Teachers' Guide

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OREGON MUSEUM OF SCIENCE AND INDUSTRY

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Teachers' Guide

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HOW TO USE THIS TEACHERS' GUIDE

The *Teachers' Guide* to ***Mindbender Mansion*** has been written for teachers bringing students to see the ***Mindbender Mansion*** exhibit. These materials have been developed as a resource for the educator to use in the classroom before and after the museum visit and to enhance the visit itself.

The guide has several sections. The exhibit overview contains information about the contents of the exhibit. The correlation to educational standards outlines how the exhibit connects to national science, math, and technology standards. The classroom activities can be used to prepare for a visit and to continue the themes of the exhibit after a visit. The Active Learning Log is an open-ended worksheet students can fill out while exploring the exhibit.

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Exhibit Overview

Enter the wonderfully puzzling world of *Mindbender Mansion*, an eclectic place full of brainteasers and interactive challenges guaranteed to test the brainpower and problem-solving skills of even the most experienced puzzlers. Visitors to this fun and quirky mansion are invited to join the Mindbender Society by gathering hidden clues and secret passwords scattered throughout the various thematic rooms of the house. The clues and passwords are revealed by solving select brainteasers and group challenges.

Visitors are encouraged to look at problems from different perspectives, setting aside preconceived ideas to solve the individual brainteasers. They are also encouraged to collaborate with their fellow mansion guests to meet the group challenges that include manipulating a tilt table, forming patterns in rolling chairs, keeping up with a conveyer belt, maneuvering a flying machine, and disco hopscotch spelling.

Solutions to individual brainteasers, successful completion of group activities, and discovery of hidden clues and secret passwords can be combined to solve the ultimate challenge—the key to becoming a member of the Mindbender Society. Visitors of all ages will enjoy challenging their minds as they try to master each of the 40 individual brainteasers and the five, large-scale group activities located in rooms throughout this fun and unconventional mansion!

Thematic areas and exhibit components include:

ENTRY

Start at the Entry and watch a large media screen that introduces the wacky Mr. E., master brainteaser, puzzler extraordinaire, and current curator of the Mindbender Society. He will explain some key features of Mindbender Mansion and how to unlock the puzzles and become a member of the Mindbender Society. There are 40 individual brainteasers and five, large-scale group activities. To become a member, visitors must solve a total of eight to eleven select brainteasers and one, large-scale group activity. **Clue cards** are available at the Entry to help keep track of clues and passwords from the puzzles that lead to membership in the Mindbender Society. There is also a clue card in the Active Learning Log at the end of this guide.

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PARLOR

In the Parlor, there are 10 individual brainteasers—three of them provide clues toward the final challenge that determines eligibility into the Mindbender Society.

(10) Brainteasers:

- **Make a Yellow Square**
  Arrange puzzle pieces to make a yellow square.
  Clue reveal: When the puzzle is solved a clue is revealed—write down this clue on the clue card to be used to unlock the Parlor Vault.

- **Tricky Triangles**
  Start with 16 sticks arranged to form eight triangles. Remove four sticks to leave only four equal-sized triangles.
  Clue reveal: When the puzzle is solved a clue is revealed—write down this clue on the clue card to be used to unlock the Parlor Vault.

- **Every Line Adds to 18**
  Insert the numbers 1–11 so that the sum of the three numbers in any straight line is 18.
  Clue reveal: When the puzzle is solved a clue is revealed—write down this clue on the clue card to be used to unlock the Parlor Vault.

- **Six Pegs That Don't Line Up**
  Place six pegs in holes on a square board so that no peg lines up with another peg along a vertical, horizontal, or diagonal line.

- **Make a Green Square**
  Arrange puzzle pieces to make a green square.

- **Move the Ring**
  Move one of the rings on the rope from one side of the knot to the other, without untying the knot.

- **15 Sticks**
  Starting with 15 sticks arranged in a pattern on the exhibit board, remove six of them to leave 10.

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- **String Houses**
  Use a rope to trace the outline of two houses without crossing or retracing your path. One house is impossible to trace. Which one is it?

- **10 Pegs, Even Lines**
  Starting with 10 pegs in a pattern, move two pegs so that every row and column has an even number of pegs.

- **Four Equations**
  Arrange the numbers 1–9 on the board so that four different equations are mathematically correct.

Parlor Vault
Set the dials of the Parlor Vault to the three clues that were revealed after successfully solving the three Parlor Brainteasers: "Make a Yellow Square," "Tricky Triangles," and "Every Line Adds to 18." If successful, a video will play where Mr. E. introduces a new educational concept related to the brain or problem solving. Visitors will then be entertained by a short, zany animation introducing a real-life inventor. At the end of the animation, Mr. E. will reveal a password that will be needed to unlock the Wall of Fame Vault that determines eligibility into the Mindbender Society.

LIBRARY
In the Library, there are six individual brainteasers—three of them provide clues toward the final challenge that determines eligibility into the Mindbender Society.

(6) Brainteasers:

- **Make a T**
  Arrange four puzzle pieces to make a capital T.
  Clue reveal: When the puzzle is solved a clue is revealed—write down this clue on the clue card to be used to unlock the Library Vault.

- **Color Match**
  Arrange six hexagons around a central hexagon so that all adjacent colors match.
  Clue reveal: When the puzzle is solved a clue is revealed—write down this clue on the clue card to be used to unlock the Library Vault.

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- **Every Line Adds to 15**
  Insert numbers 1–9 so that the sum of the three numbers in any straight line (vertical, horizontal, and diagonal) is 15.
  Clue reveal: When the puzzle is solved a clue is revealed—write down this clue on the clue card to be used to unlock the Library Vault.

- **Square or Triangle**
  Arrange four puzzle pieces to form a square or triangle.

- **Horse and Rider**
  Place the puzzle pieces so that there is one rider riding each horse correctly (right side up and facing forward).

- **Take Away**
  In this game of strategy for two players, players take turns removing pegs from the game board. The player who takes the last peg loses.

Library Vault
Set the dials of the Library Vault to the three clues that were revealed after successfully solving the three Library Brainteasers: "Make a T," "Color Match," and "Every Line Adds to 15." If you are successful, a video will play where Mr. E. introduces a new educational concept related to the brain or problem solving. Visitors will then be entertained by a short, zany animation introducing a real-life inventor. At the end of the animation, Mr. E. will reveal a password that will be needed to unlock the Wall of Fame Vault that determines eligibility into the Mindbender Society.

KITCHEN

In the Kitchen, there is one, large-scale group activity ("Feeding Frenzy"*)* and four, individual brainteasers. Visitors must be successful at the "Feeding Frenzy" activity and two of the Kitchen Brain Teasers to receive clues toward the final challenge that determines eligibility into the Mindbender Society.

Feeding Frenzy
In this large-scale activity, teamwork is necessary to successfully meet the challenge: to fill a minimum number of TV dinner trays (with five kinds of food) on a moving conveyer belt within the specified amount of time. Visitors can select a level of play (easy, medium, or hard) that determines the speed of the conveyer belt. Points are given for each

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TV dinner tray successfully filled, but no points are given for trays partially filled.
Clue reveal: If a team scores enough points and the minimum number of trays has been filled, a clue is revealed onscreen—write down this clue on the clue card to be used to unlock the Kitchen Vault.

(4) Brainteasers:

- **Shifting Squares**
  Start with 16 sticks arranged to form five squares. Move only two sticks to make four squares using all 16 sticks.
  Clue reveal: When the puzzle is solved a clue is revealed—write down this clue on the clue card to be used to unlock the Kitchen Vault.

- **Disorder**
  Arrange the numbers 1–8 on the board so that no two consecutive numbers touch.
  Clue reveal: When the puzzle is solved a clue is revealed—write down this clue on the clue card to be used to unlock the Kitchen Vault.

- **Balancing Nails**
  Balance 14 nails on the head of one nail.

- **Make a Cube**
  Put seven puzzle pieces together to make a cube.

Kitchen Vault
Set the dials of the Kitchen Vault to the three clues that were revealed after successfully solving the "Feeding Frenzy" activity and two Kitchen Brainteasers: "Shifting Squares" and "Disorder." If successful, a video will play where Mr. E. introduces a new educational concept related to the brain or problem solving. Visitors will then be entertained by a short, zany animation introducing a real-life inventor. At the end of the animation, Mr. E. will reveal a password that will be needed to unlock the Wall of Fame Vault that determines eligibility into the Mindbender Society.

MAP ROOM
In the Map Room, there is one, large-scale group activity ("Amazing Maze"*)* and four, individual brainteasers—three of the Map Room Brainteasers provide clues toward the final challenge that determines eligibility into the Mindbender Society.

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Amazing Maze
In this large-scale activity, up to four visitors work together to tilt a table in different directions, guiding a ball into several holes as quickly as possible in the allotted time. A scoreboard keeps tally and counts down the remaining time left in the game.

(4) Brainteasers:

- **Six Blocks in a Box**
  Fit six blocks together so they fit perfectly into a box and the lid can be closed.
  Clue reveal: When the puzzle is solved a clue is revealed—write down this clue on the clue card to be used to unlock the Map Room Vault.

- **10 Pegs in Each Line**
  Place pegs in each of eight boxes so there are 10 pegs in each line.
  Clue reveal: When the puzzle is solved a clue is revealed—write down this clue on the clue card to be used to unlock the Map Room Vault.

- **One Shape Fits All**
  From a group of differently-shaped blocks, find the one block that completely fills all three differently-shaped holes as it passes through.
  Clue reveal: When the puzzle is solved a clue is revealed—write down this clue on the clue card to be used to unlock the Map Room Vault.

- **Build a Pyramid**
  Using two, identically-shaped blocks, put them together to form a pyramid.

Map Room Vault
Set the dials of the Map Room Vault to the three clues that were revealed after successfully solving the three Map Room Brainteasers: "Six Blocks in a Box," "10 Pegs in Each Line," and "One Shape Fits All." If successful, a video will play where Mr. E. introduces a new educational concept related to the brain or problem solving. Visitors will then be entertained by a short, zany animation introducing a real-life inventor. At the end of the animation, Mr. E. will reveal a password that will be needed to unlock the Wall of Fame Vault that determines eligibility into the Mindbender Society.

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DISCO ROOM

Spelling Fever

In this large-scale, full-body activity, teamwork is necessary to successfully meet the challenge: to correctly spell a minimum number of words within a limited amount of time by hopping on letter squares. Start the game by touching the small screen at one end of the dance floor. Instructions are given on a large screen above the floor and the game begins when a randomly generated question appears on the large screen. The challenge is to think of the answer to the question (with help from anyone nearby) and spell it out by plotting a course down the floor and hopping on the correct letters. Visitors must land at the far end of the floor to submit their answer. If the answer is correct, they score points and then hurry back to the starting point to spell another word, or a team member can start spelling the next answer to save time and increase total points.

DINING ROOM

Move and Match

In this large-scale, full-body activity, teamwork is necessary to successfully meet the challenge. Players maneuver dining room chairs into a correct pattern within the specified amount of time. Four players each sit in a different colored chair in an enclosed pen. A pattern is revealed on-screen and the four teammates work together to maneuver their chairs into the correct pattern by using their arms to push off of one another and the pen walls. There is a second pen, so if there are eight players each pen can play against the clock and also the other pen.

Note: This activity is facilitated by museum staff.

Dining Room Tabletop Puzzle

This “Tabletop Puzzle” is for those visitors who cannot or would rather not engage in the full-body “Move and Match” activity. Four colored tiles are embedded into the tabletop and can be moved to form different patterns.

REC ROOM

In the Rec Room, there is one, large-scale group activity (“Flying Machine”) and 18 individual brainteasers.

Flying Machine

In this large-scale activity, teamwork is necessary to successfully meet the challenge. Players move a mechanical “flying machine” around a large game board hitting six targets in sequence within a specified

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amount of time. Four players work together to move the flying machine to land on the six targets. If a target is successfully hit, it lights up and the next target in the sequence begins to flash.

(18) Brainteasers:

- **Four Blocks in a Box**
  Fit four blocks together in one box so that none of the blocks sticks out above the top. Then try it with the other box.

- **Triangle or Hexagon**
  Arrange six puzzle pieces to form a triangle or hexagon.

- **Take-Apart Cross**
  Separate a seemingly solid cross into two pieces and then put them together again.

- **Make a Blue Square**
  Arrange the puzzle pieces to make a blue square.

- **Five-Room House**
  On the exhibit board is a plan of a five-room house and a rope. Pass the rope through each and every door only once without crossing the rope over itself or over a wall. (NOTE: This puzzle is impossible to solve—can you figure out why?)

- **Tie the Knot**
  Tie or untie the knot that is in the center of the rope.

- **Linked Hearts**
  Separate two linked hearts and then put them back together again.

- **Make a Square**
  Starting with four puzzle pieces arranged in a pattern, move only one piece to make a square.

- **Six Sticks**
  Arrange six sticks so that they form eight, equilateral triangles of any size.

- **A Perfect Fit**
  Fit four T-shaped puzzle pieces so that they lay flat within a large frame. Then fit them into an even smaller frame.

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- **Horseshoes**
  Remove a ring from a pair of linked horseshoes and then put the ring back on.

- **Galloping Horse**
  Put three puzzle pieces together to make a galloping horse.

- **Handcuffs**
  Untangle the ropes without removing the "handcuffs" from your wrists.

- **Crossing the River**
  Help a farmer transport a fox, a chicken, and a bag of corn across a river in a small boat—without any casualties.

- **10-Disk Triangle**
  Invert a triangle made up of 10 disks by moving only three disks.

