Brain Games

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Abstract

This unit seeks to help students Grades 4 - 12 think logically to solve popular solitaire puzzles that can be found in Variety Puzzles and Games magazines, newspapers, and online. It includes three lessons for Battleships, Cryptograms, and the Four Color Theorem. They will also explain their reasons and strategies orally and in writing and be able to transfer these skills to problem solving in mathematics.

Keywords
Standards of Mathematical Practice, critical thinking, reasoning, justify, puzzles, games, Battleships, Cryptograms, Four Color Theorem,

Unit Content

How do we teach our students to think critically? Teachers are often frustrated by students providing unreasonable answers or just taking numbers and manipulating them without justification. This unit seeks to help students think, strategize, justify, and explain solutions through playing games and solving puzzles. The standards for mathematical practices focused on include Make Sense of Problems and Persevere in Solving Them, Reason Abstractly and Quantitatively, Construct Viable Arguments and Critique the Reasoning of Others, Look For and Make Use of Structure, and Look For and Express Regularity in Repeated Reasoning.

I believe much of my ability to approach problems from a variety of perspectives as well as persistence and stamina were born from strategies gained while working on a variety of puzzles and games, particularly logic problems and solitaire games like Sudoku, Battleships (NOT the board game), word games such as cryptograms, word drops, and crossword puzzles, and board games such as Rumikub, Mastermind, and Backgammon. I had fun while expanding my skills and vocabulary and I believe my students can gain those same benefits.

Before students enter school they learn through trial and error, touching and manipulating the world around them, playing and interacting with people in their environment, and using toys to simulate situations. Often, these learning techniques are abandoned with formal education. Many students are taught the “right way” to do things instead of being encouraged to use their natural intuition to explore and build on prior learning. In the School District of Philadelphia there is currently a shift back to a more

student centered, creative problem solving method, but there is a clear dichotomy between students who prefer being told what to do and how to do it versus those who are willing to take risks to expand their learning, have discourse with their fellow thinkers, and to make viable conclusions and develop new strategies. The curriculum unit I am designing will encourage students to work together to develop logical thinking skills and to discuss and clearly explain their reasoning.

Teaching Strategies

I have chosen to focus my curricular unit around five particular areas: Nim/Takeaway games, Codes such as Braille, Morse Code, substitution codes, cryptograms, and positional codes such as Pigeon codes, Color Schemes (discrete math mapping using a maximum of 4 colors,) Battleships, and a game that is new to me called Futoshiki. In my exploration of Futoshiki, I have discovered that understanding the strategies and techniques to completing Sudoku puzzles is a prerequisite skill.

NIM- This "Takeaway Game" relates to the content of the course. There are several variations that we will look at and play in order to discover winning strategies. We will play with both two sided counters, drawings, and an oral version to address different learning styles and will document our moves as we look for patterns.

Code/decoding- We will examine cryptograms, Morse Code, Braille, and direct substitution codes and look for word patterns and other "entry" points to help us solve. With Morse Code and Braille, we will discuss the history, application, and practicality as well as the number of unique patterns that can be made. With cryptograms, we will start with word families and paragraphs about animals and plants. We will also use positional codes (such as pigpen codes) and semaphore. As they use these codes, and their skills increase, they will gain fluency and speed, which I will then tie in to learning their math facts.

Four Color Theorem activities- Coloring in any map is possible using just four unique colors. We will discover this and practice this by researching the theory on the internet and using uncolored maps of Pennsylvania Counties, the United States, the continents, and drawings from puzzle books. This problem solving activity involves logical thinking and visual discrimination.

Futoshiki- Futoshiki puzzles come in 4 by 4 to 9 by 9 varieties. Similar to Sudoku in that they involve placing the digits (1-4 in the smallest grid and 1-9) in the largest so that each digit appears once in each row and column, Futoshiki also has > and < signs placed within the puzzle which adds another layer of logical thinking. We will start with some sudoku puzzles and work our way up to Futoshiki all the while discussing our thoughts and reasoning as to how we placed the numbers WITHOUT guessing.

