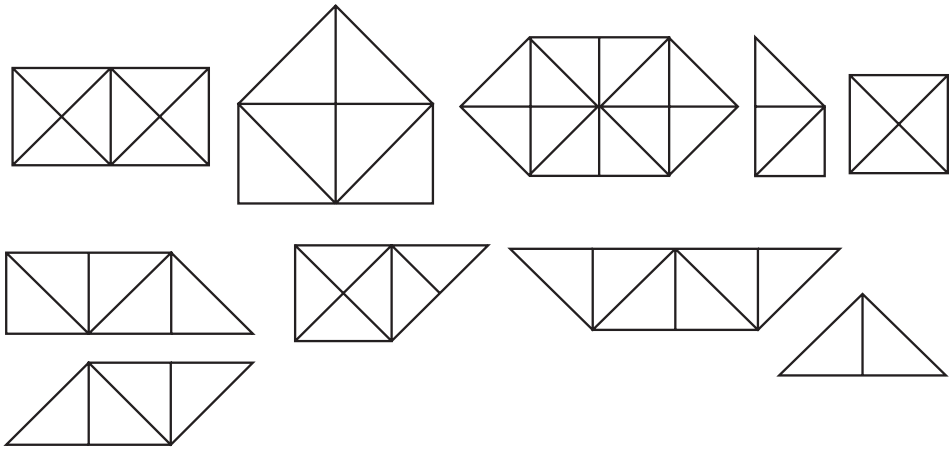
12. (*) Using equilateral triangles:



13. (*) This investigation needs to use different parts of the coordinate grid depending on the understanding your students have. Distribute the coordinate points and grid paper as appropriate. They will need to draw in the axes.

Approximate Grade Level	Grid	Coordinate Points	Figure
3 and 4	One Inch Square grid (quadrant one only)	(2, 2), (3, 5), (6, 2), (7, 5)	parallelogram
5	1/4" grid paper (quadrants 1 and 2)	(2, 2), (-8, 2), (0, 5), (-7, 5)	trapezoid
6 and 7	1/4" grid paper (all 4 quadrants)	(2, -3), (-3, 2), (4, 2), (-5, 3)	parallelogram

14. (*) Here are some of the possibilities:



15. This investigation could be extended to explore Euler's circuits. Leonhard Euler, a famous Swiss mathematician developed these rules about networks:

    - If all the vertices are even the design can be traced traveling over every edge and ending back at the starting point.
    - If there are only 2 odd vertices (those vertices having an odd number of segments), the design can be traced only by beginning at one odd vertex and ending at the other.
    - If there are more than two odd vertices it is impossible to trace in a single line.

    In this investigation, figures 1, 2, 3, 5, and 6 are traceable.

Figure	Traceable	Vertices	Edges
1	Yes	6	10
2	Yes	10	15
3	Yes	4	5
4	No	5	8
5	Yes	8	12
6	Yes	6	9
7	No	4	6

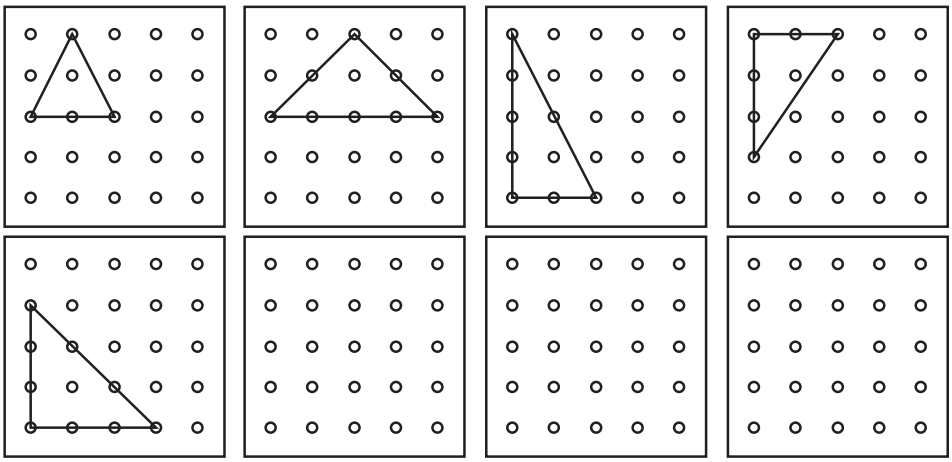
Section III: Application and Evaluation:

16. Solutions to this will vary. Generally, the letters A, B, C, D, E, H (two symmetry lines in this one), I, M, O, T, U, V, W, X will be apparent. As drawings are created and nature is examined the lines of symmetry may lie differently than just horizontally or vertically.

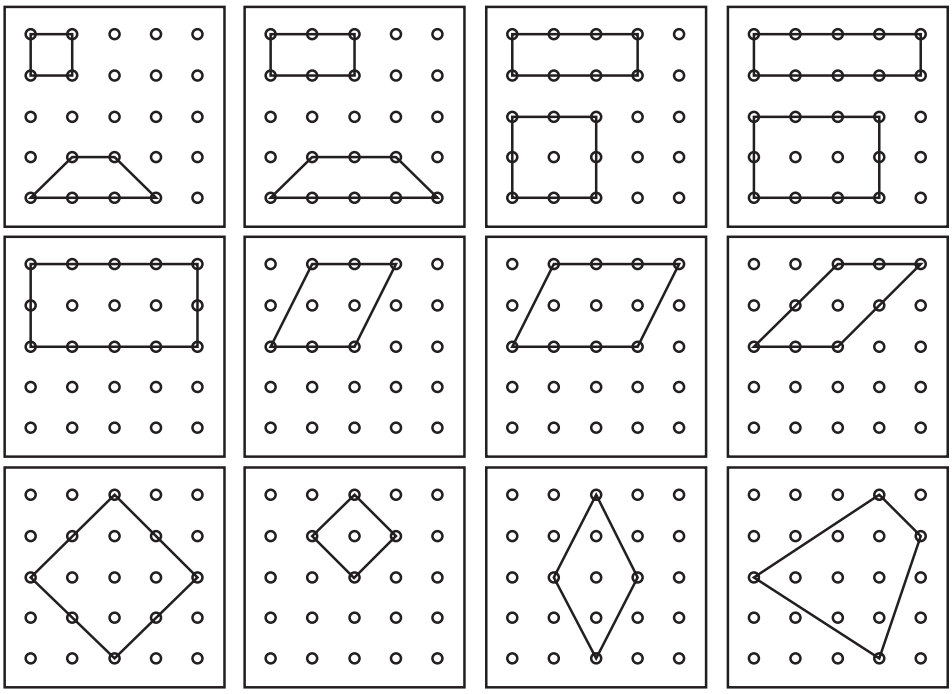
17. (*) Refer to #11 Notes. Tangrams include 2 large triangles, one medium triangle, 2 small triangles, a square and a parallelogram. Other answers will vary.

