Searching Lesson Plan

Overview—*Binary Search*

Summary

When searching for an item in a list, using a strategic searching method is useful. For example, when looking up a word in the dictionary, most people flip back and forth using alphabetical order to find the word rather than starting from the first word and reading every single word consecutively until the correct word is found. How tiring that would be! When a computer is searching through a set of data, it is important to use an appropriate searching method to minimize time spent searching. This lesson introduces the binary search algorithm and explores its utility and application.

Timeline

What	Time	Where
Raffle Ticket Worksheet	10	RaffleTicketsWorksheets.pdf
Ping Pong Demo	10	Ping Pong Ball Demo
Guess My Number	10	DecisionTree.pdf
Dragons and Cows Worksheet	10	DragonsAndCowsWorksheet.pdf
Lion Hunting	5	
What's It All About	5	

Materials

- ✓ Raffle Ticket Worksheet. Half the students will get RAFFLE #1, half will get RAFFLE #2.
- ✓ Cups and Ping-Pong Balls
- ✓ Dragon and Cows Worksheet. 1 copy per pair of students.

Lesson Preparation

Before diving into the lesson, it is recommended that you watch "Unplugged: Binary Search" which can be found here: https://www.youtube.com/watch?v=iDVH3oCTc2c. The video will give a brief introduction into binary search and will demonstrate how the ping pong activity works.

Raffle Tickets– Pairs Worksheet

Students need to work in pairs for this activity. Each pair will need a set of the Raffle Ticket Worksheet. One student will receive the sheet labeled “RAFFLE #1” and the other student will receive the sheet labeled “RAFFLE #2” **Partners cannot look at each other’s papers during the activity.**

Introduce the activity. Tell students that the school has set up a raffle and that each student may have won a prize! However, the students aren’t sure which ticket is the winning ticket. Each student will get the chance to be both the raffle holder and the raffle master. The goal is for each student to find their winning ticket.

Student A, holding the “Raffle Holder #1” sheet, will go first. The partner (Student B) should be using the Raffle Master #1 (65” TV) list. Student A will guess a ticket and record that guess on their page, e.g., ticket “C”. Student B will look at the raffle master list and either say “yes” (if the number is the winner, e.g., 189) or “no” if some other number. This continues until Student A guesses the correct ticket.

The students will then swap roles, and Student B will make guesses while Student A is the raffle master.

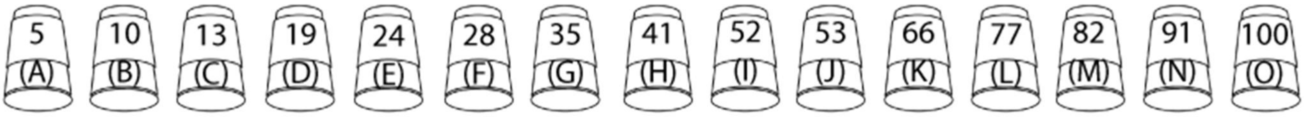
The goal of this activity is to demonstrate the variance in the number of guesses it takes to find the winning raffle ticket by randomly guessing.

After this round, discuss with the class to see how many guesses groups took. Who had the least amount of guesses? Who had the most? You may want to write all the number of guesses on the board, to give some idea of the variability using a random approach.

Ping Pong Ball Demo – Whole Class

Here is a video of this demo to reference: https://www.youtube.com/watch?v=iDVH3oCTc2c

Prep: Label 15 Ping-Pong Balls with various numbers. These numbers should be random and should NOT be equally incremented. Line up 15 cups with the numbered Ping-Pong Balls hidden underneath them. These should be lined up from least to greatest; in other words, they should be *in order.* One way to ensure that the order can be seen by the students is to label the cups alphabetically, with the lowest number being represented by “A” and the highest number being represented by “O”. Stress that the numbers are non-sequential but are in order. An example ordering can be seen below.



Have a volunteer come up and give them 4 pennies. Tell them that they are looking for a specific number. To find the number they must look under a cup. Every time they look under a cup, they must hand you one penny. Challenge them to search for a specific number with only those 4 pennies. Though you may be tempted to pick any random position, this demonstration works best when choosing the number in the 1st, 3rd, 5th, 7th, 9th, 11th, 13th or the 15th cup (e.g., you might choose 24, which is cup 5, or 83, which is in cup 13).

