Arithmentalism and Number Patterns

Mind reading - “Can we read minds with numbers?’

For students in grades K through 6th

‘Impossible Science’ lessons aim to be 75-90 minutes long for grades 3 through 6, and 60-75 minutes long for grades K through 2. The final 15 minutes for K-2 will be filled with a ‘wind down’ drawing activity (see “Evaluate” section for details).

Materials Note: Be sure to collect all 6 binary number cards from students after the class and rubber band them together. Also be sure to keep decks of cards separate from each other and replace them in their box, organized, at the end of the day

Objectives

By the end of this lesson, students will:

- **Know** there are different systems for counting unique quantities (decimal, binary, etc.) and creating patterns
- **Understand** how the binary number system uses a pattern made from the powers of 2 to represent numbers, letters, and objects
- **be able to** the number systems to make and recognize patterns, perform numerical magic tricks, and decode information

Big Ideas:

- Humans and computers use **pattern recognition** to identify and solve problems.
- A **pattern** is a list of symbols (numbers, shapes, cards, etc.) that form a recurring sequence of events.
- In addition to problem solving, pattern recognition allows humans to make educated predictions about future events in the pattern.
- We think and count using a numerical pattern known as the **decimal number system.** “Deci-” means 10.
- The decimal number system is one of many different kinds of number systems.

- Computers use a number system known as the **binary number system.** "Bi" means 2.
- Whereas you can make 10 different numbers for a given place value in the decimal system (0-9), binary only allows 2 values (0 or 1).
- Much like we use decimal numbers to represent values or objects, we can use unique combinations of binary numbers to represent letters, numbers, and objects as well.

Essential Questions:

- How do we recognize patterns made from numbers, letters, cards, or shapes?
- How can understanding patterns help us make predictions or solve problems?
- How many different ways can we count objects?
- What are binary numbers and how do they use multiples of 2 to create decimal numbers? Letters?
- How can we use the scientific method to uncover the secret patterns behind magic tricks involving cards or numbers?

Engage:

Warm Up

Invite students to share some patterns that they know. Write a quick description of the patterns, along with the first few items in the pattern on the board or on chart paper.

Impossible Science Demo (10 mins)

"Teach like a Magician" Suggested Script tagged with [TLAM]:

Perform the Binary Number Card trick for the class using one student volunteer, repeat with another student volunteer until the class is thoroughly wowed at your mind reading powers!

- Pretend to read a student's mind, asking them to think of a number between 1-1000, then (hopefully) guessing it wrong.
- Mention to the class that certain things can seem impossible, or improbable, but as we gain more information, things can become more possible or probable
- Now, with 6 magical cards in your hand (aka more information), ask your volunteer to think of a number between 1-60 (more probable), and for them not to say it aloud, you are about to read their mind!
- Go through each card with the student, asking if their number is on the card. If their answer is yes to a card, remember the number (either 1, 2, 4, 8, 16 or 32) that is in the top left of the card, ensuring they look over each card carefully
- As you go through each card, add up the corresponding number for each "Yes" response and ignore the cards they said "No" to.
- Once you finish going through all the cards, you should have a sum of the "Yes" response cards, this is your magical number! Announce your number and hold for applause.
- Repeat the trick two more times with new volunteers.

Think | Pair | Share

- *Think [1-2 min]:* Ask students to, individually, consider how they think this mind-reading magic trick works. Then, under Prompt #1 in their workbooks, have them model their answer.
- *Pair [1-2 min]:* Students pair up and take turns sharing their thoughts. They ask each other questions after sharing and formulate their combined responses to the question prompts.
- *Share [2-3 min]:* The larger group comes together and the pairs take turns summarizing their combined responses. On the board or chart paper, write down a couple of statements that summarize the group's various hypotheses.

Explore:

Activity 1 - 13 O'Clock Mystery [20 minutes]

Students will work in pairs on this activity. Distribute the materials for "Activity 1" on the Materials Page.

Lead the students through the 13 o'clock mystery following the steps below:

- **Step 1:** Give each student a suit of cards from Ace to King (Should be a total of 13 cards)
- **Step 2:** Ask the students to put them in order so that when the deck is face down, the ace is at the top of the pile and the king is at the bottom
- **Step 3:** Have the students pick any card from Ace to King and to remember it without telling anybody what it is
- **Step 4:** Have students spell out the card that they picked.
- **Step 5:** For every letter in their card, have the students move the top card to the bottom of the deck.
    - *For example, if the student picks ACE, they will move the top card to the bottom of the deck 3 times.*
- **Step 6:** Have students check the top card of their deck now and spell out the name of the card they see.
    - *For example, if their original card was an ACE, their top card will be a FOUR.*
- **Step 7:** For every letter in the top card they just looked at, have the students move the top card to the bottom of the deck.
    - *For example, if the top card is FOUR, place the topmost card on the bottom of the deck 4 times.*
- **Step 8:** Have students check the top card of their deck again and spell out the name of the new card they see.
    - *If their original card was an ACE, their top card was then a FOUR, now it will be an EIGHT.*
- **Step 9:** For every letter in the top card they just looked at, have the students move the top card to the bottom of the deck.
    - *For example, if the top card is EIGHT, place the topmost card on the bottom of the deck 5 times.*