- **Two Balls in a Rocker**
  Move two balls that sit near the center of a rocker to opposite corners.

- **Tower of Brahma**
  Move a pile of disks from one peg to another peg, following some simple rules.

- **Jumping Pegs**
  Start with four, white pegs and four, black pegs at opposite ends. Jump or move the pegs one space at a time to switch the positions of the white and black pegs.

WALL OF FAME

Now it's time for visitors to see if they are eligible to become a member of the Mindbender Society and possibly add their portrait to the "Mindbender Society Wall of Fame." Several framed portraits of esteemed members of the Mindbender Society decorate this area and there is room for new members too!

To join, visitors must enter the three to four passwords they have gathered from the four rooms of the mansion: Parlor, Library, Map Room, and Kitchen into the final vault at the Wall of Fame. If they are successful, they are officially an expert problem-solver and invited into the Society! If they are not successful, visitors are told to keep trying

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and check out the areas of the mansion that provide the clues and passwords.

If a visitor is invited to join the Mindbender Society, they can have their picture taken and personalize their portrait with a background, “thinking cap,” funny hair, etc. Once they’ve finished their portrait, they can print out their official Mindbender Society certificate with their personalized portrait and take it home. In addition, their portrait will go up on the Wall of Fame for all to see, in one of the four monitors available to highlight the newest members of the Mindbender Society!

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CORRELATION TO EDUCATIONAL STANDARDS

Mindbender Mansion provides connections to science, technology and mathematics content. The primary focus of the exhibition is problem solving, often with a mathematical emphasis. Through exhibit activities, visitors will practice the problem-solving skills that are used to explore the world through scientific inquiry and mathematics.

Research has shown that students learn science and math best when provided with a constant succession of challenges. Tasks of moderate difficulty—hard enough to facilitate learning without being so hard as to discourage—give students' minds the exercise they need to develop new skills. Problem solving is a central skill in science and mathematics and key to understanding the process of science.

Puzzles are an excellent tool to teach and practice problem-solving skills. ***Mindbender Mansion*** engages students in a wide range of ages by providing hands-on experiences solving puzzles. Most of the puzzles in ***Mindbender Mansion*** have a mathematical foundation. Sometimes the math is obvious, with numbers and equations, other times the math is more subtle. All these puzzles build problem-solving skills, demand creativity, build on prior knowledge, and encourage lateral thinking.

The multiple group activities build communication and teamwork skills, as groups of visitors work together to solve puzzles cooperatively.

To help students connect the abstract puzzles they are solving in the exhibit to real-life situations, the exhibit also features four short animations highlighting historical inventors. Each person saw a problem and solved it by creating a new invention.

SCIENCE

Science themes explored in ***Mindbender Mansion*** include:

- Patterns and relationships
- Communication of ideas
- Motions and forces
- Interdependence of organisms (food webs)

These concepts are found in the National Science Teachers Association (NSTA) science content standards. More information is on the NSTA website: http://www.nsta.org/

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TECHNOLOGY

Technology themes explored in ***Mindbender Mansion*** include:

- Role of society in developing new technologies
- Influence of technology on history
- The role of problem solving in invention
- Identifying patterns
- Communication

These concepts are found in the International Technology Education Association (ITEA) science content standards. More information is on the ITEA website: http://www.iteaconnect.org/

MATHEMATICS

The activities in ***Mindbender Mansion*** support a range of cognitive mathematics-related abilities in visitors from kindergarten through adult. The target group for ***Mindbender Mansion*** consists of children in grades 3 and up. A secondary target group is comprised of their families since cooperative experiences are encouraged by the activities.

Many activities will be appreciated by visitors regardless of whether or not they are in the target groups.

Mindbender Mansion offers opportunities that provide visitors with an engaging and stimulating experience where they:

- Solve puzzles
- Use creative-thinking and problem-solving strategies
- Consider problems from different perspectives

The activities support mathematics standards and benchmarks in the two primary compilations of standards for mathematics education: "2061: Science for All Americans" and the National Council of Teachers of Mathematics (NCTM).

Specifically, ***Mindbender Mansion*** addresses the following for grades 3 through 5 in the guidelines from "2061" and NCTM:

"2061: Science for All Americans"

Benchmark: Patterns and Relationships

- Mathematics is the study of many kinds of patterns, including numbers and shapes and operations on them. Sometimes patterns are studied because they help to explain how the world works or how to solve practical problems, sometimes because they are interesting in themselves.

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- Mathematical ideas can be represented concretely, graphically, and symbolically.

Benchmark: Mathematical Inquiry

- Numbers and shapes-and operations on them-help to describe and predict things about the world around us.
- In using mathematics, choices have to be made about what operations will give the best results. Results should always be judged by whether they make sense and are useful.

National Council of Teachers of Mathematics (NCTM)

There are 10 standards specified by NCTM:

- Numbers and Operations
- Algebra
- Geometry
- Measurement
- Data Analysis and Probability
- Problem Solving
- Reasoning and Proof
- Communication
- Connections
- Representation

Activities in ***Mindbender Mansion*** support expectations for seven of these standards in grades 3 through 5. Several of the standards are appropriate for all grades, K–12, and are so indicated.

Numbers and Operations

- Understand numbers, ways of representing numbers, relationships among numbers, and number systems
- Understand meanings of operations and how they relate to one another

Algebra

- Understand patterns, relations, and functions

Geometry

- Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships
- Apply transformations and use symmetry to analyze mathematical situations
- Use visualization, spatial reasoning, and geometric modeling to solve problems

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Problem Solving (K–12)

- Build new mathematical knowledge through problem solving
- Solve problems that arise in mathematics and in other contexts
- Apply and adapt a variety of appropriate strategies to solve problems
- Monitor and reflect on the process of mathematical problem solving

Reasoning and Proof (K–12)

- Recognize reasoning and proof as fundamental aspects of mathematics
- Make and investigate mathematical conjectures
- Select and use various types of reasoning and methods of proof

Communication (K–12)

- Organize and consolidate mathematical thinking through communication
- Communicate their mathematical thinking coherently and clearly to peers, teachers, and others
- Analyze and evaluate the mathematical thinking and strategies of others

Connections (K–12)

- Recognize and use connections among mathematical ideas
- Recognize and apply mathematics in contexts outside of mathematics

Representation (K–12)

- Select, apply, and translate among mathematical representations to solve problems
- Use representations to model and interpret physical, social, and mathematical phenomena

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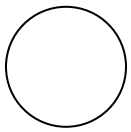
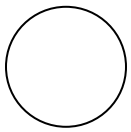
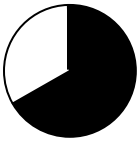
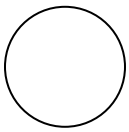
Puzzles on the Bus

Description: Students solve puzzles on their way to the museum.

Learning Objectives: Students will learn to think creatively.

SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVEL
Logic	Listening Predicting	3–8

TIME REQUIRED

Advance Preparation	Set Up	Activity	Clean Up
			
0 minutes	**0 minutes**	**40 minutes**	**0 minutes**

SUPPLIES

- A stick (Alternate options: chalk or dry-erase pen or your finger)
- Dirt (Alternate option: pavement or glass or the air)

ADVANCE PREPARATION

- None

SET UP

- Clear some dirt to draw a figure in (or find pavement to write on with chalk).

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INTRODUCING THE ACTIVITY

Let students speculate before offering answers to any questions. The answers at the right are provided primarily for the teacher's benefit.

Have you ever figured out a puzzle that seemed hard when you started? Do you remember something that was hard two years ago that seems easy now?

Then let's try this….

TEACHER DEMONSTRATION

These are puzzles you can challenge your students with while riding the bus to and from the museum, while eating lunch, or anywhere else.

Four Is the Magic Number
Tell your students that four is the magic number. Every number goes back to four. Ask for a number to demonstrate with. For example, eight is 5, five is 4, and four is the magic number. Continue to show how all numbers lead to four.

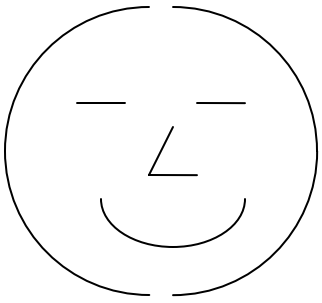
As students figure out the rule of the puzzle, allow them to answer questions. Try to have students solve the puzzle not by telling the answer, but by showing they can follow the rule.

Solution: Count the number of letters in the number. Eight is five because "eight" has five letters. Five is four because "five" has four letters.

If your students are struggling to figure out the puzzle, note that "one hundred" is 10, but "a hundred" is eight. Also "minus one" is eight, while "negative one" is 11.

The Man in the Moon
In this puzzle you draw a crude face. You can draw it in dirt with a stick or on a window with a dry-erase pen or on a chalkboard or even in the air with your finger. Every time you draw the drawing, you recite the exact same words:

Listen and watch carefully.	[cough]
This is the moon.	[draw left semicircle]
This is the man in the moon.	[draw right semicircle]
This is his eye.	[draw eye]
This is his other eye.	[draw eye]
Here's his nose.	[draw nose]
And here's his mouth.	[draw mouth]



Can you do it exactly the way I did it? [hand stick/pen/chalk to student]

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The rule for this puzzle is that if and only if you cough, you have done it correctly. You may draw the man in the moon in **any** way, and you have done it right.

To make the puzzle harder, don't correct students right away but wait until they are done drawing, or halfway done. To make the puzzle easier, make your repeated drawings obviously different.

As students figure out the rule of the puzzle, allow them to demonstrate. Try to have students solve the puzzle not by telling the answer, but by showing they can follow the rule.

Ships Are Sailing

Ships Are Sailing is a game about finding patterns. To play, one person (the captain) secretly decides what categories of cargo he or she will take in his or her ship. The captain can choose two different categories of things to take or choose a way that two things can relate to one another. For example, the captain could choose the categories:

> ***Furry*** and ***pink***
> ***Scary*** and ***calming***
> One item that ***starts with S*** and one item that ***ends with S***
> ***Goes on things*** and ***goes under things***

Setting the puzzle:

- The captain shows that they are ready to start playing by saying, "Ships are sailing."
- One of the players (a crew member) responds by asking, "And what are they carrying?"
- The captain names two cargo items that match the secret categories. For example, if the categories are ***furry*** and ***pink***, the captain could say "kittens and fingernail polish."

Solving the puzzle begins:

1. A crew member repeats the process, guessing what might be in the hold. The crew member says, "Ships are sailing."
2. Another crew member or the captain replies with, "And what are they carrying?"
3. The crew member then guesses two items that they think might go on the boat. For example, they might guess, "puppies and hair spray."
4. The captain then tells the crew which items fit the categories and would sail. In this example, the puppies go (they are furry) but the hair spray does not (it is not pink).

- The crew and captain repeat steps 1 to 4 until crew members figure out the secret categories and can consistently guess what would sail.
- When everyone has figured it out, or if the round has gone on too long, the captain can reveal the categories of cargo.
- Encourage students to show they know the answer by showing they can follow the rule, rather than stating the rule aloud.

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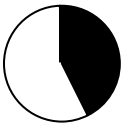
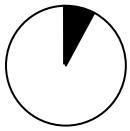
Acting Out

Description: Students solve puzzles as a group.

Learning Objectives: Students will learn that good communication is essential in problem solving.

SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVEL
Addition Food Chains Topology	Critical Thinking Experimentation Communication	4–8

TIME REQUIRED

Advance Preparation	Set Up	Activity	Clean Up
			
5 minutes	**5 minutes**	**25 minutes**	**5 minutes**

SUPPLIES

- Paper or index cards
  Optional: for Trading Places activity use multiple colors including black (1), orange (1), white (5), and green (5) or Master B: Frog, Rabbit, Carrot and Fly
- Masking tape
- Pens
- Secret Card Optional Extension: deck of cards
- Photocopies of Master A: Puzzle Rules

ADVANCE PREPARATION

- Mark four pieces of paper or index cards for Farmer Puzzle:
  - One “Fox,” one “Hen,” one “Grain,” one “Farmer.”

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- Gather 12 pieces of paper for Trading Places activity (can be used papers ready to be recycled):
  - Make five copies of the frog and rabbit from Master B and one copy of the fly and carrot.

  OR:
  - five white (rabbit)
  - five green (frog)
  - one orange (carrot)
  - one black (fly)
  - (Optional: have students cut or draw rabbits, frogs, carrot, and fly on the paper)

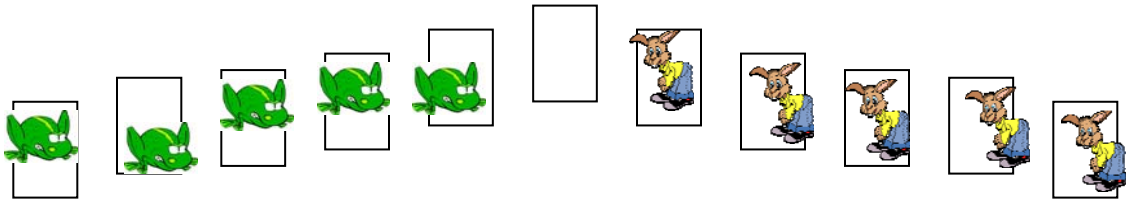
- Photocopy Master A: Puzzle Rules, one per group or one per student to facilitate students' reading of the puzzle.

- Secret Card Extension: Separate the deck of cards by suit.