Battleships- Based loosely on the board game, this solitaire puzzle requires one to locate all of the hidden ships in a grid. The easiest grids are 6 by 6 and they can increase in increments of two until 12 by 12 grids. There are also 15 by 15 grids available. The numbers across the outside on the top of each column and on the left of each row indicate how many "ship bits" are in each respective row or column. Ship bits from one ship may not touch any other ship bits from another ship, even diagonally. Thus, each ship, from one to six units long, must be surrounded by water. There are one unit ships made of a circle, two unit ships whose parts are squares rounded on one side, and Multi-part ships whose ends are rounded but whose interior parts are complete squares. In addition, there are diamond shaped bits that can represent any ship bit in the preprinted puzzles. Using logical strategies, which increase in difficulty and the grids increase in size, solvers must not guess where ship bits belong, rather where the clues dictate they MUST be.

Again, we will start with the most basic puzzles and increase the grid size as we master each level. For this puzzle in particular, the focus will be on writing logical solutions.

Classroom Activities

Battleships Lesson Plan (45 minutes) Once they learn the basics this is a good activity for kids who finish their work quickly.

Objective: Students will be able to solve 6 x 6 and 8 x 8 Battleships puzzles using logic and deduction and will be able to note their thought process step by step.

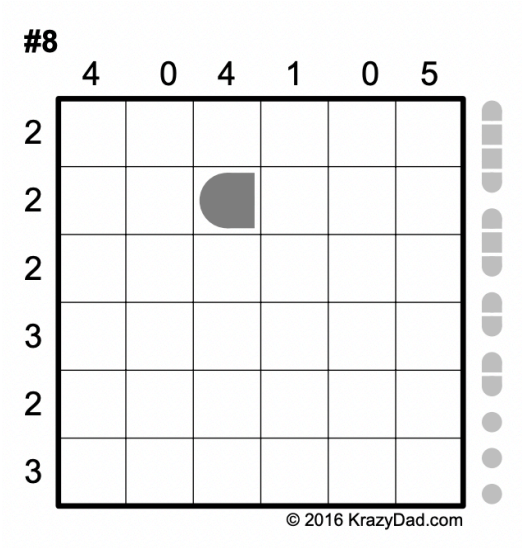
Materials: Downloadable/printable puzzles from Krazydad.com.

Standards of Mathematical Practice: Make Sense of Problems and Persevere in Solving Them, Reason Abstractly and Quantitatively, Construct Viable Arguments and Critique the Reasoning of Others, Look For and Express Regularity in Repeated Reasoning

Standard - CC.2.3.5.A.1

Graph points in the first quadrant on the coordinate plane and interpret these points when solving real world and mathematical problems.

Eligible Content - M05.C-G.1.1.1 Identify parts of the coordinate plane (x-axis, y-axis, and the origin) and the ordered pair (x-coordinate and y-coordinate). Limit the coordinate plane to quadrant I.