18. Parallel lines are equidistant from one another. Perpendicular lines are at 90 degrees (a right angle) to one another.

19. (*) This offers another perspective to spatial visualizations. Here are some of the possibilities:



20. (*) There are many solutions for this one. Here are some of the possibilities.



21. Solutions will vary due to the subject matter.

22. (*) This investigation needs to use different parts of the coordinate grid depending on the understanding your students have. Distribute the grid paper as appropriate. Students will need to draw in the axes. Offer different size grid paper for students to make scale drawings.

Approximate Grade Level	Grid
3 and 4	½ inch or 1 cm square grid (quadrant one only)
5	Quadrants 1 and 2
6 and 7	All 4 quadrants

Name: _____ Date: _____

Investigations

Bloom's Levels of Thinking Questions

Section I: Knowledge and Comprehension:

1. Choose 20 words. Define each and illustrate them.

Acute angle		
Angle		
Arc		
Center point		
Chevron		
Chord		
Circumference		
Compass		

Concave		
Congruent		
Convex		
Coordinates		
Degree		
Diagonal		
Diameter		
Equilateral		
Hexagon		

Isosceles		
Line segment		
Obtuse angle		
Parallel		
Pentagon		
Perpendicular		
Polygon		
Protractor		
Quadrilateral		

Radius		
Ray		
Rectangle		
Rhombus		
Right angle		
Scalene triangle		
Similar		
Square		
Symmetry		

Tangent		
Trapezoid		
Triangle		
Vertex		

2. Polygons

- Define a polygon.
- Name and illustrate the regular polygons with 3–12 sides.
- What happens as you add more and more sides to a regular polygon?
- Describe and illustrate the difference between a regular polygon and an irregular polygon. Show the differences with pictures.

3. Define the different types of Quadrilaterals and Triangles.

- Make a chart or poster with a picture of each type.
- Measure the angles in the quadrilateral and triangles. Sum the angles and what do you discover?

4. (*) Thinking spatially: Using only one color pencil or crayon, find all the different ways to color ½ of the squares.

5. Draw several circles using a compass or circle pattern.

- On each circle, make an illustration of one of the following geometric words pertaining to circles.
- Be sure to label each drawing as well as writing the definition of the word. Words: arc, tangent, radius, diameter, center point, chord, vertex, circumference.

- Investigate the various lengths of radius, chord, diameter, and circumference. Will one always be the longest? Will one always be the shortest? What's the relationship between radius and diameter?

6. Bob and Michelle were talking about geometric shapes. Bob said that a trapezoid is also a rectangle. Michelle did not agree. Which one is correct? Write a letter to Bob and Michelle telling them which one is right and describing the difference between a trapezoid and a rectangle.

- Include the definition and illustrations for each including their types of angles, how their diagonals intersect and parallel sides.
- Tell how the two are the same and how they are different. Use words and illustrations.
- What happens if your rectangle is a square?

7. (*) How many* different *ways can you find to fill each hexagon using pattern block shapes?

- Use pattern block shapes that fit in the hexagon.
- Trace your findings on a separate sheet of paper.
- In a chart form identify all the shapes needed to fill the hexagon.

Section II: Analysis and Synthesis:

8. (*) Pentominoes are shapes made up of 5 congruent squares. Each square completely touches the side of at least one other square.

- Using 5 1" squares, find as many different ways the squares can be put together.
- Record your findings on grid paper. Be sure that you have found them all, check to make sure none are the same if you flip or turn them.
- After you have found all the shapes, figure out which shapes will tile a plane or tessellate. In other words, can you trace around the shape over and over placing it next to a previous tracing without any gaps or overlaps between the pieces? Choose your favorite piece and make a colorful design on a piece of paper or poster. Make your design a tessellation. If you are unsure what that is, you can research tessellations on the internet.

9. Polygons: You have been asked to design a poster or chart for a second grade class that explains what a polygon is and the attributes of some regular polygons.

- On your poster/chart, illustrate regular polygons. Include those that are often hard to recognize, such as trapezoids, rhombus; and the types of triangles, including equilateral, isosceles, scalene, and right triangles. Explain how each one is defined by specific attributes such as size of angles and length of sides.
- Write a definition of any polygon with illustrations. You may want to show the attributes by comparing shapes that are polygons and those that are not polygons.

10. Investigating triangles. Will any 3 lengths of line form a triangle? Let's find out.

- Cut several strips of paper 1", 2", 3", 4" 5" long by ½" wide
- Select 3 strips and use them to make a triangle. If they work write the lengths under the heading "Makes a triangle". If they don't work, write the lengths under "Do not make a triangle"
- After you have found several that fit under each heading, look at the numbers that do and do not make triangles. Analyze why some work and some do not. Write your hypotheses for how you think the lengths of the sides compare.
- Sum the angles of each of the triangles that "worked."

11. (*) Using a 4" x 4" square, make your own set of tangrams. Use the tangram shapes to create a unique polygon. Trace around it and the shapes you used to make it.

- Justify how you know it is a polygon.
- Describe your polygon in writing using correct geometric terms.
- Ask a friend to make the same polygon using only your written description. Do not let them see your original work. You can ask more than one person to try.
- Create a poster or chart with your original polygon, your written proof it is a polygon, your description and the attempts of your friends to reproduce your polygon.

12. (*) Using equilateral triangles (green pattern block), find all the different ways 3, 4, 5, and 6 triangles can be put together to form a new shape.

- Each triangle must completely touch at least one side of another triangle.
- Trace around each new shape you find on triangle grid paper.
- Be sure to check that it is different by comparing to previously found shapes that are turned or flipped.
- Design a poster showing all the different ways for each number of triangles.
- Write about how you are sure you have found all the possible shapes and have tested for any possible flips or turns.
- Are any of your shapes regular polygons? How do you know?

13. (*) Plot coordinates on a coordinate grid. Your teacher will give you the set of coordinates and some grid paper

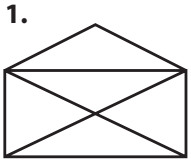
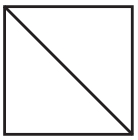
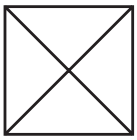
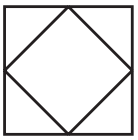
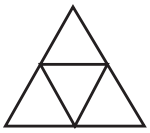
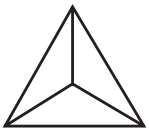
- Describe the shape you have made and tell how you know it is that shape.
- On another piece of grid paper, draw a quadrilateral with at least 2 obtuse angles. List the coordinates of each corner. Challenge a classmate to create the same shape using only your directions.
- Put your description of the shape made by the original set of directions on a poster or chart along with the ones you created. Include your classmate's attempt to follow your directions.