5 (A)
10 (B)
13 (C)
19 (D)
24 (E)
28 (F)
35 (G)
41 (H)
52 (I)
53 (J)
66 (K)
77 (L)
82 (M)
91 (N)
100 (O)

Since the ping pong balls are sorted, with each number that is revealed, some of the ping pong balls can be eliminated. If the number the student looks at is less than the number they are trying to find, that means that all numbers to one side of that number are also less than the number they are trying to find. After the student reveals the first ping pong ball, ask them which portion of the cups should be eliminated. If the student selects an optimal cup, where half the elements remaining can be eliminated, dramatically sweep the ping pong balls and cups out of line. Otherwise, gently push the eliminated cups to the side. Keep doing this until the student find the number. After one round, reset the cups and ask the class what the optimal position is in order to create a consistent search.

Discuss: How would they search an unordered list for a number? Let them think about this. In the worst case, the number they’re looking for will be at the end of the list, or it won’t exist. Then, they would have to look at every single number to be certain whether or not the number can be found.

The idea that a structured and methodical search on a sorted list is more effective and consistent than randomly guessing will be further explored in the next exercise

Guess My Number– Whole Class

Lesson Vocabulary (you may want to write on board)

- binary search

Tell students that you will pick a number between 1 and 100.
Write the numbers 1 (at the bottom) and 100 (at the top) on the board to help emphasize the location of the guesses. You want the class to guess your number. Have the students shout out numbers and listen for a guess that is NOT optimal (e.g., 50 is optimal, so pick some number close to either end, like 91 in figure 1). Call on other students to make continuous guesses until the number has been correctly guessed. Document student guesses on the board vertically indicating whether the target number is higher or lower than the guess using arrows. Figure 1 shows what might be listed for students trying to guess the number 45 after 3 rounds of guessing.

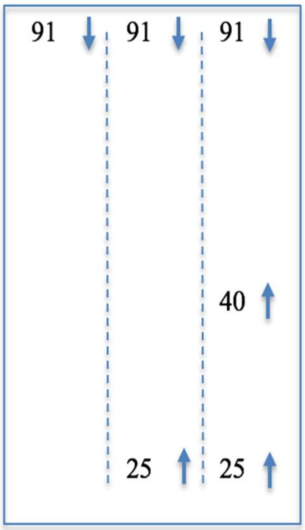


Figure 1

IMPORTANT. It's possible that a student might randomly pick your number on the first try (or within a few guesses). In other words, a random process might on occasion out-perform the binary search. For this demo to really emphasize that binary search provides a desirable limit on number of guesses, it's important for the random guesses not to appear superior. So in the event that a student guesses the secret number within 10 tries, just change the number that you originally chose in your head! You don't want the demonstration to make it seem that guessing is a better method than binary search while the method is being introduced. Later it will be good to discuss why guessing does work sometimes but is not reliable. HINT: as the students call out numbers, pick the direction (higher or lower) with the largest range. For example, if students guess 7, you wouldn't want to give the direction as less than 7 (there would be only 6 choices left). Instead, say that it's greater than 7 (which leaves 93 choices).

Write the total number of guesses that it took for students to determine the number on the board.

Next, say that you will play the game again but want to use less guesses. Lead students to select an appropriate first guess number. For example, if a student guesses the number 20 for their first guess, point out that there are now 80 numbers to guess from above 20. What is the best number to choose as a first guess to minimize the set of remaining numbers to guess from? Emphasize that splitting the list in half (the binary search algorithm) provides an efficient and reliable search method.