SET UP

Trading Places:

- Make 11 squares in a semicircle on the ground with masking tape. These squares represent "rocks" in a pond. Place them far enough apart for students to stand on them in a line, but close enough together so they can step from one to the next.
- Place the orange paper carrot at one end of the row.
  Place the black paper fly at the other end of the row.
- Put the white rabbit pages on top of the "rocks" at one end, leave the middle square empty, and put the green frog pages on the "rocks" at the other end.



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INTRODUCING THE ACTIVITY

Let students speculate before offering answers to any questions. The answers at the right are provided primarily for the teacher's benefit.

Ask the students the following questions in **bold**. Possible student answers are shown in *italics*.

Students will work together in a group to solve one or more puzzles. You may want to have a discussion with students about what rules of conduct are necessary to work in a group successfully.

We're going to solve some puzzles. You will need to work together to solve these puzzles.

What are some things that people need to do to work successfully as a group?
People need to take turns talking. No one should yell. Everyone should listen when someone is talking.

First, I'll explain the rules of each puzzle.

Then talk to each other and decide how to solve the puzzle.

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CLASSROOM ACTIVITY

Divide the students into groups. Give each group a puzzle to solve. Alternatively, have a few volunteers act out the puzzle while everyone discusses how to solve it.

In all of these classic puzzles, a few students will take the role of the puzzle pieces. They will need to discuss how best to solve the problem.

Farmer Puzzle: A farmer needs to cross a river in a boat. The farmer has brought along a fox, a hen, and some grain. The boat is too small to take them all. In fact, the boat can hold only the farmer and one of the things he has brought. If the fox and hen are left alone, the fox will eat the hen. If the hen and grain are left alone, the hen will eat the grain. How can the farmer get everything across?

Assign one student to be the farmer, one to be the fox, one to be the hen, and one to be a sack of grain. Remind the fox to eat the hen if left alone, and remind the hen to eat the grain if left alone.

Solution: The farmer should take the hen across, then come back for the fox. On the other side, the farmer should bring the hen back, then bring the grain across. Finally, the farmer returns for the hen and brings the hen across.

Trading Places:
Five students are rabbits. Each rabbit holds a white paper.
Five students are frogs. Each frog holds a green paper.
There are eleven rocks in a row on the ground. A fly is at one end of the row of rocks. A carrot is at the other end of the row of rocks.
The five rabbits stand on five rocks at one end of the row of rocks close to the fly.
The five frogs stand on five rocks at the other end of the row of rocks next to the carrot. All frogs and rabbits face the empty rock in the middle.
Only one frog or rabbit will move at a time.
Frogs and rabbits can jump forward one or two rocks. Frogs and rabbits can never jump backwards.
At the end of the puzzle, all the rabbits should be by the carrot (where the frogs started), and the frogs should be by the fly (where the rabbits started).

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Solution:

Never bring two of the same animals together until they are at the far end.

FFFFF_RRRRR	FFRFR_RFRFR	RFR_RFRFRFF
FFFF_FRRRRR	FFR_RFRFRFR	R_RFRFRFRFF
FFFFRF_RRRR	F_RFRFRFRFR	RR_FRFRFRFF
FFFFRFR_RRR	_FRFRFRFRFR	RRRF_FRFRFF
FFFFR_RFRRR	RF_FRFRFRFR	RRRFRF_FRFF
FFF_RFRFRRR	RFRF_FRFRFR	RRRFRFRF_FF
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FFRFRFRF_RR	RFRFRFRFR_F	RRRR_FRFFFF
FFRFRFRFR_R	RFRFRFR_RFF	RRRRRF_FFFF
FFRFRFR_RFR	RFRFR_RFRFF	RRRRR_FFFFF

CLASS DISCUSSION

What worked well as you were trying to solve the puzzles?
What could you have done differently that would have worked better?
What would have been easier if you were working alone?
What would have been harder if you were working alone?

Answers will vary.

If you chose to solve the puzzles in two rounds, you may want to ask the class these questions.

What was different the second time you solve a puzzle as a group?
Was it easier the second time? Harder?
What did you learn from the first experience that you could use in the second experience?

Answers will vary.

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OPTIONAL EXTENSIONS

A. Human Knot

Have every student in class stand in a circle. Everyone sticks their hands into the middle of the circle and grabs a random hand. Once everyone is holding two other hands, they have to work together, without letting go, to move back into a circle.

(Some students may end up facing out of the circle, and there can sometimes be multiple separate circles).

B. Secret Card

Separate your class into groups of 13 or smaller. Give each group ¼ of a deck of cards, all the same suit. Have each group deal one card to each student, without looking at the card. Everyone should hold their card on their forehead, so they don't know what card they have, but everyone else can see it.

Each group now must order themselves in a line, from king down to ace. They may talk to each other, but they may not reveal which card anyone is. One way to do this is to pretend they are at a royal ball at the palace, thrown by the king and queen. Everyone should bow to someone they think is higher than them, and look down at people they think are lower.

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Puzzle Rules

Farmer Puzzle
A farmer needs to cross a river in a boat. The farmer has brought along a fox, a hen, and some grain. The boat is too small to take them all. In fact, the boat can hold only the farmer and one of the things he has brought.

- If the fox and hen are left alone, the fox will eat the hen.
- If the hen and grain are left alone, the hen will eat the grain.

How can the farmer get everything across safely?

Trading Places: Five students are rabbits, and five students are frogs. Eleven rocks are lined up in a pond. To start the puzzle, each frog and rabbit stands on its own rock and faces the empty rock in the middle. Frogs line up next to the carrot. Rabbits line up next to the fly.

- Only one rabbit or frog may move at a time.
- Frogs and rabbits may jump forward.
- Frogs and rabbits never jump backwards.
- Frogs and rabbits can only jump one space or two spaces, no farther.
- Frogs and rabbits can move only onto an empty rock.

At the end of the puzzle, all the rabbits should be where the frogs started beside the carrot, and the frogs should be where the rabbits started, beside the fly.

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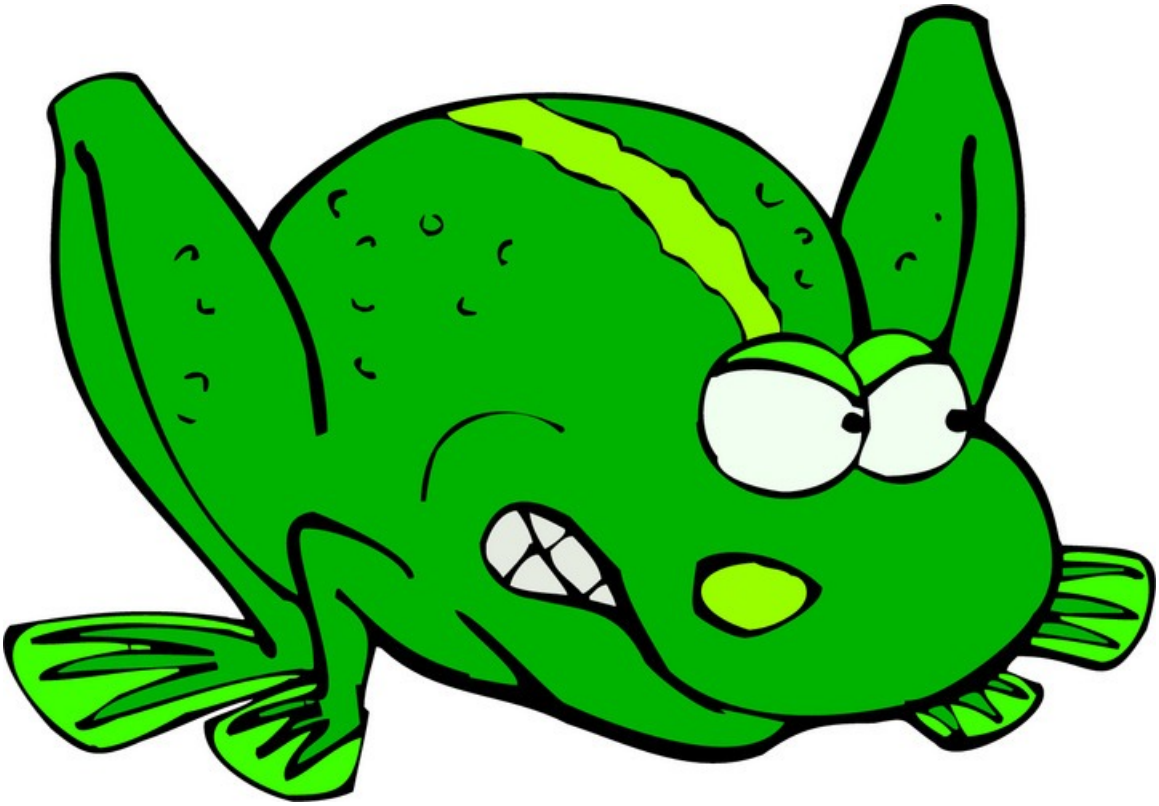

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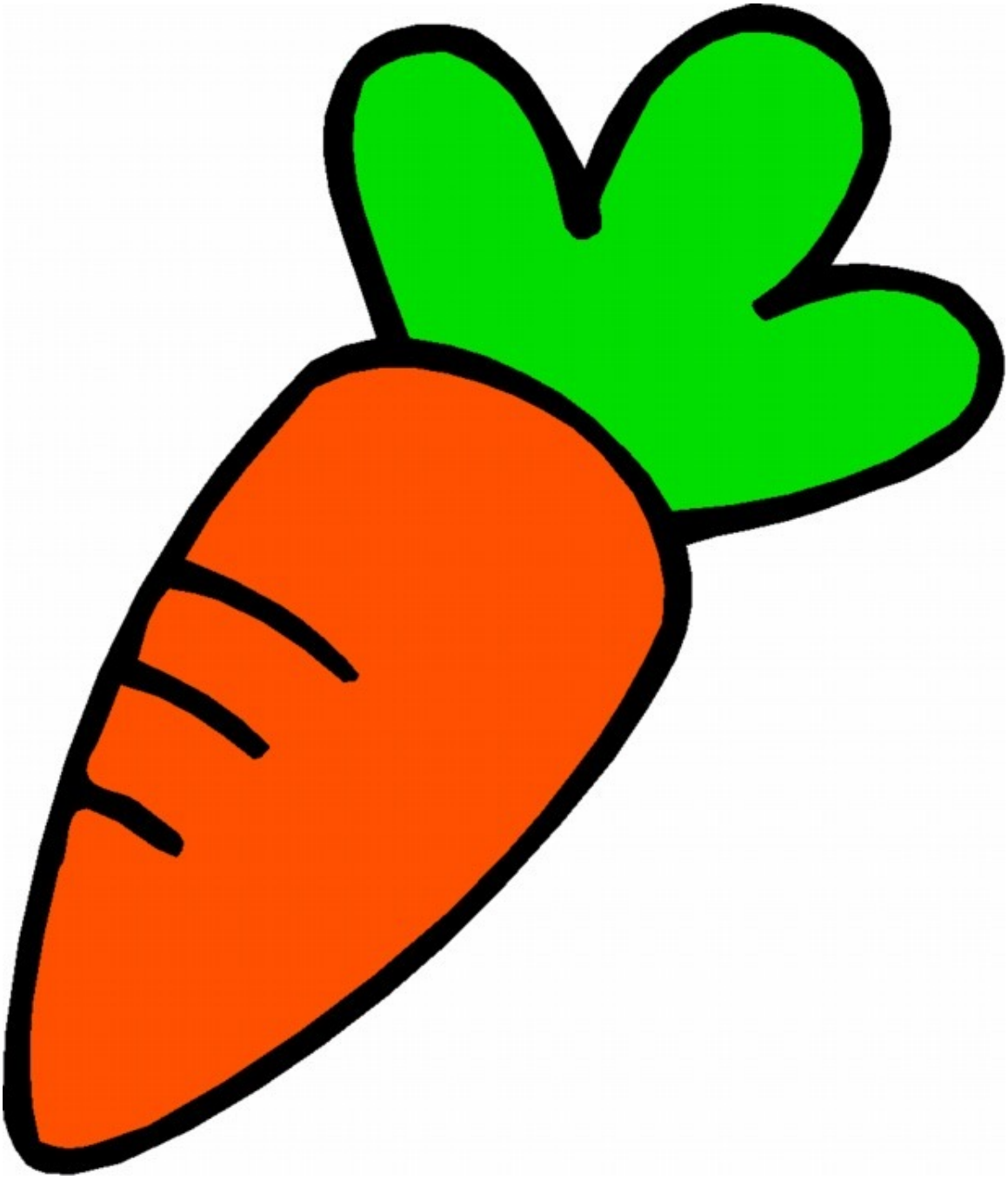

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Circular Logic

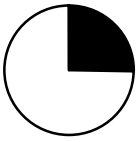
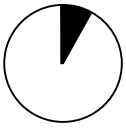
Note: Some of the puzzles in *Mindbender Mansion* depend on centripetal acceleration for their solution. This lesson is an extension of that topic.

Description: Students will make predictions based on observing objects in motion.

Learning Objectives: Students will be able to demonstrate their understanding of centripetal force by describing, comparing, and predicting the motion of objects.

SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVEL
Physics of Motion Centripetal Acceleration	Observing Predicting Describing	K–5

TIME REQUIRED

Advance Preparation	Set Up	Activity	Clean Up
			
15 minutes	**5 minutes**	**20 minutes**	**5 minutes**

SUPPLIES

- A bucket with a handle
- A rope (1 meter or longer)
- Something to put in the bucket (water, confetti, Ping-Pong balls, etc.)
- A broken hula hoop (or other flexible, curvy thing you can destroy—garden hose, electric cable, etc.)
- Saw to cut hoop
- An intact hula hoop (or any other round thing—garbage can lid, Frisbee, etc.—ideally, the same thing as the broken one above)
- Small ball (golf ball, marble, 2 cm ball bearing, etc.)