14. (*) How many different shapes can you make by folding a square?

- Cut out a square and fold it in half each way, side to side and along its diagonals then fold each corner into the center.
- By folding only on the lines you just made on the square, find the following shapes: Rectangle, Triangle, trapezoid, parallelogram, smaller square, pentagon, hexagon.
- How many different shapes of each kind can you find? Trace around each, record and label each shape.

15. Networks are figures that can be examined to see if they have traceable pathways. When a path comes to a point or intersection that is called a vertex. The segment between two vertices is called an edge.

- Use your pencil and see if you can trace these figures without retracing any line and without lifting your pencil.

1.  **2.**  **3.**  **4.**  **5.**  **6.**  **7.** 

- Make a chart showing each figure and label each with whether or not they are traceable.
- How many vertices and edges does each figure have?
- How many odd and even vertices does each figure have? Does the number of odd/even vertices make a difference in the ability to trace the figure?
- Write a summary of what you think a figure must have to be traceable.

Section III: Application and Evaluation:

16. There are many ways that symmetry occurs all around us including in nature and in the text books you read. Many capital letters have one or more line of symmetry.

- Print the letters of the alphabet in capital letters.
- Draw the line(s) of symmetry for each letter.
- If there are no lines of symmetry, write none.
- Defend your decisions by explaining what a line of symmetry is and how you know the lines you have drawn are lines of symmetry.
- Look at pictures of plants and animals. What lines of symmetry do you see? Make a list.
- Make 2–3 shapes of your own. Cut them out, trace them on a piece of paper and see if you can find one or more lines of symmetry. Be sure to rotate your original drawing to test for symmetry.
- Mount your letters, justifications and your shapes on chart paper and share with the class.
- Add any observations you have made about where lines of symmetry can be found in everyday life around you.

17. (*) A set of Tangrams has seven distinct pieces. Look at the set after you cut it out and evaluate the pieces based on the idea of congruence.

- Which pieces are congruent? Trace them and justify how you know they are congruent.
- What pieces are similar? Trace the pieces and justify how you know they are similar.
- Can you make 2 congruent figures from the pieces of the Tangram set? Trace them and justify why you know are congruent.
- Can you make similar figures with the Tangram pieces? Trace them and justify your decision that they are similar.

18. Lines that go in a certain direction are often parallel or perpendicular.

- Illustrate each type of these lines.
- Write a justification for how you know the lines are parallel or perpendicular.
- Look around your home, at illustrations in magazines or around your classroom. Find and list at least 10 places you observe the use of parallel and 10 places where perpendicular lines are used.
- Illustrate at least 5 different shapes that contain parallel and or perpendicular lines. Find and illustrate 2 shapes with diagonals that are perpendicular.

19. (*) A geoboard has 25 dots. Using a piece of geoboard dot paper draw as many different triangles with one dot inside that you can find.

- Check each triangle to make sure it is different from ones you have already found.
- Trace ones you have found to see if they are the same as others by putting the original on top of another. They are different if their size is different.
- Evaluate the triangles you have found. Write the name of the type of triangle found.
- Were there any equilateral triangles? Justify your answer, yes or no.

20. (*) Geoboards can be used to find many different types of shapes.

- Use a piece of geoboard dot paper.
- Find as many different quadrilaterals as you can. Different means different in size. Do not draw a shape that is a flip or turn of another shape already drawn.
- Draw each one on the dot paper and label the kind of quadrilateral it is.
- Justify your labels of regular quadrilaterals.
- Make a chart or poster of your drawings and justifications. Share it with your class.

21. Real life shape search

- Look for triangles, quadrilaterals, pentagons, hexagons and octagons in the world around you.
- Draw a picture of the object with the shape and justify how you know it is the shape you named.
- Note where you saw the shape.
- Look for patterns of repeating shapes.
- Draw the pattern or design.
- Name the shape(s) in the design and note down where you found it.
- Put your findings together in a brochure explaining all about how geometry is found in our world.

22. (*) Many game creators like to design "dot to dot" type games. This can be done on a coordinate grid.

- Find a design, shape or cartoon you like.
- Draw it on a piece of coordinate grid paper.
- Write the coordinates a classmate would have to plot in order to reproduce your design.
- Challenge a classmate to plot your coordinates and discover your original drawing.
- Use a different gauge of graph paper (bigger or smaller) and duplicate the coordinates. Your new drawing is a scale drawing of your original. How would you explain "scale drawing" to a fellow student? Where have you seen scale drawings in real life?

Let's Investigate: Plane Geometry!

Dear Parents,

We are starting an independent investigation unit about Plane Geometry. In this unit, each student is responsible for his/her choice of investigations. They will sign a contract along with you stating their goal for the projects they wish to do and the grade they intend to accomplish. This unit is intended to help students develop their organizational skills as they plan how they will collect information from their investigations and keep the record of their completed work. They are responsible for designing a means of sharing their new knowledge with their classmates and the teacher. The difficulty and level of success of the work will determine each student's evaluation (grade/rubric score).

Students can choose to work on their own, with a partner or in a small group. The contract they share with you reflects the investigations they have chosen to complete as well as their goal for a final grade. The rubric on the contract explains the grading expectations. They are expected to complete a minimum of _____ investigations from each of three levels by _____. The rubric on the contract explains the grading expectations.
(date)

By completing this unit students will have a chance to investigate plane (two-dimensional) geometric concepts on their own as well as do projects that interest them.

Please discuss the choices your son or daughter has made. By signing the contract you will let him/her know you support the choices (s)he has made and you know the date the finished projects are due.

Thank you for your help and support,

_____
(S)

Name: _____ Date: _____

Investigation Contract

I understand that I will need to complete _____ activities by _____ (date). I will complete the following activities selected from three different categories. My goal is to get _____ total points for my projects.

Here is my plan for presenting my findings using written or oral format or using technology.