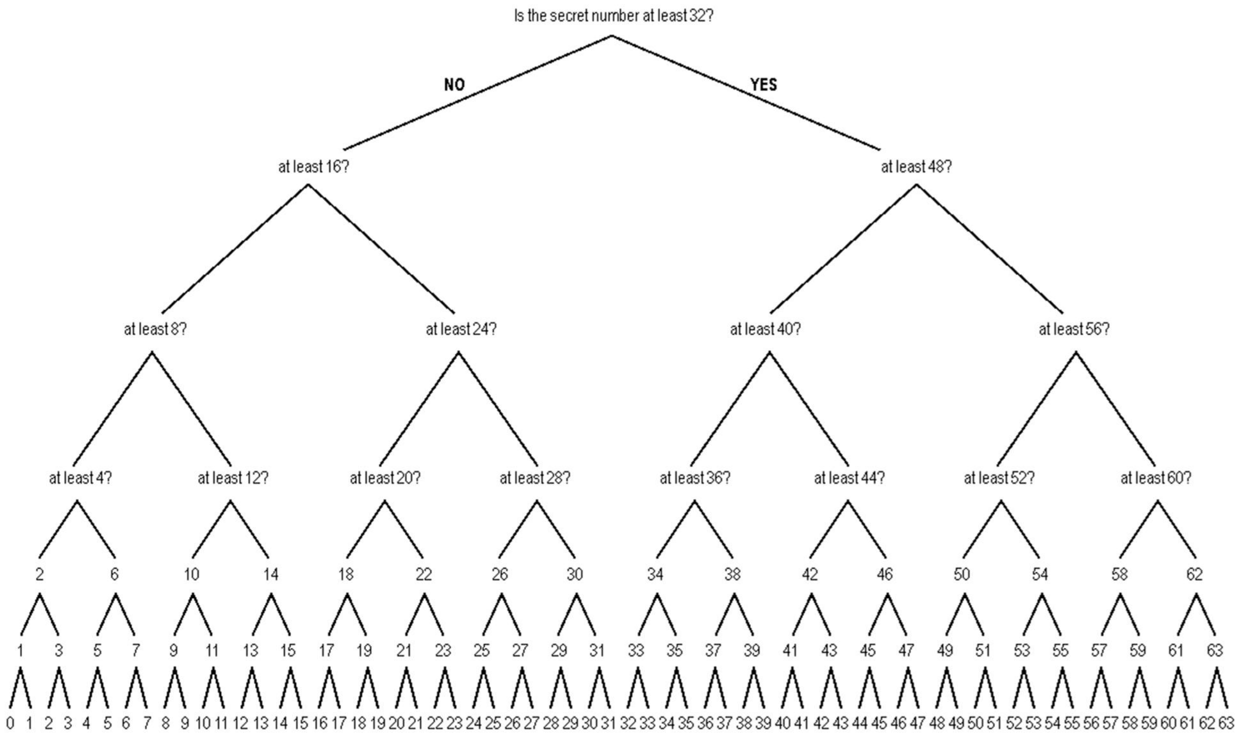
Next have students guess a number between 1 and 1000 to prove the efficiency of the binary search algorithm. During this round, the focus will be on documenting the number of values that are eliminated from the list with each round of guessing. Choose a student to take the first guess. Write the guess on the board exactly like was done in the previous guessing game. Emphasize the number of values that have been eliminated from the set of possible guess values due to the binary search algorithm. For example, if the student guesses the number 500 and you state that the value is greater than 500, all 500 numbers below the number 500 have been eliminated. (if the student guesses some number other than 500, engage the class in a discussion of how to choose the optimal guess). Document the number of values that have been eliminated somewhere on the board. Call on a student to guess a second value. Again, emphasize and document the number of values that have been eliminated with this guess (hopefully 250). Continue having students guess values but this time instead of documenting each guess on the board, document the number of values that have been eliminated with each guess until the number of values remaining reaches 1. The number of guesses should be no more than 10.

Example: assume the target is 675
First guess: 500. Eliminates 500. Number is greater.
Second guess: 750. Eliminates 250. Number is lower.
Third guess: 625. Eliminates 125. Number is higher.
Fourth guess: 688 (or 687). Eliminates 63. Number is lower.
Fifth guess: 656. Eliminates 32. Number is higher.
Sixth guess: 672. Eliminates 16. Number is higher.
Seventh guess: 680. Eliminates 8. Number is lower.
Eighth guess: 676. Eliminates 4. Number is lower.
Ninth guess: 674. Eliminates 2. Number is higher.
Tenth guess: 675.