SAFETY PRECAUTION: Keep choke hazards away from young students.

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ADVANCE PREPARATION

- Cut ¼ of broken hula hoop off so ¾ of the circle remains. (The hoop should go through 270 degrees.) Alternatively, cut a length of hose or stiff tubing that can simulate ¾ of a hula hoop.
- Tie rope securely to bucket handle.

SET UP

- Gather supplies: bucket, rope, two hula hoops (or alternative) and small ball.

INTRODUCING THE ACTIVITY

Let students speculate before offering answers to any questions. The answers at the right are provided primarily for the teacher's benefit.

Ask the students the following questions in **bold**. Possible student answers are shown in *italics*.

Have you ever played with a hula hoop before?
Yes. No. It's my favorite toy ever.

(Set the hoop flat on the floor.)
I'm going to roll this ball around the inside of this hoop. What do you think will happen?
It will roll around in a circle, touching the hoop.

(Roll the ball around the inside edge of the hoop.)
Can you trace the motion of the ball in the air with your hand?
Students draw circles in the air.

Why does the ball touch the edge when it rolls around the hoop?
Answers will vary.

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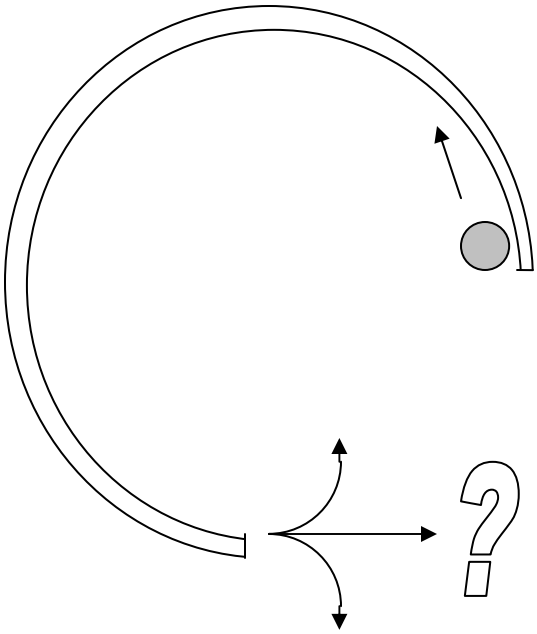
TEACHER DEMONSTRATION

Part 1: Broken Hoop



After rolling the ball around inside the normal hula hoop, explain that you are going to do the same thing with the broken hoop. Ask students to predict what will happen when the ball reaches the end of the hoop. Which way will the ball go?
Have students predict the path of the ball by tracing it in the air with their hand or by drawing it on paper.

The ball will move straight once the hoop is no longer touching it. This is a demonstration of Newton's first law of motion: moving things move in a straight line unless something pushes or pulls on them.

For older students: on each part of the hula hoop, draw an arrow to show what direction the ball is moving at that point. The arrows will be straight lines tangent to the circle. At each point the ball is moving straight, but the hula hoop pushes it to change direction. Once the ball reaches the end of the hula hoop, there is no longer a force to make it change direction, so it continues going straight.

Part 2: The Bucket

(Note: Although the water should stay inside the bucket, you may choose to perform this part of the demonstration outdoors.)

Next show the class the bucket. Pour water (or confetti or something else) into the bucket. Ask the class what will happen if you turn the bucket upside down.

Now swing the bucket back and forth on the rope, eventually fast enough to go in a full vertical circle above your head (the same circle that you move in on a Ferris wheel). Carefully slow the bucket down without spilling any water. End the demonstration by pouring the water out of the bucket and showing the bottom of the bucket so the students can see that the water remained inside the bucket and that a normal bucket was used.

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CLASS DISCUSSION

Ask for student observations. There is no correct answer. Let students guide the discussion and present their hypotheses before discussing explanations.

What happened to the water in the bucket?

Why didn't it fall out?

The water stayed in the bucket because of its *inertia* and the force that was pulling on it—*centripetal acceleration*.

Things move when a *force* pulls or pushes on them. Examples of forces that push or pull are: hitting a ball with a bat (pushing), moving a wagon by the handle (pulling), or gravity pulling you toward the Earth.

Acceleration is a big word that means changing motion. When a car speeds up, or slows down or turns, it accelerates. The bucket is turning in a circle, so it's accelerating. And the *force* that makes it *accelerate* comes from the rope pulling on it.

Just like the hula hoop kept the marble going in a circle, the rope kept the bucket moving in a circle. While gravity is pulling on the water, the water was pulled more to the side, and gravity wasn't strong enough to pull it down. The force of the bucket pulling the water to the side is more than the force of gravity pulling it down. The bucket kept the water moving in a circle.

OPTIONAL EXTENSIONS

A. Tiny Buckets

Students can make their own buckets out of string and paper cups. They can punch holes in the side of the cup near the top to run string through, put water in the cup, and try to spin them without spilling water.
This activity would work best outside.

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B. Penny on a Coat Hanger

A trickier version of the water and bucket demonstration is to bend a wire coat hanger so it becomes a long wire with a hook on one end.
Balance a penny on the hook, then spin the coat hanger. You can get the penny to stay on the hook in the same way you get water to stay in a bucket.

Here's an amateur video of this demonstration:
http://www.youtube.com/watch?v=puANHiKdx-c

C. Flying Bucket

While spinning the bucket on the rope, you could choose to let go of the bucket in mid-swing. Ask students to predict what will happen and where the bucket and the water will go.
This is also an outdoor activity.

GLOSSARY

Force:	Something that causes an object to change its motion.
Centripetal Acceleration:	When a force holds a moving object in circular motion, as with a rope pulling on a spinning bucket, or gravity holding the Earth in orbit around the sun.
Inertia:	Objects keep doing what they're doing, unless they're forced to change. Things that are moving, keep moving in a straight line. Things that are not moving, stay still.
Centrifuge:	A machine that spins things to sort them by weight. Heavier things have more inertia, so they push lighter objects aside as they work to the outside.
Gravity:	A force that pulls things toward the center of the Earth.

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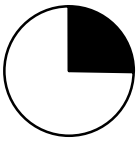
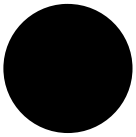
Memory Match

Description: Students match pairs and then use the pairs to play Memory.

Learning Objectives: Students will practice their pattern recognition and problem-solving skills.

SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVEL
Biology Math	Problem Solving Pattern Recognition Observation	K–3

TIME REQUIRED

Advance Preparation	Set Up	Activity	Clean Up
			
15 minutes	**5 minutes**	**60 minutes**	**5 minutes**

SUPPLIES

- Photocopies of the game pieces and student procedure sheets
- Scissors (1 pair per student)
- Envelopes to store the game pieces (1 per student)
- Large paper clips to clip together the sets of game pieces (2 per student)
- Crayons, colored pencils, or fine-tip markers (optional)
- Tape (optional)

SAFETY PRECAUTION: Always be careful with students using scissors.

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ADVANCE PREPARATION

Make one copy of game pieces for each student on colored cardstock. If your students are able to read, you may also want to make copies of the student procedure sheets.

For younger students, you may want to cut out the cards in advance.

SET UP

- Have the supplies ready to hand out or stacked on tables.

TEACHER DEMONSTRATION

Use the Practice Pairs sheet to demonstrate the activity. First, show students how to cut out the squares along the lines. Second, match the pairs as a class. Third, play Memory by taking turns flipping over pairs of cards with volunteers from the class. To make sure everyone can see the cards, tape them to the board, use an overhead projector, or have students crowd around a table.

CLASSROOM ACTIVITY

Students should work alone or in groups of two. Each group follows the directions below. For younger students, you may want to focus on the matching. Older students can quickly move to playing Memory with a classmate.

Hand out the materials. If students are old enough to read the student procedure sheet, hand that out as well. Otherwise, help students through the steps as a class.

Help students cut out the first set of pairs. Allow them time to match the pairs. Have them show their pairs to their neighbors to see if everyone agrees which cards go together.

Once everyone has matched their cards, have them turn the cards over and mix them up. Have students organize the cards in a grid like the one shown on the student procedure sheet.

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Explain how students can now use the cards to play Memory. Individually, let students try to match the pairs by flipping over two cards at a time. Remind students to keep the cards in the same place when they flip them over. This will help them remember where individual cards are later when they need them to complete a pair. For younger children, understanding the game and strategies for remembering where the cards are when they are upside down can take some practice. Once they understand the process, they can play with friends and try out the other sets of pairs.

CLASS DISCUSSION

Ask for student observations. There is no correct answer. Let students guide the discussion and present their hypotheses before discussing explanations.

Ask the students the following questions in **bold**. Possible student answers are shown in *italics*.

Was it hard to remember where the matches where when the cards were upside down?

Yes. No. Sometimes.

What helped you remember where they were so you could make a match?

I could remember the shape.
I always put it back in the same place.
I flipped the cards over in order.
I paid attention when my partner played so I could remember the cards they found too.

Encourage students to notice that it was important to be observant and systematic when trying to find the matches. These same skills are important for any problem-solving situation.

OPTIONAL EXTENSIONS

A. Make Your Own Memory Game

Allow students to think up their own version of a memory game using matching pairs. Allow students to draw their

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set of cards and see if their classmates can figure out the matches and play Memory with them.

B. Science and Math Sets

Make memory card sets based on other science topics that you are working on in class. Examples include:

- Life cycles: make a set with frogs and tadpoles, caterpillars and butterflies, and other animals that change shape during different life stages.
- Plants: make a set with seeds and plants, e.g., a pumpkin seed and a pumpkin plant, a pine cone and a pine tree, etc.
- Arithmetic/subtraction/multiplication/division: make a set with an equation on one card and the answer on the other (e.g., Card A says “1+2,” Card B says “3”).
- Where things come from: make a set with a product and its source. For example, use milk and a cow, egg and a chicken, T-shirt and a cotton plant, paper and a tree, etc.

C. Language Sets

You could also make match sets for teaching letters and sounds. For example, sets could include upper and lower case letters, letters and objects that start with that letter, or objects that start with the same sound.

CROSS-CURRICULAR CONNECTIONS

MATH	**Use matching sets with numbers or arithmetic problems.**
LANGUAGE ARTS	**Use matching sets to learn about letters, sounds, and words.**

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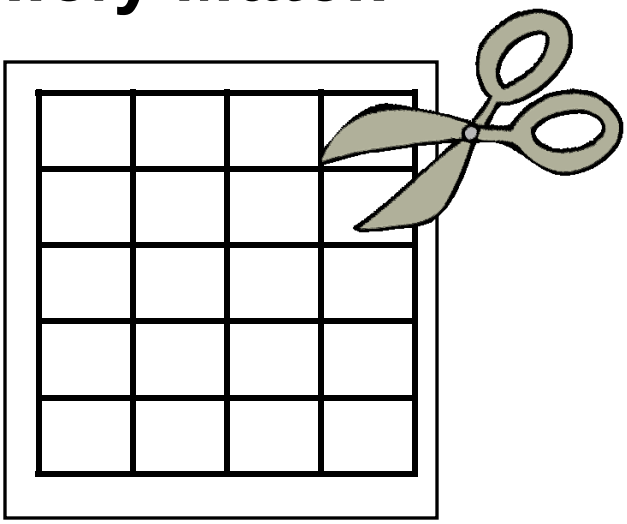
Student Procedure:
Make a Memory Match

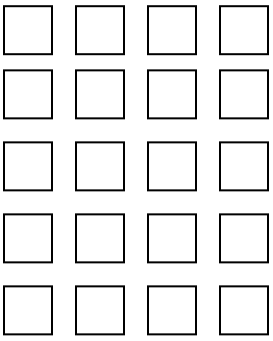
1 **Cut out the squares.**



2 **Find the pairs that match.**

- Can you figure out which cards go together?

3 **Turn the cards upside down and mix them up. Lay them out in a grid like this…**



4 **Try to find the pairs that match by flipping over two squares at a time.**

- If you don't get a match, flip the squares back over and try again.
- Keep trying until you find all of the pairs.

5 **Try again with a friend.**

- Make sure all of the squares are upside down**.**
- Mix them up and arrange them in a grid.
- Take turns flipping over two cards at a time.
- If you find a pair, you get to take the cards.
- At the end, count how many pairs you found.