_____

_____

Knowledge and Comprehension (Remembering and Understanding)

Investigation #	Completion Date	Points Possible	Points Earned

Analysis and Synthesis (Analyzing and Creating)

Investigation #	Completion Date	Points Possible	Points Earned

Application and Evaluation (Applying and Evaluating)

Investigation #	Completion Date	Points Possible	Points Earned

Total points: _____

Student signature _____

Parent signature _____

Teacher signature _____

Name: _____ Date: _____

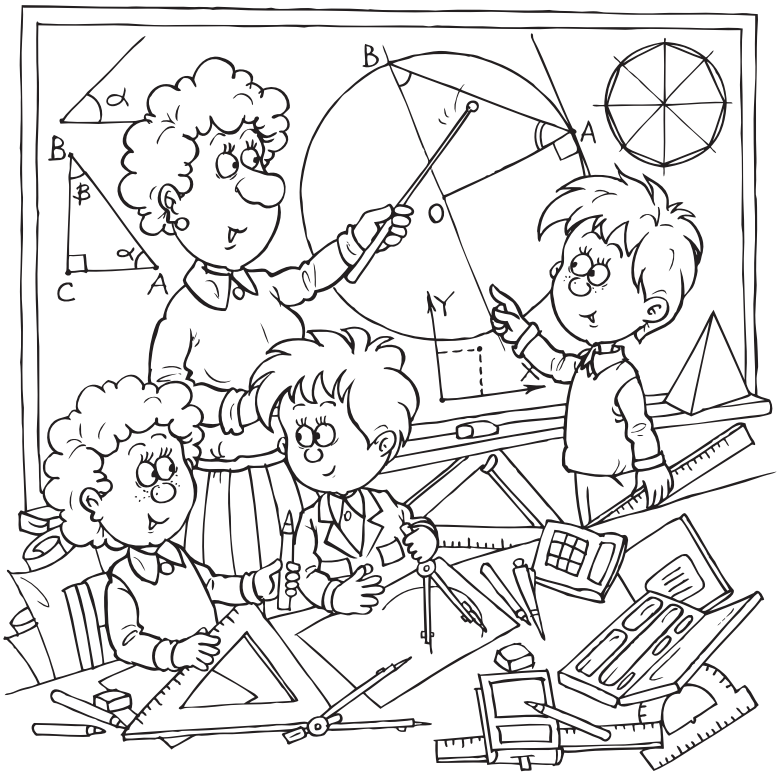
Scoring Rubric for Investigations

Expectations		Section I Knowledge & Comprehension	Section II Analysis & Synthesis	Section III Application & Evaluation	Goal
Exceeds expectations: Fully accomplishes the purpose of the task; demonstrates clear understanding of probability concepts; recorded work communicates thinking clearly, using some combination of written, symbolic or visual means.	Complete. clear and well communicated	**4**	**8**	**12**	
Meets expectations: Substantially completes the purpose of the task; displays essential grasp of the probability concepts; recorded work communicates a large part of the thinking.	Complete	**3**	**6**	**9**	
Approaching expectations: Partially accomplishes the task with limited grasp of probability concepts; recorded work may be incomplete, misdirected, or not clearly presented; strategies may be ineffectual or not appropriate.	Mostly complete with some understanding	**2**	**4**	**6**	
Falls far below expectations: Little or no progress toward accomplishing the task; approach may lead away from task completion; shows little evidence of appropriate reasoning.	Incomplete with little understanding	**1**	**2**	**3**	

Instructions for Individual or Group Investigations

1. Read and discuss your investigation
2. Decide the best way to carry out the investigation and how you will record your findings. Record your commitment on your contract.
3. Carry out your investigation
4. If working with another person or a group, decide who will do what when you present your findings to the class.
5. When presenting your findings:

- Describe your investigation.
- Explain how you or your group decided to carry out the investigation.
- Relate your results/findings. Share any work you created.
- What did the investigation teach you about Plane Geometry?



Name: _____ Date: _____

Observation Checklist

Use this chart to record your observations of student performance during lesson activities.

Students' names	Cooperative participation	Understanding of task	Ability to	Comments

Rating Scale:

10 (date) = Student fully accomplished the task
6 (date) = Student substantially accomplished the task
3 (date) = Student shows partial or limited progress toward accomplishing the task
1 (date) = Student shows little or no progress toward accomplishing the task

Name:_____ Date: _____

Let's Investigate! Plane Geometry

Reflection

Three things I learned about Plane Geometry are:

_____

_____

_____

The investigation I liked the most was:

_____

I liked this one because:

_____

_____

_____

Another Plane Geometry topic I might want to explore more if I had more time is:

_____

The hardest part of this assignment was:

_____

_____

The easiest part of this assignment was:

_____

_____

What advice do you have for students doing this assignment next year?

_____

_____

_____

Name:_____ Date: _____

Midway Report

Student(s) I am working with: _____ _____

I (we) have completed _____ investigations

I (we) need help with:

_____

_____

_____

_____

_____

_____

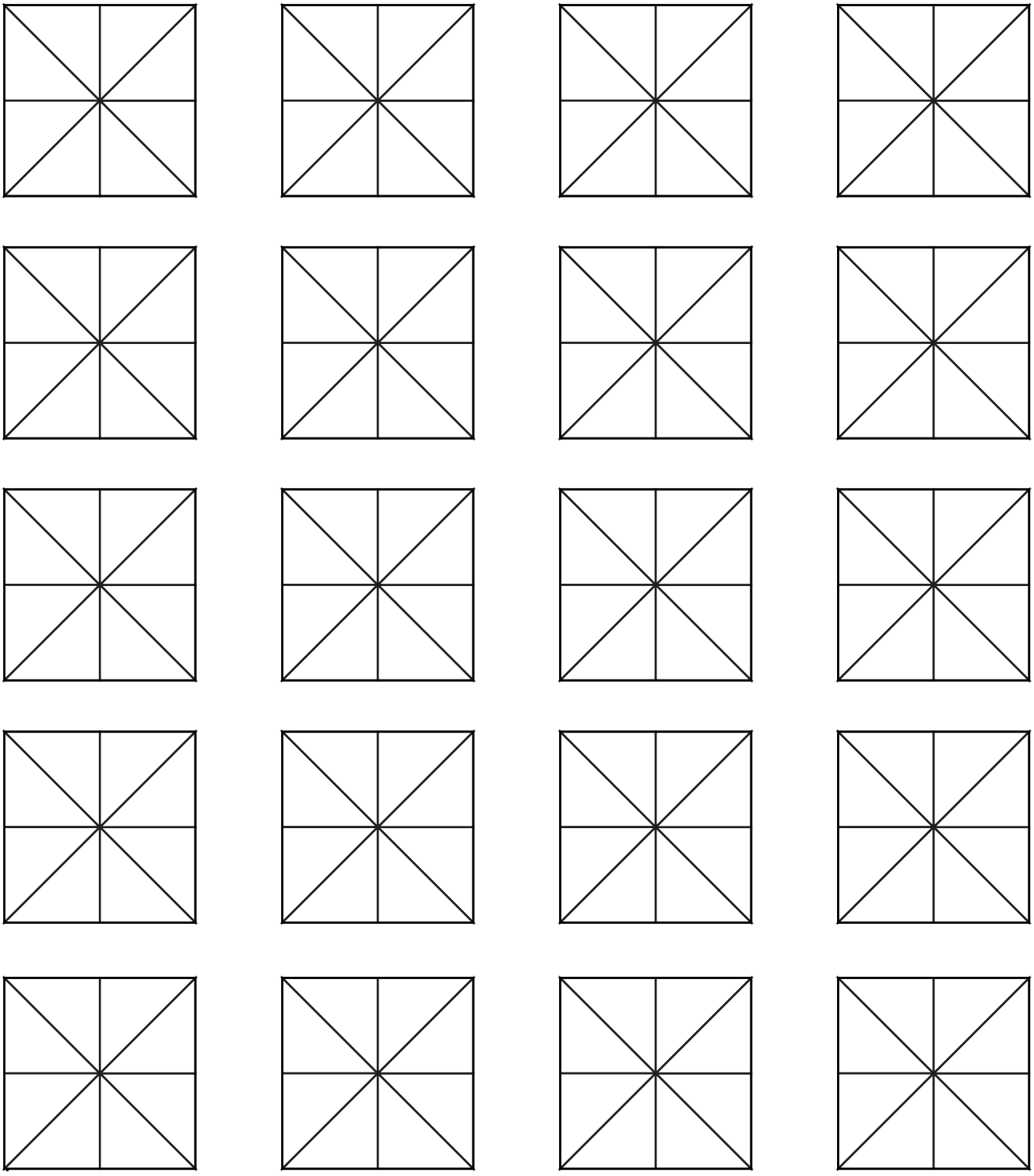
_____

I (we) will present my findings on (date): _____

Name:_____ Date: _____

Thinking Spatially With Squares

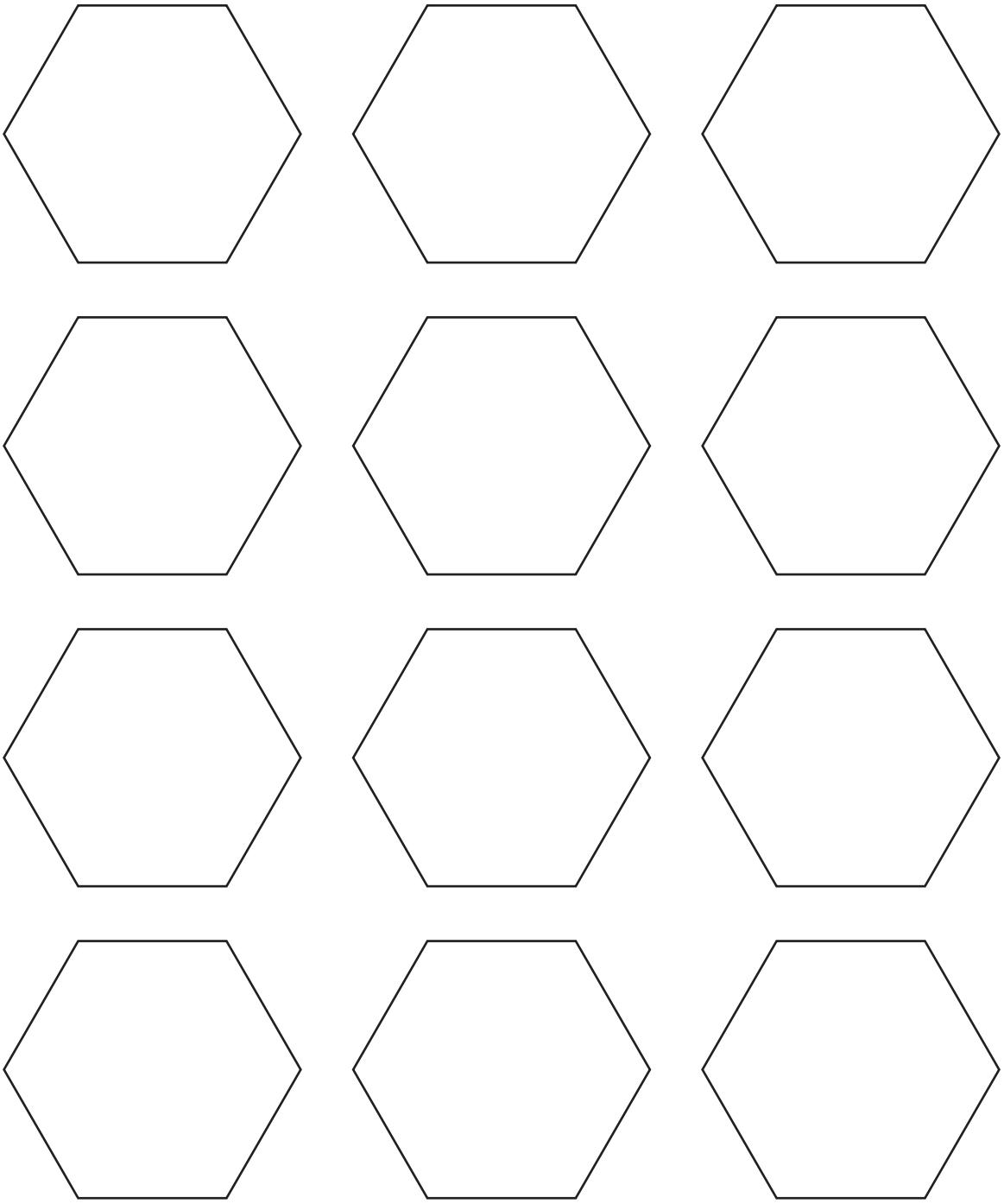
Thinking spatially: Using only one color pencil or crayon, find all the different ways to color ½ of the squares.



Name:_____ Date: _____

Thinking Spatially With Polygons

How many *different* ways can you find to fill each hexagon using Pattern blocks? Trace your findings.