NOTE: Ten is the **maximum** number of guesses. It’s possible for the number to be found in less than ten guesses, e.g., if the number were 750, 625, 688, etc.

Decision Trees– Whole Class

As a group discussion, show a fully-formed decision tree for a binary search on numbers from 0 to 63.This decision tree shows why some numbers will take fewer than the maximum number of guesses in a binary search.



Dragons and Cows – Pairs Worksheet

Students need to work in pairs for this activity. Each pair will need a set of the Dragons and Cows Records. Partners cannot look at each other's papers during the activity.

Introduce the activity. Tell students that a dragon has invaded the kingdom and is eating cows. Each student will have a chance to prevent the dragon from eating all the cows. This activity is similar to the raffle ticket, but now the cows are in order by weight, so students should try to use binary search to find the dragon as quickly as possible.

Day 1. The dragon is attacking Daffodai. The student with the worksheet titled Day 1: Daffodai will go first. The goal is to find which cow the dragon is attacking by guessing a cow and asking how much it weighs (e.g., How much does M weigh?). The person holding the worksheet titled Day 2: Draconia has the list of how much each cow weighs.

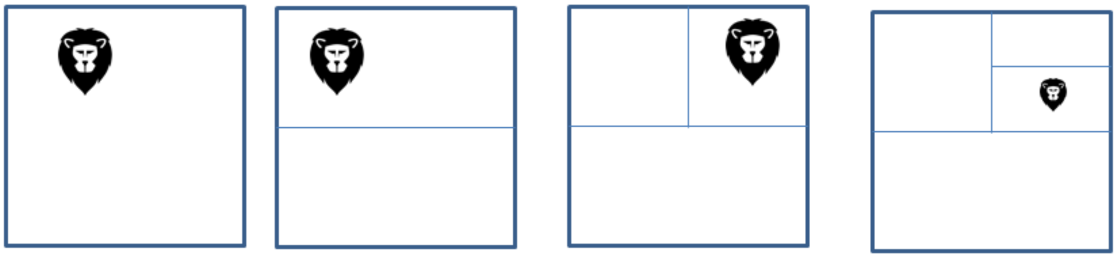
Day 2. The dragon is attacking Draconia. Partners will switch roles.

If students use Binary Search, they will end up only having to guess at most 5 times.

Lion Hunting– Whole Class

Draw a big square on the chalkboard/whiteboard and label it "the desert." Tell the students that there is a lion loose in the desert, and it's our job to build a fence around it so it doesn't hurt anyone. We don't want to catch it any other way, since it's a very cranky lion. How should we do it?

Answer: build a fence dividing the desert into two halves. The lion is now in one of the halves. Next, build a fence across the half containing the lion, constraining the lion to one quarter of the desert. Continue building fences across the half of the remaining desert containing the lion, until the lion is cornered. (We've assumed the lion can't get out of the desert.)



What’s It All About Discussion – Whole Class

Computers can process information very quickly, and you might think that to find something they should just start at the beginning of their storage and keep looking until the desired information is found. This is what we did in the Raffle Tickets activity. But this method is very slow—even for computers. For example, suppose a supermarket has 10,000 different products on its shelves. When a bar code is scanned at a checkout, the computer would have to look through as many as 10,000 numbers to find the product name and price. Even if it takes only one thousandth of a second to check each code, ten seconds would be needed to go through the whole list. Imagine how long it would take to check out the groceries for a family!

A better strategy is binary search. In this method, the numbers are sorted into order. Checking the middle item of the list will identify which half the search key is in. The process is repeated until the item is found. Returning to the supermarket example, the 10,000 items can now be searched with fourteen probes, which might take two hundredths of a second—hardly noticeable.

One of the biggest search problems in the world is faced by Internet search engines, which must search billions of web pages in a fraction of a second. The data that a computer is asked to look up, such as a word, a bar code number or an author’s name, is called a *search key*. These searches are much more complex than the binary search algorithm covered in this lesson, and computer scientists are still developing more efficient ways to address this challenge.