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Game Pieces: Set #1

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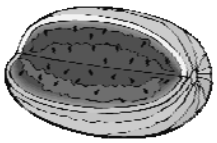
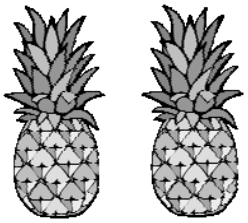
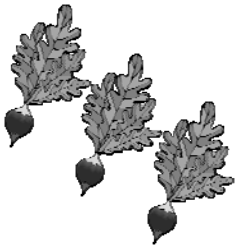
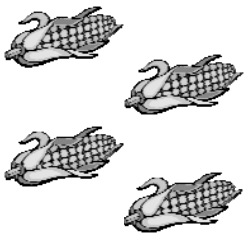
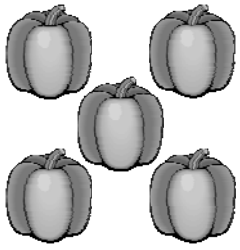
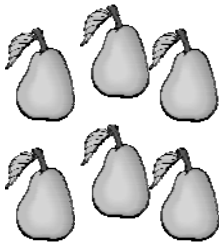
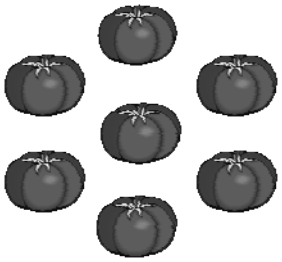
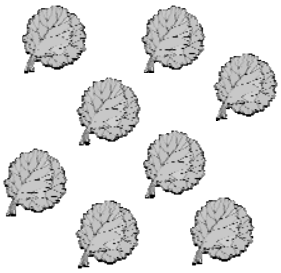
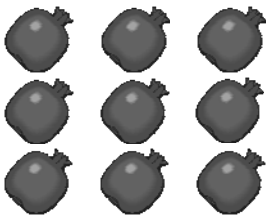
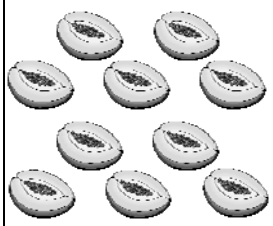
5	6	7	8
9	10		
			
			

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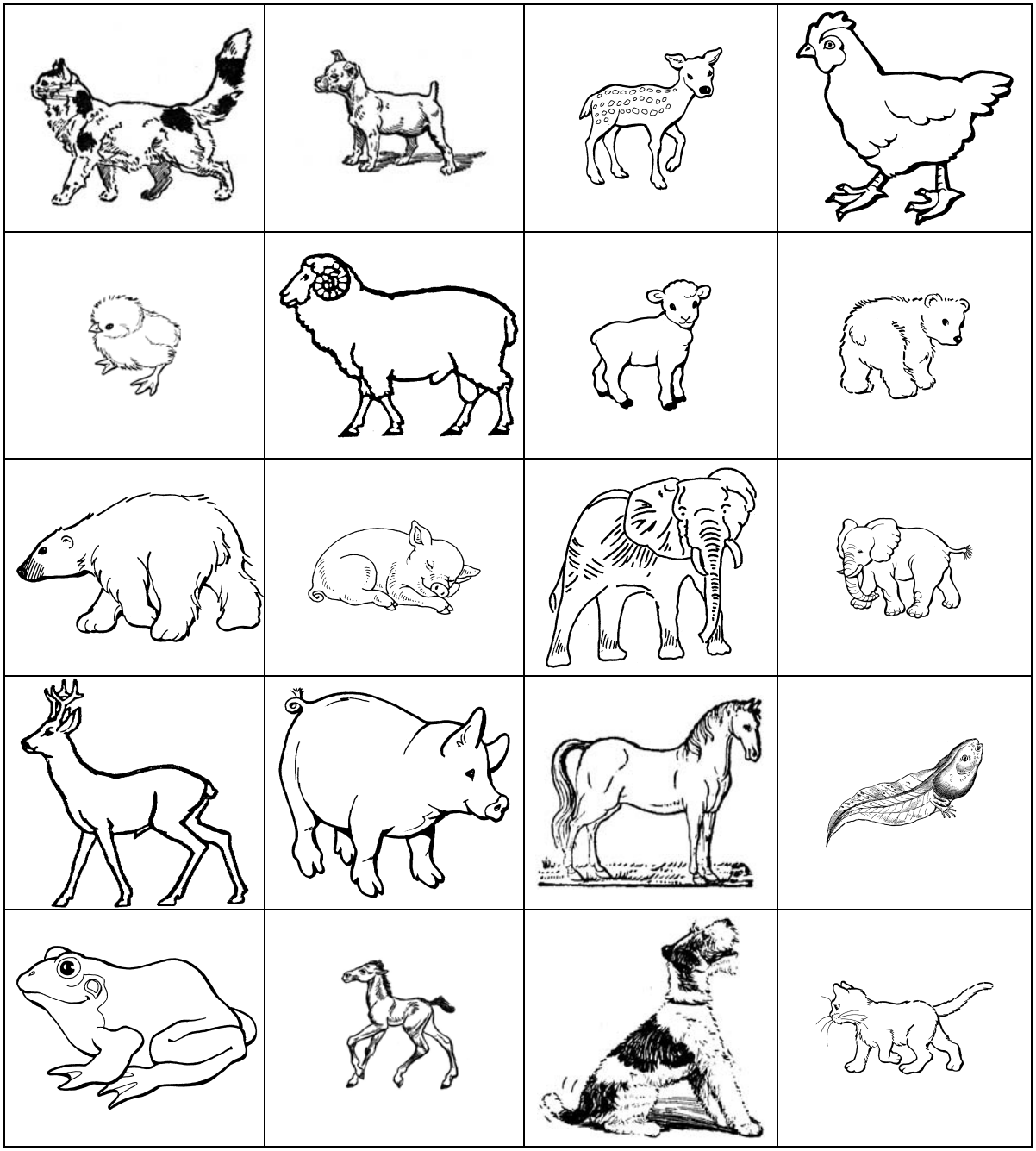
Game Pieces: Set #2



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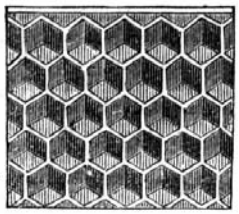
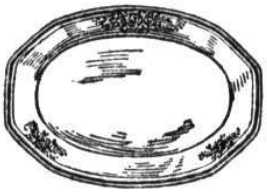
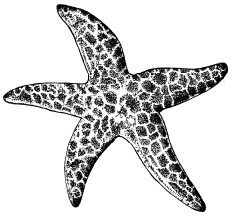
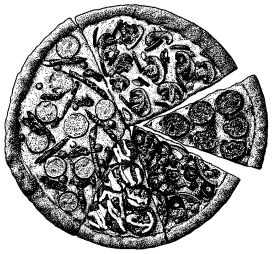
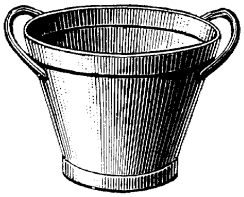
Game Pieces: Set #3

Rectangle	Triangle	Circle	Oval
Trapezoid	Hexagon	Heart	Diamond
Star	Square		
			
			

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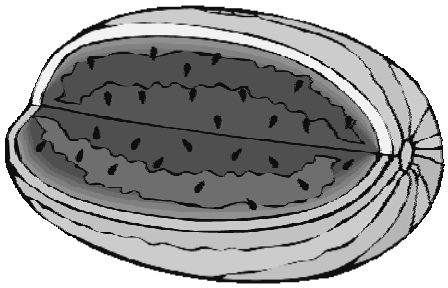
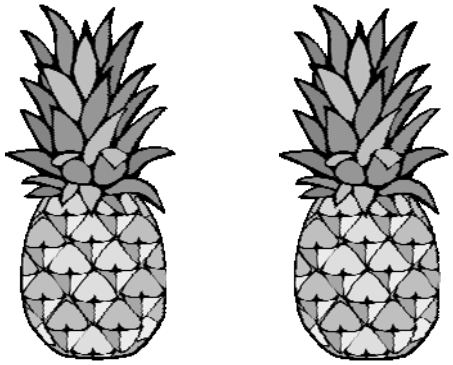
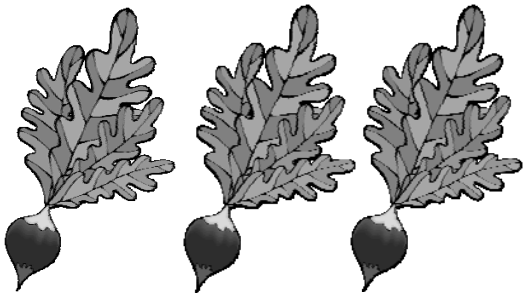
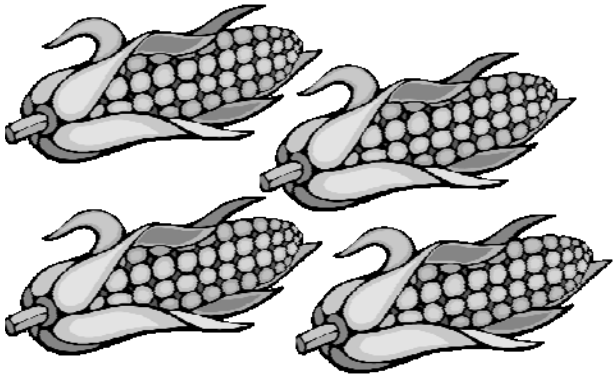
Game Pieces: Practice Pairs

1	
2	
3	
4	

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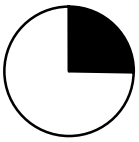
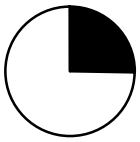
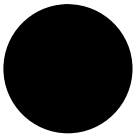
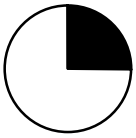
Games from around the World

Description: Students play strategy games from around the world.

Learning Objectives: Students will learn to use strategy and logical thinking through playing multicultural games.

SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVEL
Logic	Logical Thinking Strategy	4–8

TIME REQUIRED

Advance Preparation	Set Up	Activity	Clean Up
			
15 minutes	**15 minutes**	**60 minutes**	**15 minutes**

SUPPLIES

- Materials to photocopy: Student Procedure sheets and Game Boards (1 for every 2 students).
- Paper
- Scissors (1 pair per student)
- Optional: two different colored games pieces (checkers pieces work well).

SAFETY PRECAUTION: Make sure students are safe with the scissors.

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ADVANCE PREPARATION

- Photocopy Game Boards and Student Procedure sheets.

SET UP

- Have the supplies ready to hand out or stacked on tables.

INTRODUCING THE ACTIVITY

Let students speculate before offering answers to any questions. The answers at the right are provided primarily for the teacher's benefit.

Ask the students the following questions in **bold**. Possible student answers are shown in *italics*.

What does strategy mean?
Strategy is thinking about what the best plan is to help you reach your goal. If you're playing a game, it's figuring out the best way to play so you win.

What games have you played that require strategy?
Risk, chess, checkers, tic-tac-toe, video games, etc.

What tools do you use to find good strategies when you play strategy games?
I try lots of different moves to see which work best.
I always watch my opponent to see what moves he/she uses.
I think about what the other person will do if I make different moves.
I always think about what my next step will be if I make that move.

You can help students think about being observant and using logic to think about appropriate strategies. Logic may include thinking through possible moves and determining which ones are most likely to be successful. Students can also use logic to guess what their opponents might do in response to their moves. In addition, being a good observer helps students learn about what strategies work well and how their opponent thinks.

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CLASSROOM ACTIVITY

Students should work in pairs. Each group follows the directions on the Student Procedure sheets. Brief background information on the origin of the games is also provided on the Student Procedure sheets.

Achi—Ghana
After discussing the introductory questions and handing out the materials, walk through the student procedure for achi. You can demonstrate how to play the game by challenging the class to a game on the whiteboard or chalkboard. Draw the game on the board and use tape or magnets to attach the game pieces. Once students understand the game, allow them to play together in pairs. Once students have finished a few rounds of achi, ask them what strategies worked best.

Banqi—China
Repeat this process with Banqi (pronounced ban-chi). Banqi takes longer to play and involves more complex strategy. Give students enough time to play at least one game (about 15 minutes) before interrupting to allow them to discuss their strategies.

CLASS DISCUSSION

Ask for student observations. There is no correct answer. Let students guide the discussion and present their hypotheses before discussing explanations.

What did you like about achi and banqi?

They were fun/hard/new/seemed simple but were really complicated.

What strategies did you try? Did they work?

In achi, it helped if you got the middle square because then you had more options later.
In banchi, you really had to think about whether it was worth losing one piece so that you could capture more pieces later.

How could you find more successful strategies for these games?
You could play a lot more.
You could look on the Internet or in a book.
You could find someone who is really good to help you learn.

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Other than when you play games, when would you need to use strategy to be successful in life?
When you are trying to win an argument with your brother/sister.
When you're in court and you want to win the case.
When you are trying to solve a crime and you have to figure out where the criminal is hiding.

Help students think about how using strategic thinking, logic, and observation can help them be successful in many situations in life. Also, encourage them to identify resources for learning good strategies for new situations.

OPTIONAL EXTENSIONS

A. Mancala

Mancala is a general name for several different games based on planting seeds. People have been playing these games in North Africa for at least 1300 years. Today, versions of mancala are played throughout the world, especially in Africa and Southern Asia.

To play mancala, students need only an egg carton, two cups, and some large beans, marbles, or other "seeds." Have students research different versions of mancala on the Internet and teach each other how to play.

B. Strategy Stations

Students can choose their favorite strategy game to research and present to the class. They can use common games like Risk and chess or learn about games that are less popular in the US like mahjong, Chinese chess, Go, and Kalah. Students should explain how the game works, where it is from, its history, and strategies for winning.

To share the games, have students present in front of the class, write up directions and background information, and/or host an open house where each student has a game station where they teach guests and other students how to play their game.

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CROSS-CURRICULAR CONNECTIONS

SUBJECT	Activity
SOCIAL STUDIES	**Use a world map to mark the countries of origin for the games that you learn.** **Learn more about these countries by having students research other aspects of their cultures such as food, climate, language, etc.**

RESOURCES

http://www.lawrencehallofscience.org/exhibits/mathworld.html
Lawrence Hall of Science website on multicultural games that use math. LHS also has a book on the subject: *Math Around the World* by Beverly Braxton and Philip Gonsalves.

http://en.wikipedia.org/wiki/Category:Abstract_strategy_games
Wikipedia has information on several strategy games from around the globe.

http://woodpress.org/banqi/
Good website describing a different version of banqi.

http://www.rocketsnail.com/mancala/classic.htm
An online version of mancala.