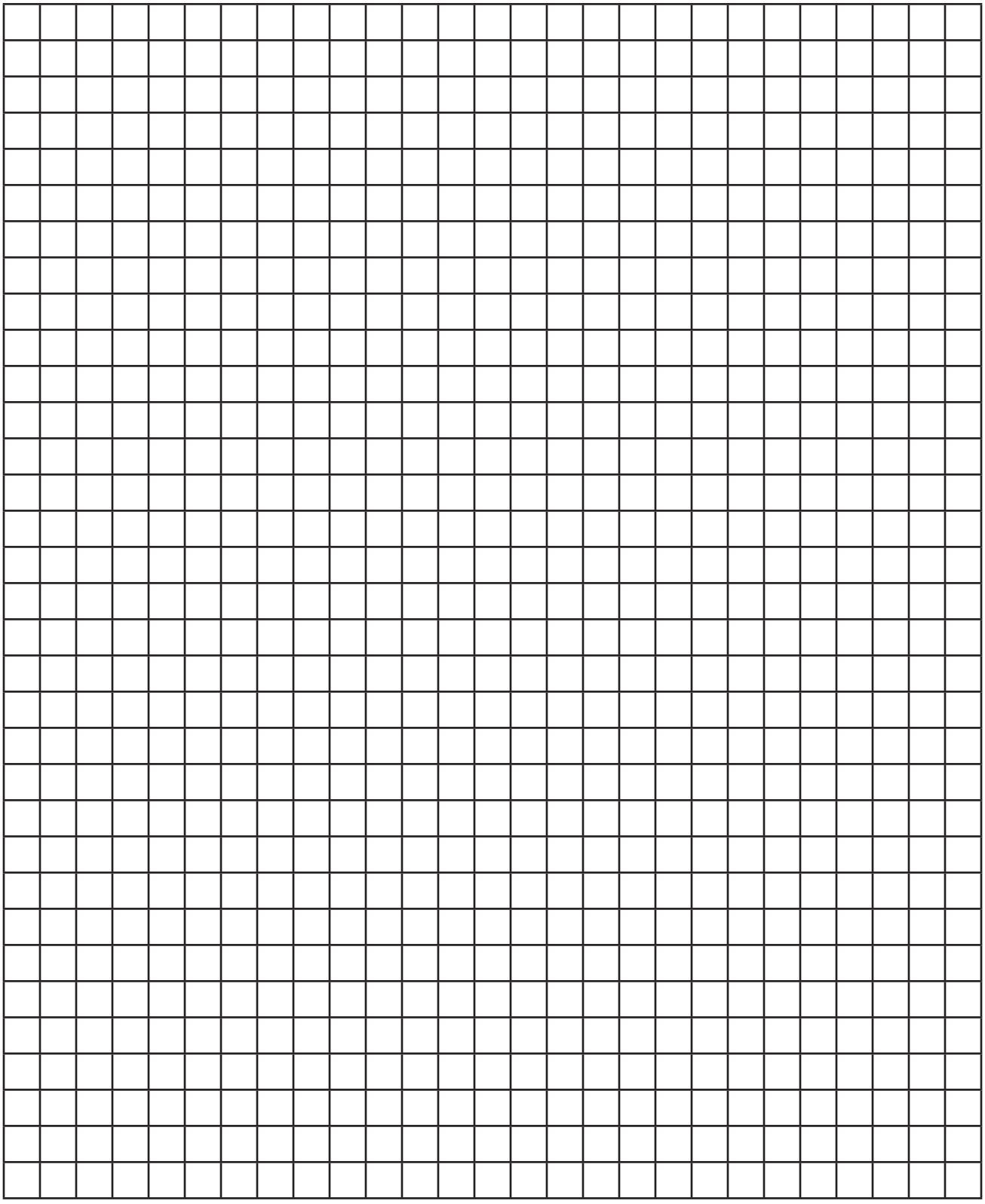
Name:_____ Date: _____

One Inch Grid Paper

Master

Name:_____ Date: _____

¼" Grid Paper



Making Your Own Tangrams

Materials needed:

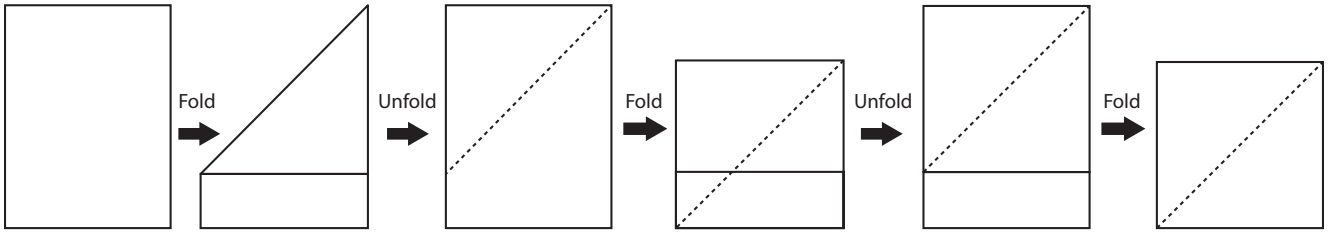
- a rectangular piece of paper suitable for folding
- a pair of scissors
- a ruler (optional)

A set of tangrams consists of seven pieces:

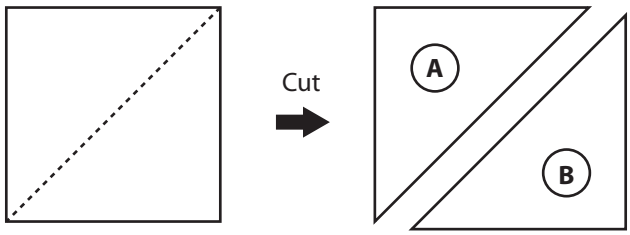
- a small square
- two small congruent triangles
- two large congruent triangles
- a medium-size triangle
- a parallelogram

You can make your own set of tangrams from a single piece of paper. Just follow these simple steps:

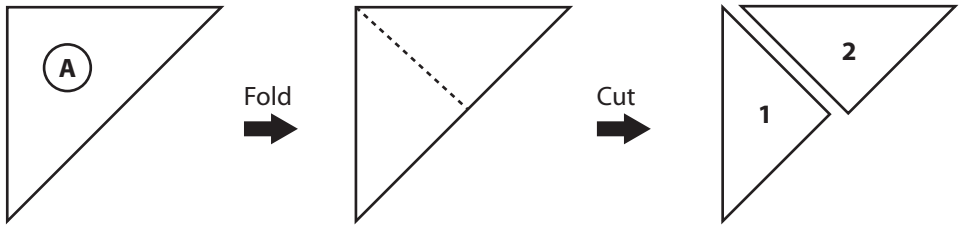
1. Fold a rectangular piece of paper so that a square is formed. Cut off the extra flap.



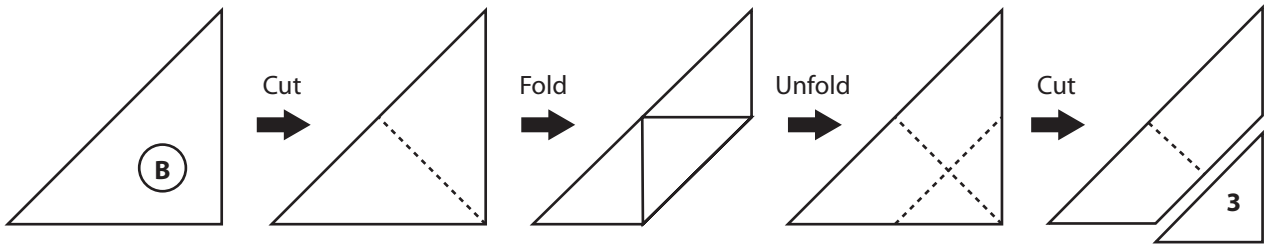
2. Cut the square into two triangles.