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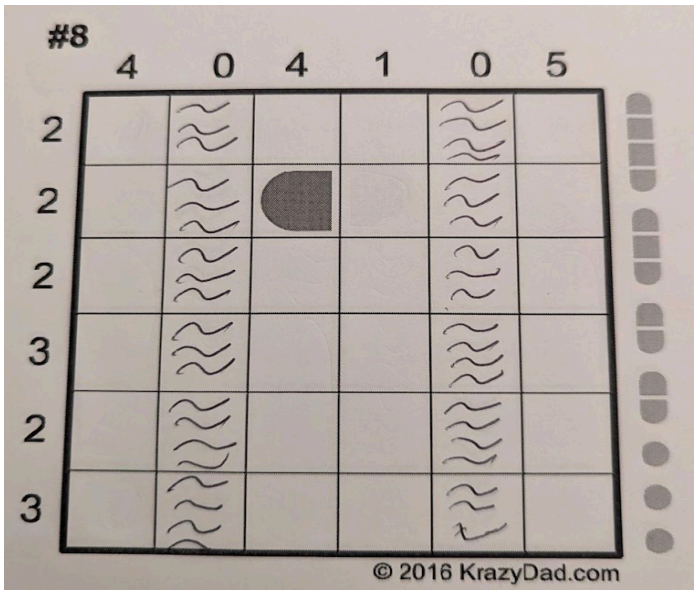
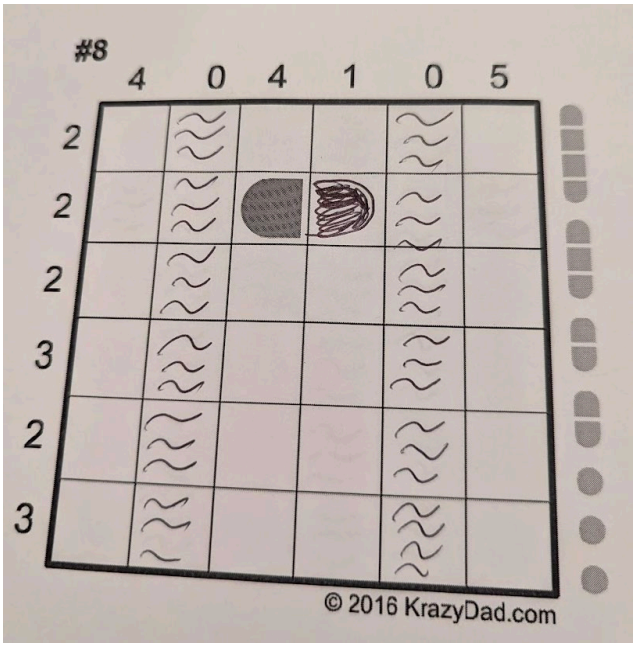
Procedures:

1.) Introduce the rules and, based on the given information, ask what the students can conclude or fill in on the grid. For ease of identifying rows and columns, I will count rows from the bottom and columns from left to right and refer to squares as Column 2, Row 3, similar to the coordinate plane x, y one then up method. Sample answers for the above krazydad.com puzzle (https://krazydad.com/battleships/sfiles/BSHIPS_6x6_v1_4pp_b1.pdf) should include:

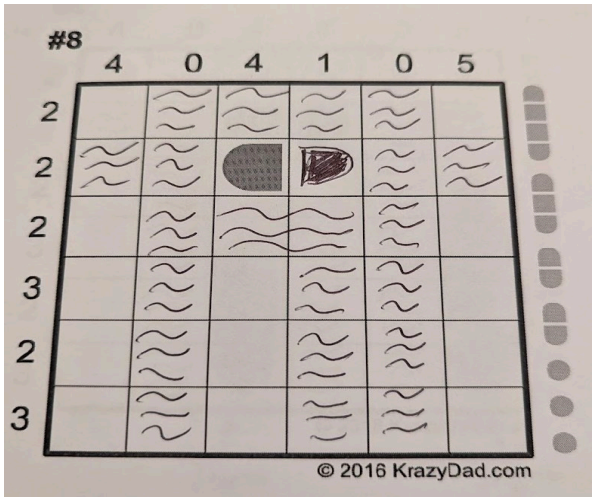
1.) Put water in the two columns with 0 ship bits. (Columns 2 and 5)- **This is ALWAYS a good starting point for any Battleships puzzle.** Water can be drawn with wavy lines or w's.