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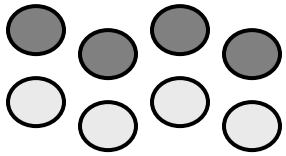
Student Procedure:
How to Play Achi

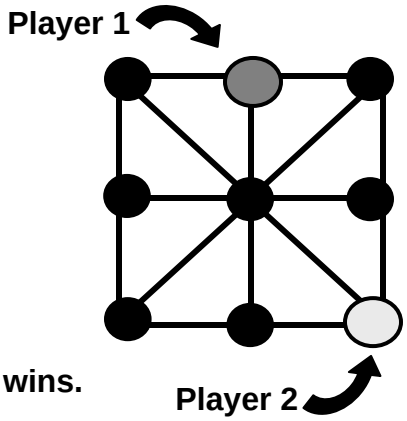
Achi is a game played by the Asante people of Ghana, West Africa. It is similar to tic-tac-toe, except players are allowed to move their pieces.

1 **Each player needs four game pieces.**

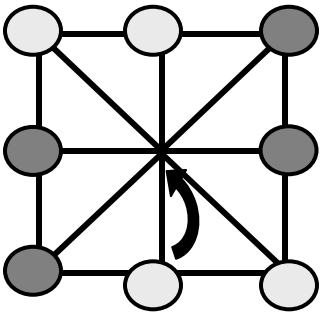
- The players' pieces should be different colors.
- You can use checkers pieces, large beans, or cut out the circles at the bottom of this page.



2 **Take turns placing game pieces on the board.**
The goal is to get three in a row.

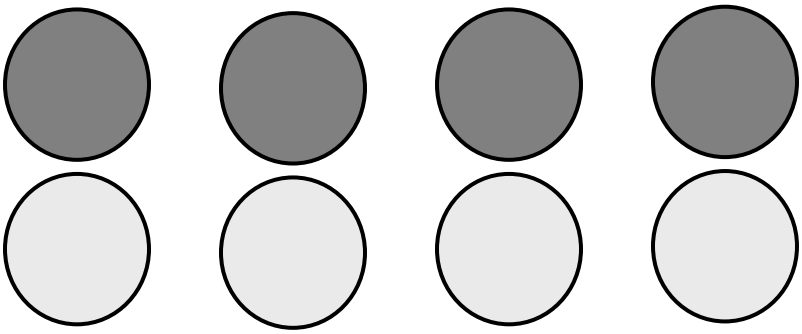


3 **If no one wins after all pieces are played, take turns sliding one piece at a time along the lines into the empty space until someone gets three in a row and wins.**



For example, in this game Player 2 could move one of his or her pieces into the middle of the board to win the game.

Game Pieces



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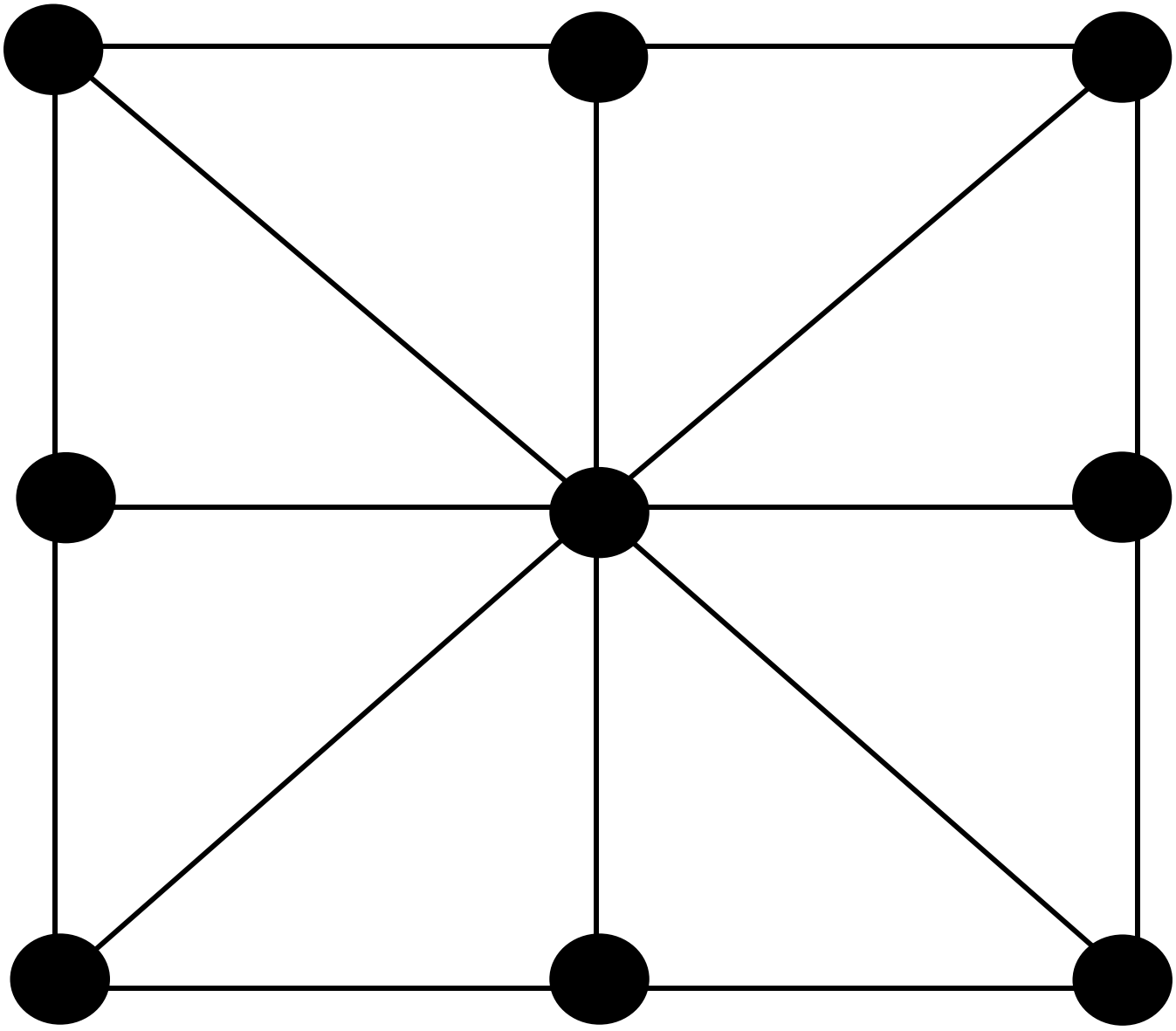
Achi Game Board



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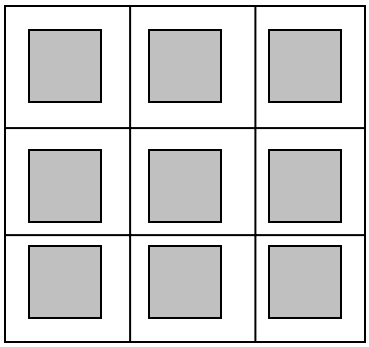
Student Procedure: How to Play Banqi

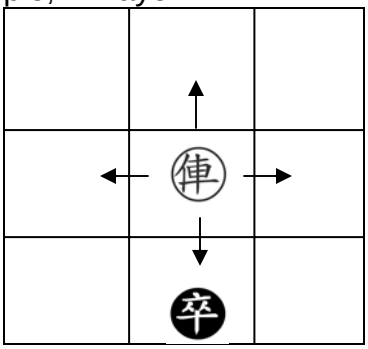


1 **Cut out the game pieces.**

2 **Place them on the game board upside down.**

3 **Take turns flipping over game pieces.**

- Player 1 can flip over any game piece to start.
- Player 1 claims the color of the first piece played. For example, if Player 1 flips over a white soldier, Player 1 will be white and Player 2 will be black.

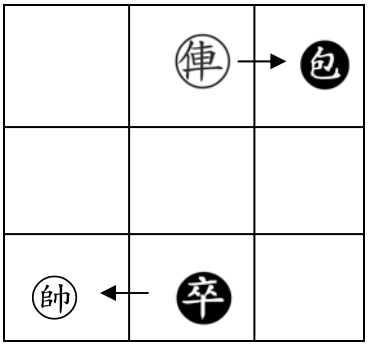


4 **Move pieces that are already showing.**

- You can choose to move a piece or flip over a new piece until all the pieces are right side up.
- You can only move pieces of your color.
- Pieces can move one space up, down, left or right. Pieces can NOT move diagonally.
- Pieces can either move to an empty square or capture another piece.

5 **Capture your opponent's pieces.**

- A piece can only capture other pieces of the same rank or a lower rank.
- Rank goes in this order: *king, chariot, horse, cannon, elephant, guard, soldier.*
- The only exception is that a king can NOT capture soldiers, but soldiers CAN capture the king.



6 **The game is over when one player captures all of the other player's pieces.**

- If players get to the point where they are moving pieces but the game is not moving forward, the player with the highest ranking piece wins.

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Banqui Game Pieces

 KING	 KING	 GUARD	 GUARD
 ELEPHANT	 ELEPHANT	 GUARD	 GUARD
 ELEPHANT	 ELEPHANT	 CHARIOT	 CHARIOT
 HORSE	 HORSE	 CHARIOT	 CHARIOT
 HORSE	 HORSE	 SOLDIER	 SOLDIER
 SOLDIER	 SOLDIER	 SOLDIER	 SOLDIER
 SOLDIER	 SOLDIER	 SOLDIER	 SOLDIER
 CANNON	 CANNON	 CANNON	 CANNON

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Banqui Game Board

RANK	KING	CHARIOT	HORSE	CANNON	ELEPHANT	GUARD	SOLDIER

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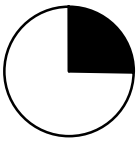
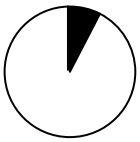
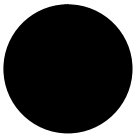
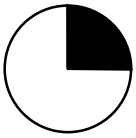
Color Sudoku

Description: Students use logic skills to solve color Sudoku puzzles.

Learning Objectives: Students will learn to use logical thinking to solve problems.

SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVEL
Logic	Problem Solving	5–8

TIME REQUIRED

Advance Preparation	Set Up	Activity	Clean Up
			
15 minutes	**5 minutes**	**60 minutes**	**15 minutes**

SUPPLIES

- Colored game pieces—M&M's or Skittles candy works well for 4x4 and 6x6 puzzles if you are willing to give students candy. Otherwise, colored stones, buttons, or squares of colored cardstock work fine. You will need the following colors: red, orange, yellow, green, light blue, dark blue, brown, pink, and purple. Each student will need 18 pieces of each color.
- Materials to photocopy: Sudoku puzzle sheets (1 per student)
- Colored markers (optional)

SAFETY PRECAUTION:	**M&M's candies, even the plain variety, contain trace amounts of peanuts. Don't let students with peanut allergies eat them.**

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ADVANCE PREPARATION

- Organize game pieces by color (students can also make their game pieces by cutting small squares out of colored cardstock).
- Make copies of Sudoku Puzzle Boards.

SET UP

- Have the supplies ready to hand out or stacked on tables.

INTRODUCING THE ACTIVITY

Let students speculate before offering answers to any questions. The answers at the right are provided primarily for the teacher's benefit.

Ask students the following questions in **bold**.
Possible student answers are shown in *italics*.

Have you every played Sudoku?
Yes. No. It's my favorite thing ever.

How do you play Sudoku?
You have to place the numbers 1–9 (smaller squares use 1–4 or 1–6) in a grid so that each number (or color) appears once in each row and column. There are also smaller boxes of nine (or four or six) squares within the big grid. Each small box must have one of each number (or color) in it.

What does it take to be good at Sudoku?
You have to be a good problem solver. You have to think logically.

What does it mean to think logically?
You have to figure out what your options are and then one by one figure out which options work.

What are some other situations where you have to think logically?
When you do math.
When you have to figure out how to get somewhere on the bus using only a bus schedule and a map.

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TEACHER DEMONSTRATION

Review the rules of Sudoku:

1. Each row must contain one game piece of each color.
2. Each column must contain one game piece of each color.
3. Each small box must contain one game piece of each color.

Do the first 4x4 puzzle on the board as a class. Help students figure out which color goes in the empty boxes using logical arguments. For example, “this box has to be red because all of the other rows already have a red square.”

CLASSROOM ACTIVITY

Students can work alone or in pairs.

Allow students to do the easier 4x4 puzzles to learn the basic rules and concept of the game. Once they have mastered that, introduce the 6x6 puzzles.

When students have finished the 6x6 puzzles, give students the 9x9 puzzles. These are significantly more difficult. Once students have tried doing the 9x9 for a little while, stop the group and ask what strategies they’ve found to help them solve the more difficult puzzles.