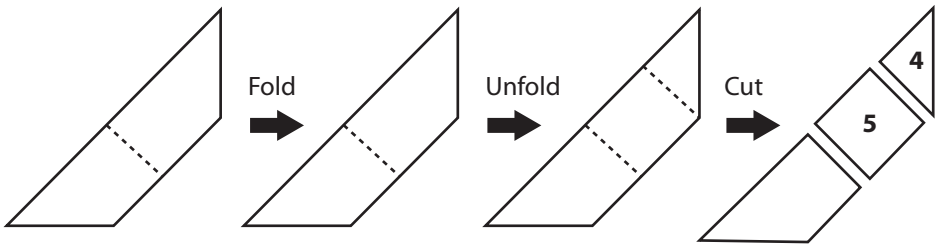
3. Take one triangle and fold it in half. Cut the triangle along the fold into two smaller triangles.



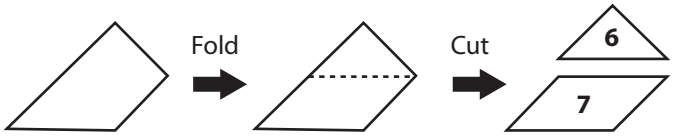
4. Take the other triangle and crease it in the middle. Fold the corner of the triangle opposite the crease and cut.



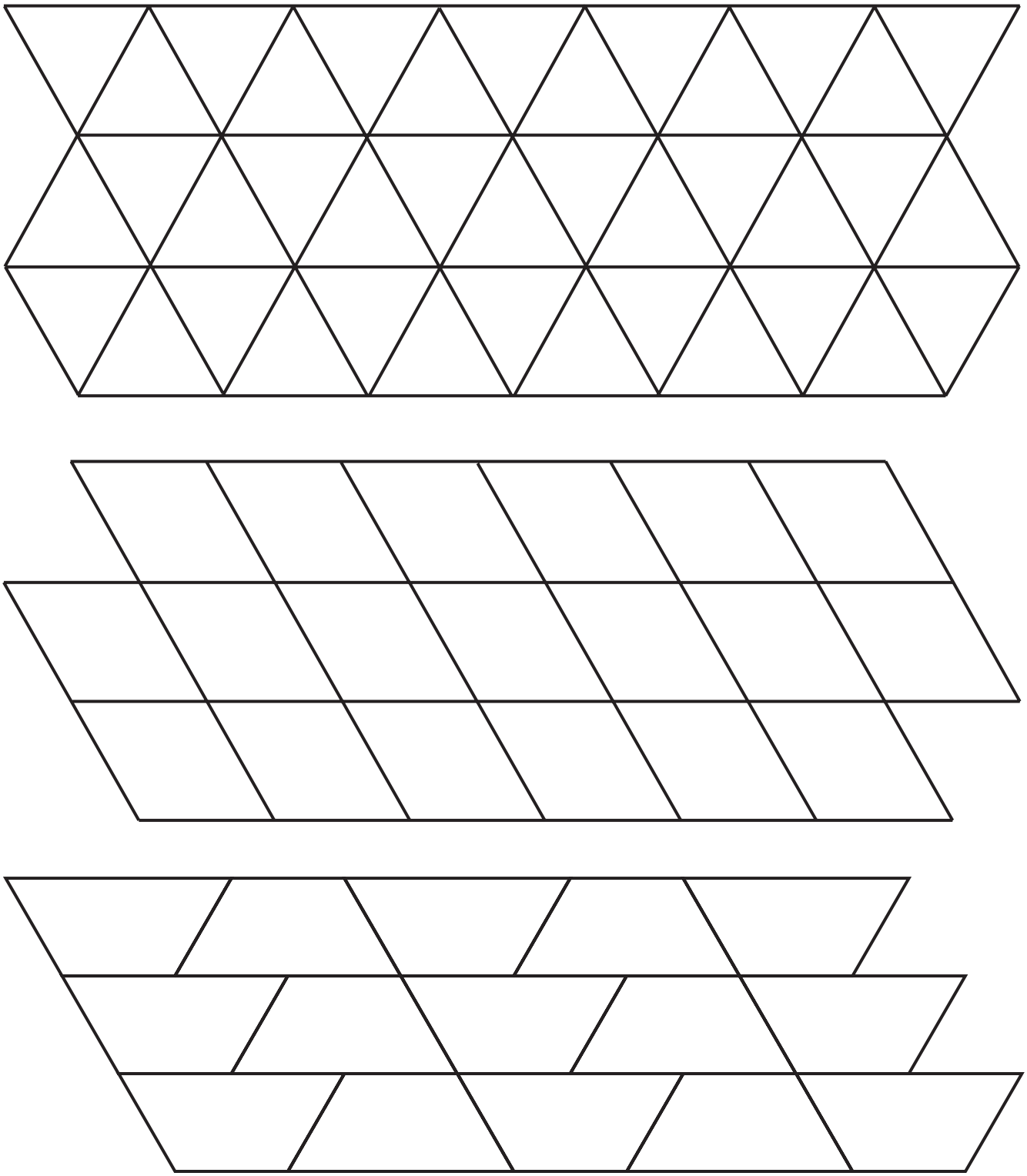
5. Fold the trapezoid in half and fold again. Cut along both folds.