2.) Since row 5 has just two ship bits and a left end is in Column 3, Row 5, the other part should be in Column 4, Row 5.3.) Water can be filled in in the rest of Row 5 since two of





two ship bits have been logically placed. Similarly, water can be filled in in the rest of Column 4. Students might also say that (Column 3, Row 4,) (Column 4, Row 4,) (Column 3, Row 6,) (Column 4, Row 6) should also be filled with water because they are touching ship bits. *(This is also good second step after filling in the 0 rows and 0 columns: Look for given ship bits and put water in all surrounding squares* ***except*** *where the*

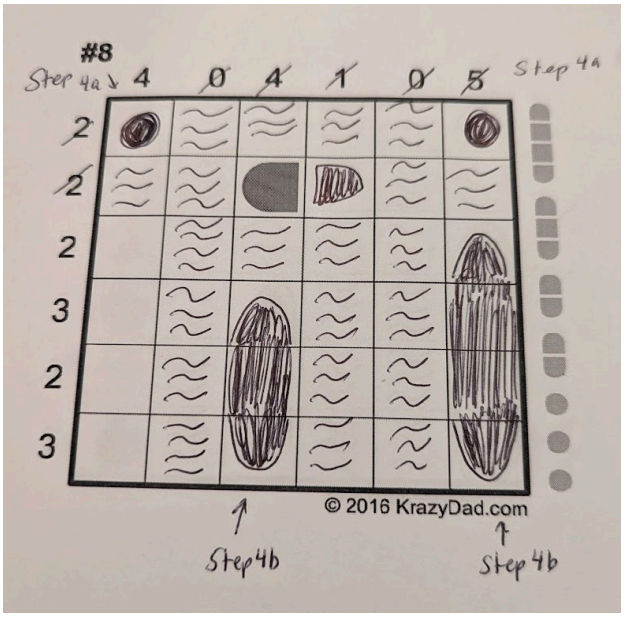


ship might have attached ship bits.)

4.) Looking at SOL 3, there are many next steps that can be taken.

a.) Row 6 has to have two ship bits and there are only two spaces available. Both of them are surrounded by water or the edges of the grid so they must both be circles (or

one ship bit ships.) b) Columns 4 and 6 use the same reasoning to place a three bit ship and four bit ship respectively.



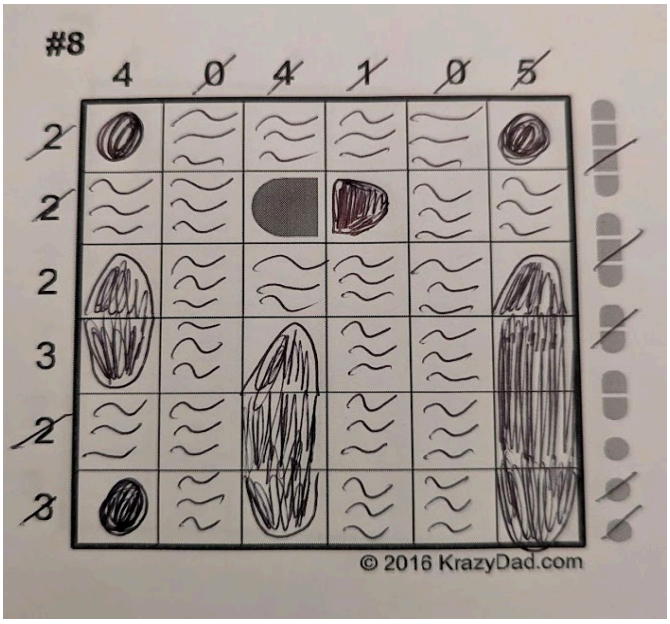
5.) There are now just 4 empty squares left and if you look at the column they're in, there are three more boxes that contain ship bits. DO NOT let your students guess! We are not looking at what COULD fit, but what MUST be. If you have guided your students up to this point, now would be a good time to let them finish the puzzle and write an explanation for how they knew where to put each ship bit.