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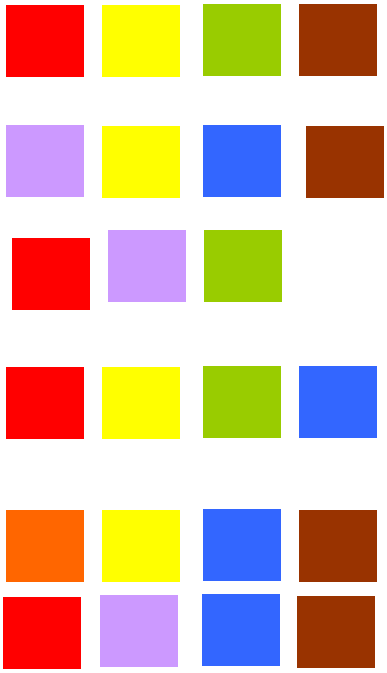
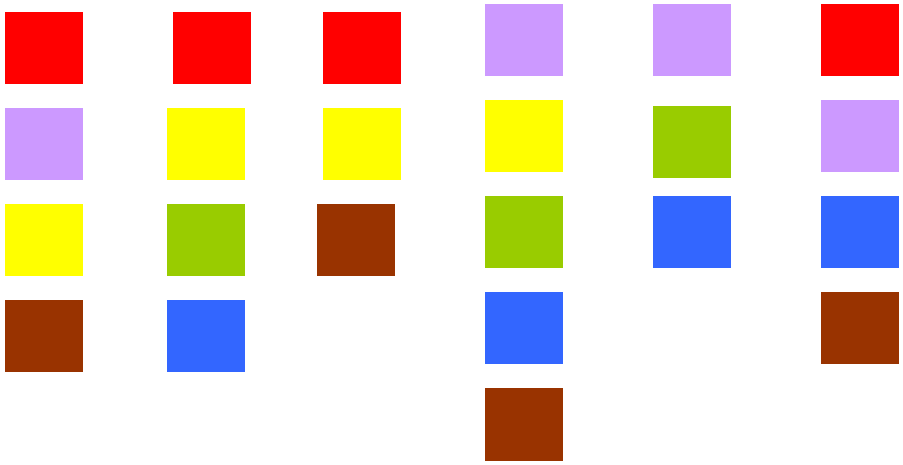
If students are struggling, help them find ways to logically figure out which colors go where. One way of doing this is to line up extra game pieces along the side of each row and column that represent the colors that have not been used (see diagram below). This allows students to see which colors can be used for each box, and they can easily compare boxes in each square of four, six, or nine.

Example

	PURPLE	BLUE			
		GREEN	RED		
BLUE				BROWN	YELLOW
	BROWN	PURPLE			
GREEN				RED	
				YELLOW	GREEN





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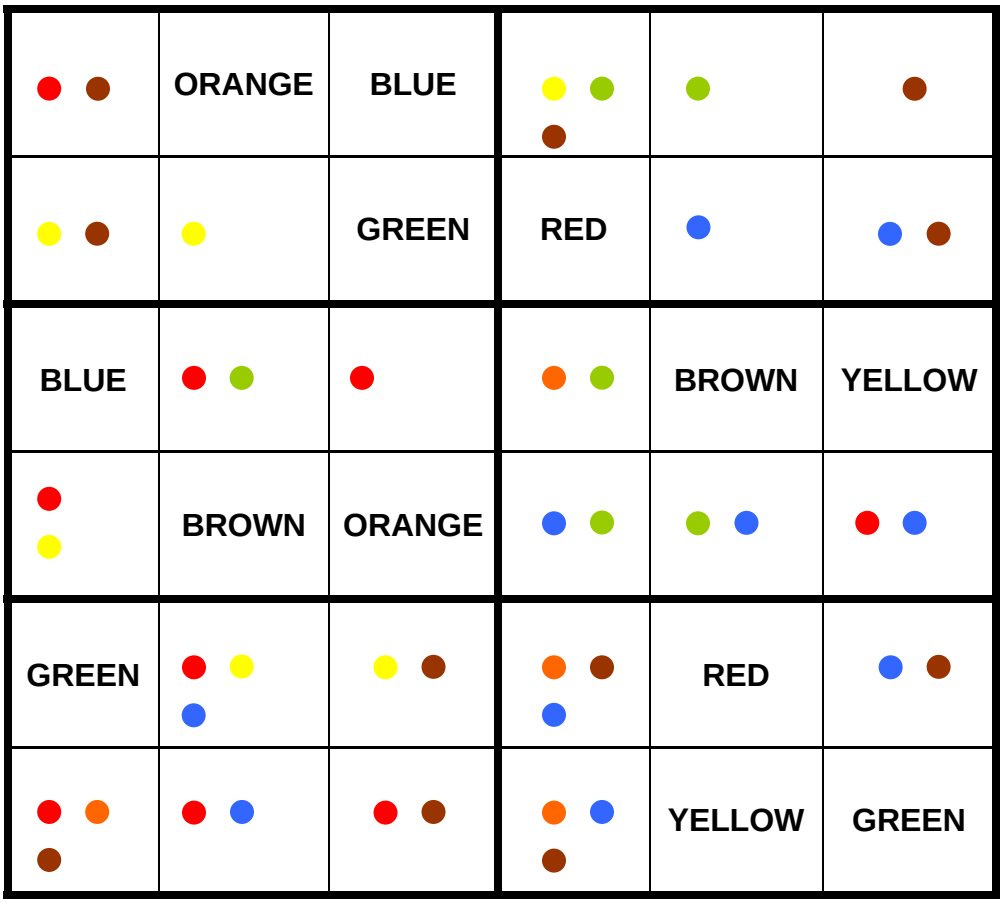
Students can also use colored markers to put small dots in each box representing which colors could go in that space. Any box that has only one color possible must be that color. As they decide which boxes contain a particular color, students adjust the possible colors in other boxes.

Example



CLASS DISCUSSION

Ask for student observations. There is no correct answer. Let students guide the discussion and present their hypotheses before discussing explanations.

What did you find difficult about solving the Sudoku puzzles?
It was hard to know which color fit. Sometimes I would try a color, and it would mess everything up later.

What helped you figure out what colors would fit?
I just tried different things until it worked.

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For each box, I figured out which colors could fit. I started with the boxes that only had one possible color, and that helped me figure out the ones around it.

How did you use "logical thinking" to help you solve the puzzles?
By going step by step, I used logic to find my options, start with the easy parts, and slowly work up to the more complicated stuff.

Help students recognize how logic helped them solve the puzzles. By breaking down the steps and applying the rules of the game to each individual square, students can logically figure out the answers rather than just guessing.

OPTIONAL EXTENSIONS

A. Make Your Own Sudoku

Have students try to make their own Sudoku board. Start by filling in the whole board, and then blank out most of the squares. Students should then test their puzzles to see if they left enough squares to actually solve the puzzle. They can also switch puzzles with classmates and rank how hard each puzzle is to solve.

RESOURCES

http://www.sudokupuzz.com/
More 9x9 Sudoku puzzles for different levels.

http://www.dailysudoku.com/sudoku/kids/
Sudoku puzzles specifically for kids.

http://www.paulspages.co.uk/sudoku/howtosolve/
Suggestions for how to solve Sudoku puzzles.

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Sudoku Games

Level 1: 4x4 **(Red, Yellow, Green, Blue)**

	BLUE		**RED**
YELLOW		**GREEN**	
			YELLOW

1

	BLUE		
		RED	
	YELLOW		

2

3

		BLUE	
RED			
			BLUE
	GREEN		

4

BLUE	**YELLOW**		
			RED
YELLOW			

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Sudoku Games
Level 1: 4x4—SOLUTIONS

RED	**YELLOW**	**BLUE**	**GREEN**
GREEN	**BLUE**	**YELLOW**	**RED**
YELLOW	**RED**	**GREEN**	**BLUE**
BLUE	**GREEN**	**RED**	**YELLOW**

#1

YELLOW	**RED**	**GREEN**	**BLUE**
GREEN	**BLUE**	**YELLOW**	**RED**
BLUE	**GREEN**	**RED**	**YELLOW**
RED	**YELLOW**	**BLUE**	**GREEN**

#2

#3

GREEN	**YELLOW**	**BLUE**	**RED**
RED	**BLUE**	**YELLOW**	**GREEN**
YELLOW	**RED**	**GREEN**	**BLUE**
BLUE	**GREEN**	**RED**	**YELLOW**

#4

RED	**GREEN**	**BLUE**	**YELLOW**
BLUE	**YELLOW**	**RED**	**GREEN**
GREEN	**BLUE**	**YELLOW**	**RED**
YELLOW	**RED**	**GREEN**	**BLUE**

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Sudoku Games

Level 2: 6x6 #1

(Red, Orange, Yellow, Green, Blue, Brown)

	ORANGE	**BLUE**			
		GREEN	**RED**		
BLUE				**BROWN**	**YELLOW**
	BROWN	**ORANGE**			
GREEN				**RED**	
				YELLOW	**GREEN**

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Sudoku Games

Level 2: 6x6 #1—SOLUTION

RED	**ORANGE**	**BLUE**	**YELLOW**	**GREEN**	**BROWN**
BROWN	**YELLOW**	**GREEN**	**RED**	**ORANGE**	**BLUE**
BLUE	**GREEN**	**RED**	**ORANGE**	**BROWN**	**YELLOW**
YELLOW	**BROWN**	**ORANGE**	**GREEN**	**BLUE**	**RED**
GREEN	**BLUE**	**YELLOW**	**BROWN**	**RED**	**ORANGE**
ORANGE	**RED**	**BROWN**	**BLUE**	**YELLOW**	**GREEN**

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Sudoku Games

Level 2: 6x6 #2

(Red, Orange, Yellow, Green, Blue, Brown)

	RED			**GREEN**	**YELLOW**
		BROWN	**ORANGE**		
		YELLOW	**GREEN**		
YELLOW	**GREEN**			**BLUE**	**BROWN**

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Sudoku Games

Level 2: 6x6 #2—SOLUTION

ORANGE	**RED**	**BLUE**	**BROWN**	**GREEN**	**YELLOW**
BROWN	**YELLOW**	**GREEN**	**BLUE**	**RED**	**ORANGE**
GREEN	**BLUE**	**BROWN**	**ORANGE**	**YELLOW**	**RED**
RED	**ORANGE**	**YELLOW**	**GREEN**	**BROWN**	**BLUE**
BLUE	**BROWN**	**RED**	**YELLOW**	**ORANGE**	**GREEN**
YELLOW	**GREEN**	**ORANGE**	**RED**	**BLUE**	**BROWN**

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Sudoku Games

Level 2: 6x6 #3

(Red, Orange, Yellow, Green, Blue, Brown)

		ORANGE	**GREEN**		
GREEN					**ORANGE**
	ORANGE			**YELLOW**	
	GREEN			**BROWN**	
RED					**BROWN**
		YELLOW	**BLUE**		

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Sudoku Games
Level 2: 6x6 #3—SOLUTION

BROWN	**RED**	**ORANGE**	**GREEN**	**BLUE**	**YELLOW**
GREEN	**YELLOW**	**BLUE**	**BROWN**	**RED**	**ORANGE**
BLUE	**ORANGE**	**BROWN**	**RED**	**YELLOW**	**GREEN**
YELLOW	**GREEN**	**RED**	**ORANGE**	**BROWN**	**BLUE**
RED	**BLUE**	**GREEN**	**YELLOW**	**ORANGE**	**BROWN**
ORANGE	**BROWN**	**YELLOW**	**BLUE**	**GREEN**	**RED**

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Sudoku Games

Level 3: 9x9 #1

(Red, Orange, Yellow, Green, Dark Blue, Light Blue, Brown, Pink, Purple)

PURPLE	**RED**	**PINK**		**GREEN**	**YELLOW**			
LIGHT BLUE		**ORANGE**	**BROWN**			**DARK BLUE**		**PINK**
					BROWN	**LIGHT BLUE**	**PURPLE**	
			YELLOW		**ORANGE**	**RED**		
			RED		**PURPLE**		**BROWN**	**YELLOW**
	PINK				**GREEN**	**PURPLE**		**BROWN**
GREEN		**PURPLE**	**ORANGE**			**YELLOW**		
	BROWN			**YELLOW**				**LIGHT BLUE**

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Sudoku Games

Level 3: 9x9 #1—SOLUTION

DARK BLUE	YELLOW	BROWN	PINK	ORANGE	LIGHT BLUE	GREEN	RED	PURPLE
PURPLE	RED	PINK	DARK BLUE	GREEN	YELLOW	BROWN	LIGHT BLUE	ORANGE
LIGHT BLUE	GREEN	ORANGE	BROWN	PURPLE	RED	DARK BLUE	YELLOW	PINK
RED	ORANGE	YELLOW	GREEN	PINK	BROWN	LIGHT BLUE	PURPLE	DARK BLUE
BROWN	PURPLE	LIGHT BLUE	YELLOW	DARK BLUE	ORANGE	RED	PINK	GREEN
PINK	DARK BLUE	GREEN	RED	LIGHT BLUE	PURPLE	ORANGE	BROWN	YELLOW
YELLOW	PINK	DARK BLUE	LIGHT BLUE	RED	GREEN	PURPLE	ORANGE	BROWN
GREEN	LIGHT BLUE	PURPLE	ORANGE	BROWN	PINK	YELLOW	DARK BLUE	RED
ORANGE	BROWN	RED	PURPLE	YELLOW	DARK BLUE	PINK	GREEN	LIGHT BLUE

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Sudoku Games

Level 3: 9x9 #2

(Red, Orange, Yellow, Green, Dark Blue, Light Blue, Brown, Pink, Purple)

	PINK			BROWN			ORANGE	
		YELLOW	ORANGE	LIGHT BLUE	PINK	DARK BLUE		
		BROWN	DARK BLUE		GREEN	YELLOW		
	BROWN	PURPLE				PINK	RED	
RED		PINK				LIGHT BLUE		DARK BLUE
	LIGHT BLUE	DARK BLUE				ORANGE	PURPLE	
		GREEN	PURPLE		ORANGE	RED		
		RED	YELLOW	DARK BLUE	BROWN	GREEN		
	DARK BLUE			RED			YELLOW	