6. Fold the remaining small trapezoid and cut it in two.



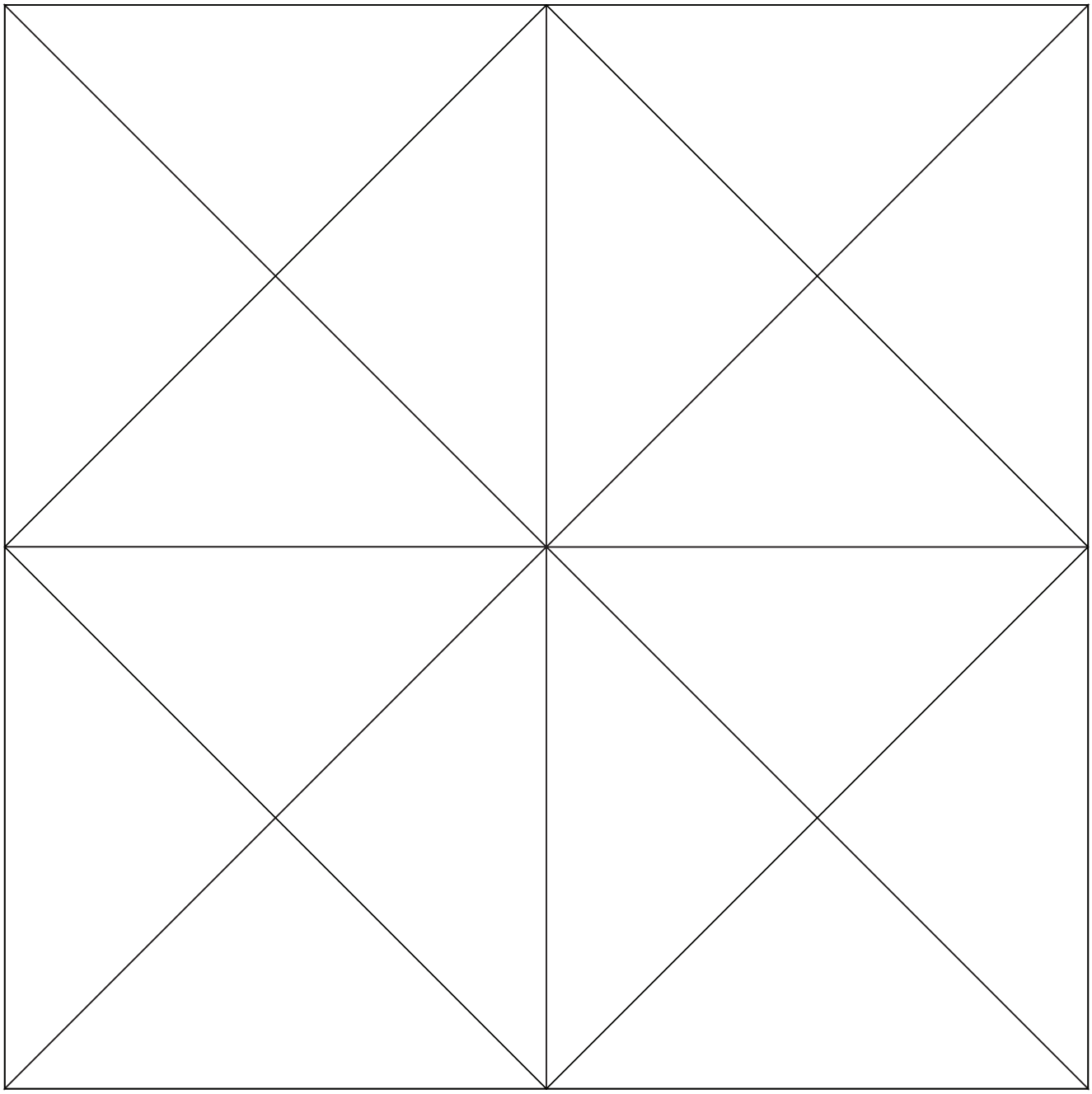
Pattern Block Template



Name:_____ Date: _____

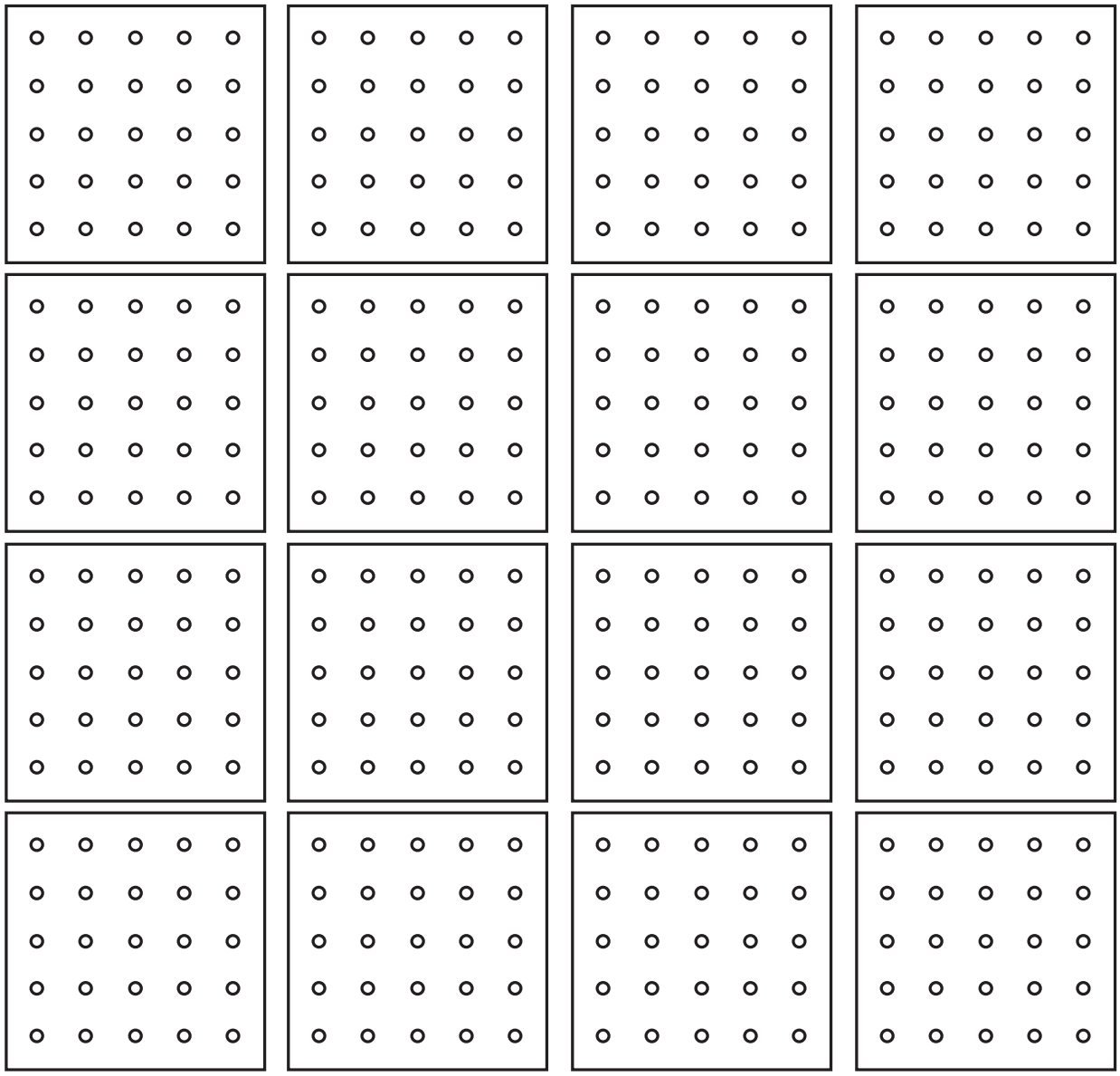
Fold a Square

1. Cut out the square.
2. Fold along each line, forward and backward.



Name:_____ Date: _____

Geoboard Dot Paper



Teacher Feedback Form

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Please use the release form on the following page.

Your name: _____

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E-mail: _____

Interact unit: _____

Comments: _____

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Release Form for Photographic Images

To Teachers:

To help illustrate to others the experiential activities involved and to promote the use of simulations, we like to get photographs and videos of classes participating in the simulation. Please send photos of students actively engaged so we can publish them in our promotional material. Be aware that we can only use images of students for whom a release form has been submitted.

To Parents:

I give permission for photographs or videos of my child to appear in catalogs of educational materials published by Interact.

Name of student: _____ (print)

Age of student: _____ (print)

Parent or guardian: _____ (print)

Signature: _____ Date: _____

Address:

_____

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_____

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