Sample answers include, but are not limited to:

a.) Column 1 Row 4 must have a ship bit because it's the only empty box in the row and there are two bits in that row. Column 1 Row 3 must have a ship bit because it's the only empty box in the row and there are three bits in that row (two already filled in.) Column 1 Row 2 must have water because the two bits are already filled in and because the three bit ship is already placed in the grid.) Column 1 Row 1 must be a ship bit because there's a total of 4 in the at column and after filling in the others in that column, this makes the fourth ship bit.

b.) Column 1 Row 2 must be water because the two of two bits are already filled in that row. That leaves the other three empty squares needing to be filled in with ship bits- one a single and one a two bishop because that's all that's left and it satisfies the rest of the clues.

c.) The two bit ship that is left cannot be in Column1 Row 2 and Column 1 Row 3 because then water would have to be in Column 1 row 1and Column 1 Row 4 and there wouldn't be any place in Column 1 to out the fourth ship bit.



Helpful Hints

Use pencil!

Color a little bit of a square if you know there's a ship bit there but you don't know whether it's a single ship, a middle or an end part.

Cross off the numbers on the outside when the row or column is completed.

Cross off the ships on the right as you use them so that you know what is left.

Check your answers when finished to make sure you have met ALL requirements.

As ship bits are placed in the grid, fill in the water where it MUST go adjacent to all ship bits.

Be prepared with more puzzles. Students tend to catch on fairly easily to the rules and strategies . Once they've demonstrated correct solutions and explanations, they can advance to 8 x 8 puzzles. As they progress, they should develop more strategies on their

own. (For example, looking at the numbers and the placement of water and other ship bits can lead to a conclusion that the largest ship couldn't fit in a certain row or column and there might be only one place that it does fit.) Students can pair up on different same level puzzles and read their reasoning descriptions to their partner critical feedback.

Cryptograms and Codes/Decoding Lesson Plans (Two or three 45 minutes classes)

Objective: Students will be able to decode cryptograms and describe their thought process and deductive reasoning.

Materials: Coded words with a theme (Crypto-Family), coded story (Crypto-Quote), variety of code puzzles. Free printable Crypto Families can be found on line and in Variety Puzzle Books.

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Procedures:

Cryptograms are simple one to one letter substitution puzzles. Most commonly they are famous quotes, witty words of advice or general thoughts, but they can also be lists of 8 - 10 one or two word encrypted words that are related to a theme (red foods, French Impressionists, Taylor Swift songs, etc.) commonly called Crypto-Families or crypto families and some are paragraphs about animals or plants or famous people. In all puzzles, if a G represents an L in one word, all G's represent L's throughout that puzzle. This does NOT mean if G's represent L's then L's represent G's. (This can be linked to a discussion of the symmetric property of equality in math, etc.)

The crypto families are a good type of crypto puzzle to teach first because you can guess a word that fits the category and look for an encoded word that as the same pattern of letters. Words with double letters are a good place to start. An example and possible reasoning pattern follows:

Category: Fruits

Start by looking for a pattern, double letters, or pairs or trios of repeating letters. In this puzzle you might guess that GHHKL is APPLE or EGBGBG is BANANA. That would lead to filling in the G's as A's, H's as P's K = L, and L = E throughout the rest of the puzzle. (SEE NEXT PAGE)

GHHKL

ANGHLV

MGXLNRLKYB

EGBGBG

JWLNNO

YNGBAL

ANGHLTNSQX

HQBLGHHKL

A P P L E

G H H K L

A P E

A N G H L V

A E E L N

M G X L N R L K Y B

B A N A N A

E G B G B G

E

J W L N N O

A N E

Y N G B A L

A P E

A N G H L T N S Q X

P NE A P P L E

H Q B L G H H K L

The next realization would be that Q = I to make “Pineapple” and replace the other Q with an I.

A P P L E

G H H K L

A P E

A N G H L V

A E E L

M G X L N R L K Y B

B A N A N A

E G B G B G

E

J W L N N O

A N E

Y N G B A L

A P E I

A N G H L T N S Q X

P I N E A P P L E

H Q B L G H H K L

Next, someone might point out that the group of letters ANGHL appear in both the second and seventh words and could try A = G, N = R, V = S, T = F, S = U, and X = T to get “grapes” and “grapefruit.”