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Sudoku Games

Level 3: 9x9 #2—SOLUTION

DARK BLUE	PINK	LIGHT BLUE	RED	BROWN	YELLOW	PURPLE	ORANGE	GREEN
PURPLE	GREEN	YELLOW	ORANGE	LIGHT BLUE	PINK	DARK BLUE	BROWN	RED
ORANGE	RED	BROWN	DARK BLUE	PURPLE	GREEN	YELLOW	LIGHT BLUE	PINK
GREEN	BROWN	PURPLE	LIGHT BLUE	ORANGE	DARK BLUE	PINK	RED	YELLOW
RED	ORANGE	PINK	BROWN	YELLOW	PURPLE	LIGHT BLUE	GREEN	DARK BLUE
YELLOW	LIGHT BLUE	DARK BLUE	PINK	GREEN	RED	ORANGE	PURPLE	BROWN
BROWN	YELLOW	GREEN	PURPLE	PINK	ORANGE	RED	DARK BLUE	LIGHT BLUE
LIGHT BLUE	PURPLE	RED	YELLOW	DARK BLUE	BROWN	GREEN	PINK	ORANGE
PINK	DARK BLUE	ORANGE	GREEN	RED	LIGHT BLUE	BROWN	YELLOW	PURPLE

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Sudoku Games

Level 3: 9x9 #3

(Red, Orange, Yellow, Green, Dark Blue, Light Blue, Brown, Pink, Purple)

		PINK		DARK BLUE		YELLOW		
	PURPLE	RED	GREEN		YELLOW	DARK BLUE	LIGHT BLUE	
			ORANGE		BROWN			
PINK		DARK BLUE		YELLOW		GREEN		PURPLE
		PURPLE		GREEN		ORANGE		
ORANGE		GREEN		RED		BROWN		PINK
			YELLOW		PINK			
	DARK BLUE	LIGHT BLUE	RED		GREEN	PURPLE	PINK	
		BROWN		PURPLE		RED		

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Sudoku Games

Level 3: 9x9 #3—SOLUTION

LIGHT BLUE	ORANGE	PINK	PURPLE	DARK BLUE	RED	YELLOW	BROWN	GREEN
BROWN	PURPLE	RED	GREEN	PINK	YELLOW	DARK BLUE	LIGHT BLUE	ORANGE
DARK BLUE	GREEN	YELLOW	ORANGE	LIGHT BLUE	BROWN	PINK	PURPLE	RED
PINK	LIGHT BLUE	DARK BLUE	BROWN	YELLOW	ORANGE	GREEN	RED	PURPLE
RED	BROWN	PURPLE	PINK	GREEN	DARK BLUE	ORANGE	YELLOW	LIGHT BLUE
ORANGE	YELLOW	GREEN	LIGHT BLUE	RED	PURPLE	BROWN	DARK BLUE	PINK
PURPLE	RED	ORANGE	YELLOW	BROWN	PINK	LIGHT BLUE	GREEN	DARK BLUE
YELLOW	DARK BLUE	LIGHT BLUE	RED	ORANGE	GREEN	PURPLE	PINK	BROWN
GREEN	PINK	BROWN	DARK BLUE	PURPLE	LIGHT BLUE	RED	ORANGE	YELLOW

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Spin Cycle

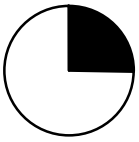
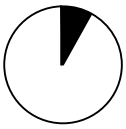
Note: Some of the puzzles in *Mindbender Mansion* depend on centripetal acceleration for their solution. This lesson is an extension of that topic.

Description: Students spin objects on a rope to measure centripetal acceleration.

Learning Objectives: Students will learn which factors affect circular motion.

SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVEL
Physics of Motion Centripetal Acceleration	Observing Predicting Measuring	4–8

TIME REQUIRED

Advance Preparation	Set Up	Activity	Clean Up
			
15 minutes	**5 minutes**	**40 minutes**	**5 minutes**

SUPPLIES

For each group of students:

- String (30 cm per group)
- Meter stick
- 10 cm of pipe wide enough to pass the string (or a strong cardboard tube, like the tube in plastic wrap)
- Stopwatch—a clock with a second hand will work
- Bolt—long enough to hold 10 nuts
- 10 metal nuts that fit on the bolt
- Washer

SAFETY PRECAUTION: **Students must be adequately spaced apart so they don't hit each other.**

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ADVANCE PREPARATION

- Measure and cut string into 30 cm lengths.
- Measure and cut the pipe or cardboard tube into 10 cm lengths. (For plastic pipe or sturdy cardboard tube, you may need to use a saw or serrated blade. If you do not have one, ask a janitor or someone who has a sharp blade to cut it for you. Use appropriate safety precautions.)

SET UP

- Organize students into groups of two to four.
- Hand out the following supplies to each group: one piece of pipe or cardboard tube, one length of string, one washer, one bolt, 10 nuts.

INTRODUCING THE ACTIVITY

Let students speculate before offering answers to any questions. The answers at the right are provided primarily for the teacher's benefit.

Ask the students the following questions in **bold**. Possible student answers are shown in *italics*.

Have you ever heard of centripetal acceleration or centrifugal force?
Yes. No. They're my favorite band.

What happens when you spin something in a circle?
Water stays in a bucket. I get dizzy.

In this activity, we're going to measure how something moves when you spin it in a circle on a string.

CLASSROOM ACTIVITY

Students should work in groups of two to four. Each group follows the directions below.

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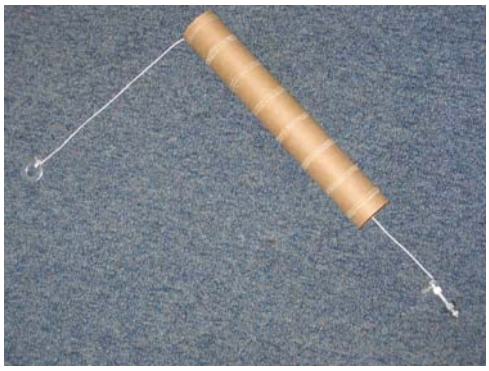
Student Procedure: Spin Cycle

1 **Tie a bolt to one end of the string.**



2 **Run the string through the pipe or tube.**

- Tie a washer to the free end of the string.

3 **Be safe.**

- Stand with your arms spread out as far as you can.
- Be sure that other students are standing farther away than you can reach with your arms spread out.
- **Be careful:** do not hit anyone when you spin your washer.

4 **Swing the washer in a circle and measure how fast it goes.**

- Make a prediction: How many times do you think the washer will spin around in a circle in 10 seconds?
- Hold the pipe vertical, with the washer on the top end and the bolt on the bottom.
- Keep the speed as steady as possible.
- Use the stopwatch to time how many times the washer goes in a circle in 10 seconds. (Or have one student say “start” and “stop” to time for 10 seconds, while another student counts the circles.)

5 **Make changes, note differences.**

- Try spinning the washer faster or slower. What happens?
- Try adding nuts to the bolt. Add one nut at a time and measure circle time with each nut. How does it change?

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CLASS DISCUSSION

Ask for student observations. There is no correct answer. Let students guide the discussion and present their hypotheses before discussing explanations.

What did you find out?

How fast did you have to spin the washer to hold up one nut? How about five nuts? Ten?

When you get the washer to spin in a steady circle, all the forces pulling on the washer are balanced. The inertia of the washer pulls the nuts and bolt into the pipe, and the nuts and bolt pull on the string to pull the washer into the pipe. When you spin it at the right speed, these forces balance, and the washer moves in a circle.

As you add nuts to the bolt, you change the amount of force on the washer. With more weight on the string, the washer has to move faster to hold up the greater force. You spun the washer faster, with more force, to hold up the nuts. So you counted more spins per 10 seconds when there were more nuts on the bolt.

Older students can draw a diagram and label forces and direction of motion.

OPTIONAL EXTENSIONS

A. Bucket on a Rope

You can briefly swing a bucket full of water on a rope to demonstrate the forces involved in circular motion.

B. Penny on a Coat Hanger

A trickier version of the water and bucket demonstration is to bend a wire coat hanger so it becomes a long wire with a hook on one end.

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Balance a penny on the hook, then spin the coat hanger. You can get the penny to stay on the hook in the same way you get water to stay in a bucket.

A video demonstrating how to do this can be found at: http://www.youtube.com/watch?v=puANHiKdx-c

C. Glycerin on a Record Player

If you put a transparent, waterproof container with two cups of glycerin or corn syrup in it on a record player and spin it quickly (72 rpm), you'll see the surface of the liquid bend into a parabola. Put the container in the center of the record player. (A record player doesn't move fast enough to do this trick with water.)

The liquid will move up the sides of the container and out of the middle. The liquid is moving to the outside of the container because of its inertia. The moving liquid is trying to move in a straight line, past the container. The container keeps the liquid in circular motion, but the liquid keeps moving to the outside of the container.

If you have access to something that spins faster than a record player, you can try using other clear liquids to see if they behave differently. You could also vary the speed of the wheel to see differences in behavior.

D. Centrifuge of Science

With a bucket and a rope, you can explore how different materials have different amounts of inertia. Put foam pellets, marbles, and walnuts (or any other objects of varying weight) into a bucket in a well-mixed pile, then spin the bucket on the rope quickly for a few seconds. (You can spin in a vertical circle or a horizontal one, it doesn't matter. A horizontal circle may be easier.) The heavier objects should move to the bottom of the bucket, while the lighter objects should be on the top.

This is how panning for gold works, as well as centrifuges used for sorting all kinds of materials, from blood to uranium. In all these machines, objects with more mass push strongly to the bottom of the container, shoving the lighter objects aside.

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GLOSSARY

Force: Something that causes an object to change its motion.

Centripetal Acceleration: When a force holds a moving object in circular motion, as with a rope pulling on a spinning bucket or gravity holding the Earth in orbit around the sun.

Inertia: Objects keep doing what they're doing, unless they're forced to change. Things that are moving keep moving in a straight line. Things that are not moving stay still.

Centrifuge: A machine that spins things to sort them by weight. Heavier things have more inertia, so they push lighter objects aside as they work to the outside.

Gravity: A force that pulls things toward the center of the Earth.

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Spin Cycle
Student Data Sheet

Number of nuts on bolt	Number of spins in 10 seconds
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

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Active Learning Log

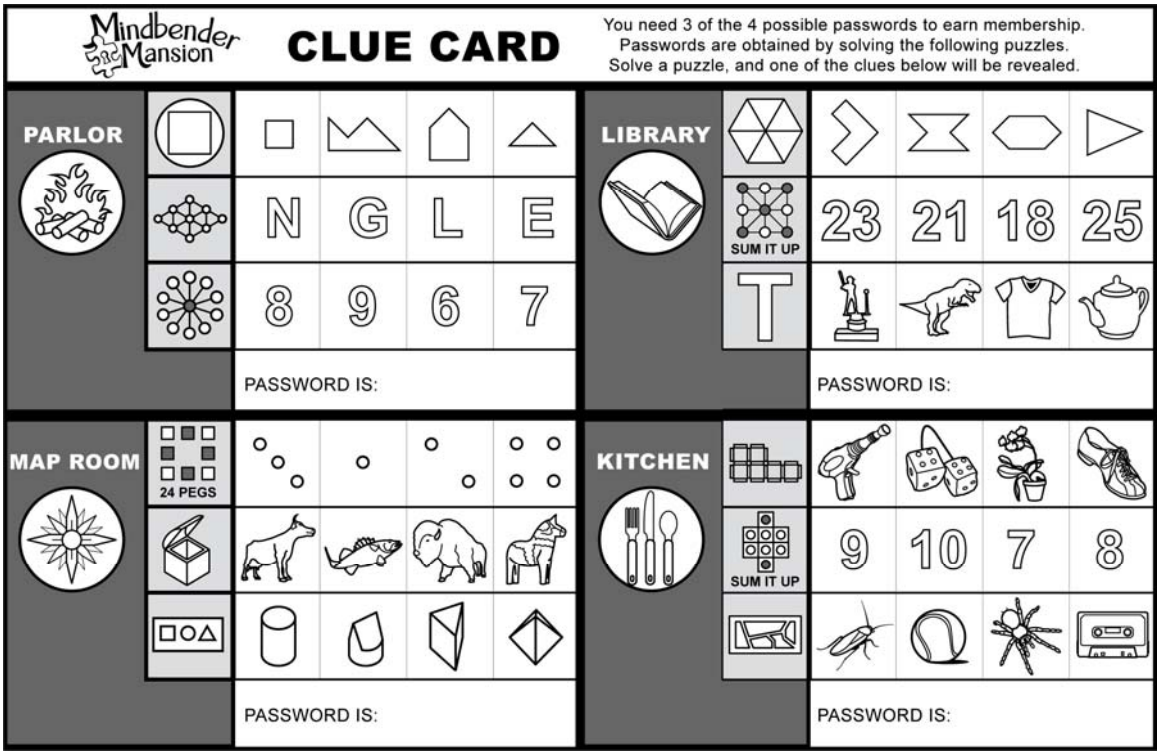
Name:_____

Which puzzle is your favorite? Why? Without giving them the answer, what hint would you give a friend to solve this puzzle?

How did you use teamwork or cooperation to solve a puzzle?

Which puzzle was the hardest for you? How did you solve it?

Draw a picture of the answer of a puzzle you solved:



This is your clue card for ***Mindbender Mansion.*** Throughout the mansion there are special puzzles that will give you clues when you solve them. In certain rooms, find the three clues, and then go to the vault. Put in your clues to get a password and write it down.

Once you have at least three passwords, you can go to the Wall of Fame and join the Mindbender Society!

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