- **Step 10:** Now, Have a student announce to the class a random value, Ace through King and place their topmost card on the bottom of the deck, as many times as the value of the random card that was announced.
    - *In the continued example, if the student originally picked ACE, they would move the top card to the bottom of the deck 1 time.*

ACE=1, 2=2, 3=3, 4=4, 5=5, 6=6, 7=7, 8=8, 9=9, 10=10, JACK=11, QUEEN=12, KING=13

- **Step 11:** Now, Have The students check their top card. They will all be astonished to find that if steps were followed properly, everyone has the same card!

After the students have completed the trick 1-2 times, have them work through the steps of the scientific method in order to find out how the trick works, this may involve going through the trick a number of times so students may observe and test hypothesis:

- **Ask a Question:** All great experiments start with a question. Ideally, a question has been inspired by performing each trick with the students. An example question might be: “Is there an explanation for how my card landed on top?”
- **Research the Question:** Normally, this section would involve collecting their prior knowledge about the subject, observations they have made, or data from previous experiments. For this activity, they will start with any observations they noticed when you did the trick. They may also run through the trick themselves a couple times to gain more insight.
- **Form a Hypothesis:** A hypothesis is an educated attempt at answering the question based on the research for a question. For this activity, they will answer the question by guessing how the trick is done.
- **Test with an Experiment:** Students will now attempt to recreate the card trick with the explanation they came up with to see if their answer explains how the trick works.
- **Collect Data:** While conducting their experiment, students will record all of their observations about how their experiment worked or didn’t work.
- **Analyze Data:** After collecting all of their observations as data, students will analyze why their strategy worked or did not work. If their strategy did not work, form a new hypothesis based on the results from the first experiment and then retest. Repeat this process until time runs out, or a solution is found.
- **Communicate Results/Conclude:** Once the experiments have all been completed, summarize the results by stating what has been learned about the card trick. Have students share their answers with the rest of the class.

Activity 2 - Pattern Magic

Students will work in groups of 4 on this activity. Distribute the materials for “Activity 2” from the Materials Page.

Lead the students through the Impossible Science Card Trick, then have them revisit the Scientific Method Steps to try to figure out how it works!

- **Step 1:** Have 4 students in each group recombine their cards to make a full deck. Shuffle the cards.
- **Step 2:** Once the cards have been shuffled, cut the deck into four approximately equal piles. Each pile should have between 9 and 16 cards.
- **Step 3:** Each student should pick up a pile and hold it facedown.
- **Step 4:** Look at the top card and memorize it. Place the card back on top.
- **Step 5:** For each letter in the words I-M-P-O-S-S-I-B-L-E S-C-I-E-N-C-E, Place the card that is on the top of the deck on the bottom of the deck. (17 letters means 17 cards)
- **Step 6:** Starting with the new top card, discard the first card using the word "unlikely". Now rotate the new top card to the bottom of the deck using the word "likely"
- **Step 7:** Keep switching back and forth between discarding the "unlikely" cards and then keeping the "likely" cards until there is only one card left.
- **Step 8:** Look at the final card and compare it to the original top card that you memorized. They are the same card!!

After the students have completed the trick 1-2 times, have them work through the steps of the scientific method in order to find out how the trick works, this may involve going through the trick a number of times so students may observe and test hypothesis:

- **Ask a Question:** All great experiments start with a question. Ideally, a question has been inspired by performing each trick with the students. An example question might be: "Is there an explanation for how my card landed on top?"
- **Research the Question:** Normally, this section would involve collecting their prior knowledge about the subject, observations they have made, or data from previous experiments. For this activity, they will start with any observations they noticed when you did the trick. They may also run through the trick themselves a couple times to gain more insight.
- **Form a Hypothesis:** A hypothesis is an educated attempt at answering the question based on the research for a question. For this activity, they will answer the question by guessing how the trick is done.
- **Test with an Experiment:** Students will now attempt to recreate the card trick with the explanation they came up with to see if their answer explains how the trick works.
- **Collect Data:** While conducting their experiment, students will record all of their observations about how their experiment worked or didn't work.
- **Analyze Data:** After collecting all of their observations as data, students will analyze why their strategy worked or did not work. If their strategy did not work, form a new hypothesis based on the results from the first experiment and then retest. Repeat this process until time runs out, or a solution is found.
- **Communicate Results/Conclude:** Once the experiments have all been completed, summarize the results by stating what has been learned about the card trick. Have students share their answers with the rest of the class.

Once done, have each group place their cards back in the original box and place it back in the materials bag/tub

Activity 3 - Binary Numbers [20 minutes]

Grades 3-6:
Students will work in pairs on this activity. Distribute the materials for "Activity 3" on the Materials Page.