A P PLE

G H H K L

G RA P E S

A N G H L V

A TER E L

M G X L N R L K Y B

B A N A N A

E G B G B G

E R R

J W L N N O

R A N G E

Y N G B A L

GR APEF RUIT

A N G H L T N S Q X

P INEAP P LE

H Q B L G H H K L

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From there logic leads to Y = O forming ORANGE. By examining what letters are left, the last word is CHERRY.

Cryptofamilies are a good place to start Cryptograms if the themes are appropriate. (I wouldn't use "Movie Directors" but would try "Australian Animals" or "Pizza toppings." They can involve taking guesses to start, but they also involve thinking about word structure, patterns in words, and the theme. The next type of puzzle I would use is one that includes a picture of an animal, plant, or famous person because they help give a good entry point to the puzzle. As skills improve, I would introduce more generic cryptograms.

Helpful Hints for Cryptograms (not as applicable for Cryptofamilies)

1.) Single letter words must be "a" or "I" unless they are a person's initial.

2.) Two letter words that start with the same letter can be "as" and "an," "if," "in," or "is," "it," "on" or "or," and "be and by." Often two consecutive two letter words represent "It is." If you think a two letter such as "PL" is "if" or "or" and then see another two letter word that begins the L such as LJ, your "if" or "or" is probably wrong because there are no two letter words that start with "F" or "R."

3.) Double letter words can help narrow down possibilities, as can writing the alphabet and crossing off letters as you assign them because there is a one-to-one correspondence.

4.) The pattern "ABCBD" could be "never, " four letter words that start and end with the same letter include "that," and the most frequently used letters in the English language are "e, t, a, i, o, n, s, h, and r."

5.) Use pencil!

Why would a math paper include word puzzles? These word puzzles include looking for patterns and the process of elimination. Many students do not read word problems critically and solving cryptograms can improve reading skills. Any puzzle that exercises one's brain makes the solver more flexible, and in some ways, more rigid of a thinker. Lastly, ANY tools that one adds to one's tools belt improves that chances of getting the job done.

Color Schemes-discrete math mapping using a maximum of 4 colors (One 45 minutes lesson with follow up puzzles for practice.)

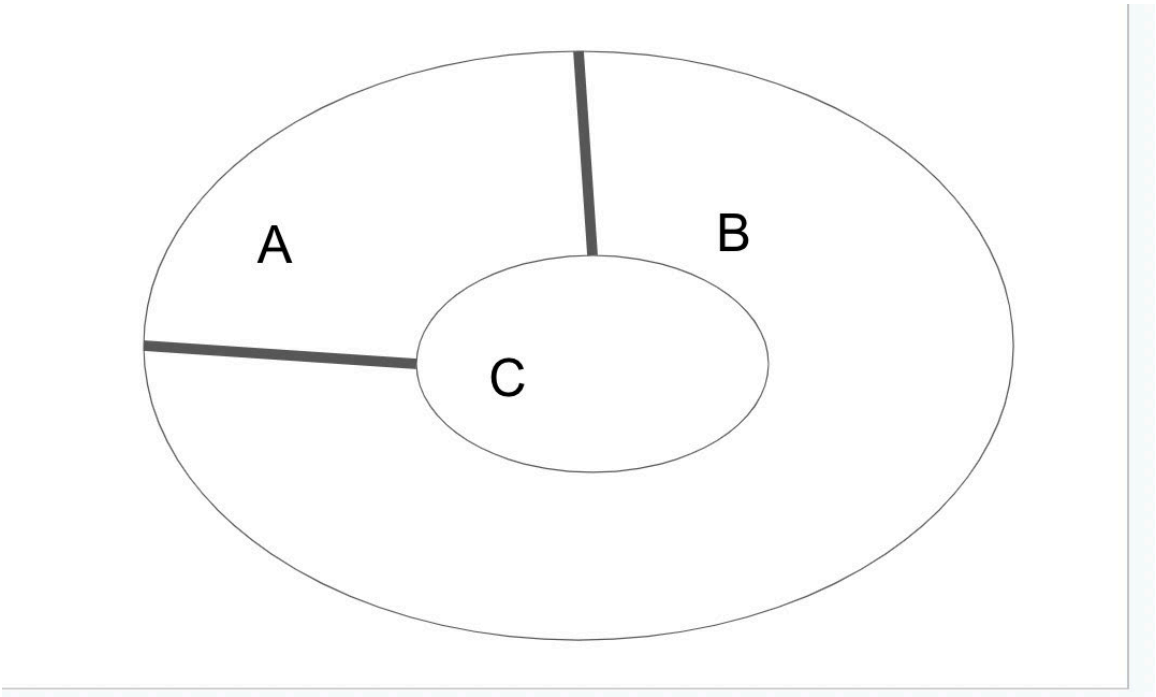
Objective: Students will be able to color in regions on a design or blank map using no more than four colors and with no adjacent regions having the same color.

Materials: Blank maps or geometric designs.

Standards of Mathematical Practice: Make Sense of Problems and Persevere in Solving Them, Look For and Express Regularity in Repeated Reasoning

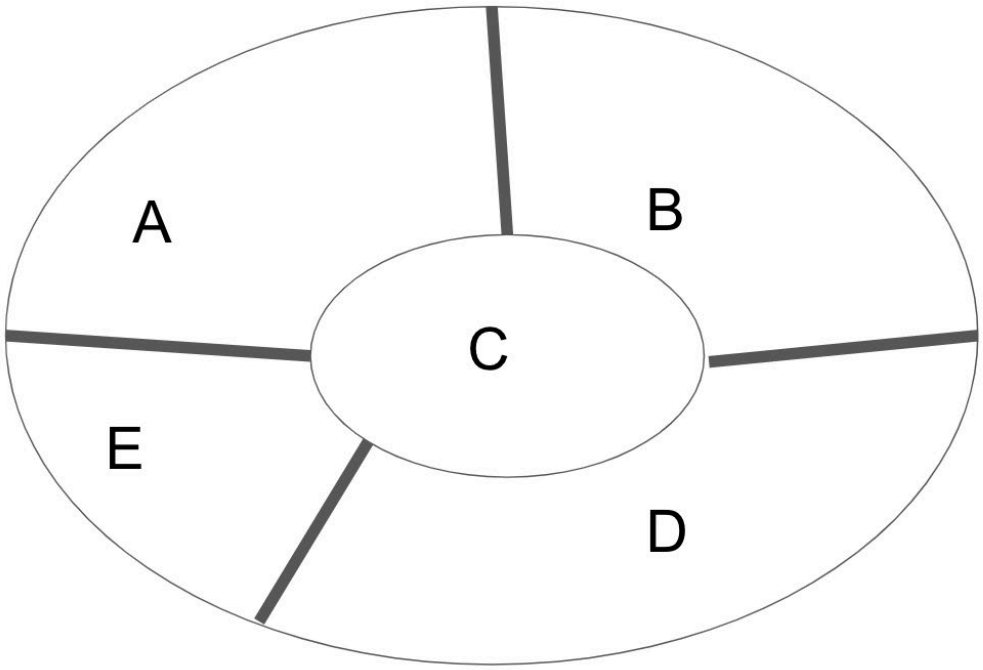
Procedures:

1.) Given the following geometric design color the three regions with as few colors as possible so that no two regions that share a border are the same color. How many colors did you need? (Correct Answer: 3. A- Color 1, B Color 2 since it touches A, C- Color 3 since it touches both A and B)



2.) Given the following geometric design color the regions with as few colors as possible so that no two regions that share a border are the same color. How many colors did you need? (Correct answer: 3. If students say 4 have a discussion of strategies and share drawings to show that only 3 are needed. A- Color 1, B- Color 2 since it touches A. C Color 3 since it touches both A and B. D can be Color 1 because it doesn't touch A and

HAS to be different than C and B which it does touch. Finally, E can be the same as B because it doesn't touch B bit does much C and D.)