- Hand out sticky notes, each student taking 6 and writing the numbers 1, 2, 4, 8 , 16 and 32 on them.
- Ask the class, does anything seem patterned or significant about these numbers?
    - *After fielding answers, share that each digit, multiplied by 2, comes to the next number in the sequence (or working backwards through the sequence, divided by 2)*
- Explain to them that there's another magical element to these numbers, and it is the basis for binary code, which uses exclusively 1's and 0's to represent values.
- Note that for the numbers 1, 2, 4 and 8, you can add these numbers in different combinations to equal every number between 1-15.
- Bring in the 16 card to the existing group of cards to demonstrate that the numbers can be added in different combinations to equal every number between 1-31.
- If necessary, bring in the 32 card to show that these 6 numbers (1, 2, 4, 8, 16 and 32) can add up to every number between 1-63!
- Lead discussion, asking students to test these out for themselves, and then lead discussion on what the next set of binary numbers would be (128, 256, 512, etc.)

Grades PreK-2:
Students will work in pairs on this activity. Distribute markers and graph paper to students, and display the Binary Decoder Worksheet on a projector.

Students will use binary patterns to send and receive secret messages.

- Explain to students that computers represent each letter of the alphabet with a pattern of 0s and 1s, called binary. They will represent the zeroes as black squares, and the 1s as white squares.
- Using the binary decoder key, they will send a secret message to their partner by coloring in squares on their grids.
- Their partner will then attempt to decode the message with their own key.
- Practice sending messages back and forth by sending:

- One letter
- Words that have three letters or less
- Your name!

At this point, have students return to their workbooks and, under Prompt #2, attempt to explain with a model and words why the specific numbers used in the Impossible Science trick allow for you to predict the number a person selected.

Explain:

Lecture with manipulatives [10 minutes]:
Using the provided materials and experiments, explain the "Big Ideas" of the lesson. Be sure to highlight the following:

- Humans and computers use **pattern recognition** to identify and solve problems.
- A **pattern** is a sequence of symbols (numbers, shapes, cards, etc.) that form a sequence that you can use to predict future events.
- We can use what we know about a given pattern to create secret messages or make predictions that seem magical - such as always identifying a person's card or selected number.
- We think and count using a numerical pattern known as the **decimal number system.** "Deci-" means 10.
- The decimal number system is one of many different kinds of number systems.
- Computers use a number system known as the **binary number system.** "Bi" means 2.
- Whereas you can make 10 different numbers for a given place value in the decimal system (0-9), binary only allows 2 values (0 or 1).
- Each zero or one in a binary number represents a multiple of the number 2. For example, the binary number 1111 is the decimal number 15:

  $$1\ 1\ 1\ 1 = 8 + 4 + 2 + 1 = 15$$

- Believe it or not, we can use multiples of 2 to create every number from 0 to positive infinity!

The Reveal: The top left corner number on each of the 6 number cards is a multiple of 2 - 1, 2, 4, 8, 16, 32 - which represent the binary number place values. Each card contains only those numbers that require the number in the top-left corner to create them. By adding those top-left number values together from the "Yes" pile, you are creating the unique number the person selected as if you were a computer!

At this time, have students return to their journals and, under Prompt #3, explain with models and words how the three Activity experiments demonstrated the use of numerical patterns to create the Impossible Science trick.

Elaborate:

Experiment - Magic Binary Cards [15 minutes]:
Students will work in pairs on this activity. Distribute the materials for "Experiment" from the Materials Page.

Now that the students know the secret of the Binary Number Cards, have them practice performing the trick to a partner in class.

As students get more comfortable with the trick, encourage them to add more cards to their trick.

Share Out:
If time allows, encourage students to share their expanded tricks with other students.

Modify / Extend:

Extension Activity 1 - Binary Bracelets [10 minutes]:
Students will work individually on this activity. Distribute the materials for "Extend 1" from the Materials Page.

Students will use the binary letter decoder and a 16 grid strip to create a binary letter bracelet using their first and last name initials.

Evaluate:

Under Prompt #4 in their workbooks, challenge students to return to their answers to the Warm Up Activity and, with a model, explain how they can use patterns of numbers to create, send, and decode secret messages. Encourage older students to include written explanations using the new vocabulary from the lesson.

Materials

Materials Note: Be sure to collect all 6 binary number cards from students after the class and rubber band them together.

Impossible Science Demo (per class)

- One set of Binary Number Cards

Activity 1 (per student pair)

- A full deck of cards

- Scientific Method handout (x2)
- Pencil for scientific method steps

Activity 2 (per student group of 4)

- A full deck of cards
- Scientific Method handout (x4)
- Pencil for scientific method steps

Activity 3 (per student pair)

Grades 3-6

- Binary Numbers Worksheet
- Pencils
- Sticky notes (at least 8 per student pair)

Grades PreK-2

- Binary Numbers Decoder worksheet
- Markers

Experiment (per student pair)

- Binary Number Cards

Extend 1 (per student)

- Binary Numbers Decoder worksheet
- Markers
- Scissors
- Tape