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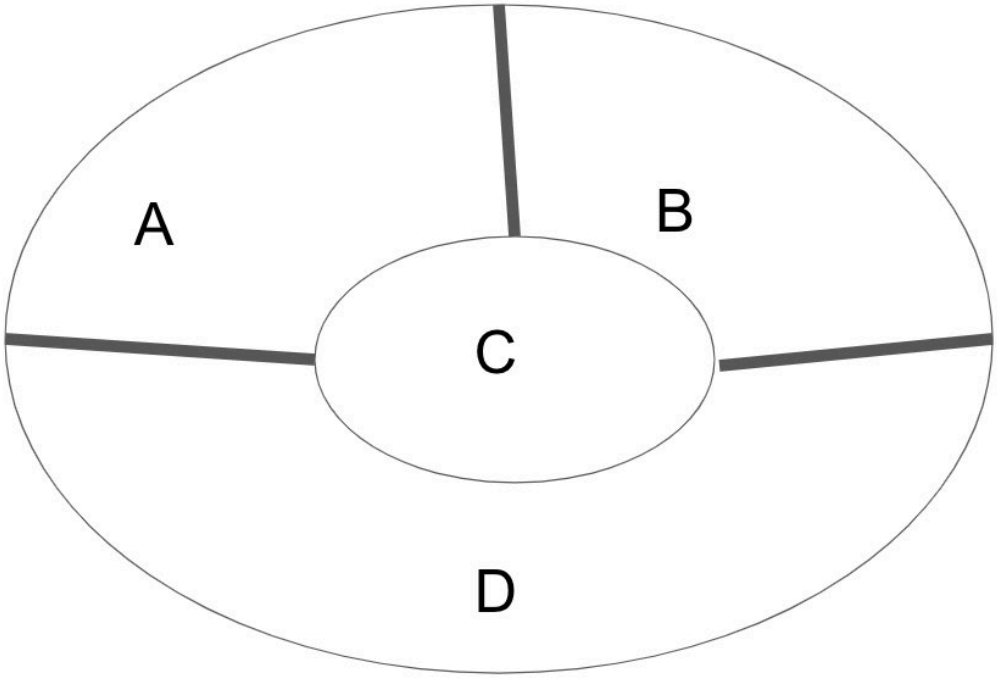

touches both A and B. D- Color 4 because it touches A, B, and C.)

4.) Challenge them to make a drawing that they think would require 5 colors and then share it with a partner to see if it can be colored with fewer than 5 colors. **If the coloring is taking two much time, students can mark the regions with numbers from 1-5.**

5.) Next, provide a map of a region of the US such as New England, Western States, Southeastern United States, etc. A map of Australia is good to use as well because it does not have an overwhelming number of states. (Google free printable blank Map of _____) The students can number the ratios to show different colors or they can use small pieces of construction paper or colored card stock. Challenge them to "color" the map with four to fewer colors.

Options: Tennessee and Missouri both border 8 other states. If students suspect that fewer colors might be needed with an odd number of surrounding states, they can use a map of Kentucky which borders 7 states.

6.) Other easily obtainable blank maps that can be used for bigger challenges are the continents, the entire Unites States, and map of your state's counties.

Resources

(krazydad Battleships Puzzle 6 x 6 Puzzles Book 1 Puzzle 8)

https://krazydad.com/battleships/sfiles/BSHIPS_6x6_v1_4pp_b1.pdf

https://www.google.com/search?q=most+frequently+used+letters+in+english