Grade Level	Middle School
Duration	4 Class Periods
CS Standards Addressed	8.1.8.CS.2: Design a system that combines hardware and software components to process data. 8.1.8.CS.3: Justify design decisions and explain potential system trade-offs 8.1.8.AP.1: Design and illustrate algorithms that solve complex problems using flowcharts and/or pseudocode. 8.1.8.AP.6: Refine a solution that meets users' needs by incorporating feedback from team members and users. 8.1.8.AP.4: Decompose problems and sub-problems into parts to facilitate the design, implementation, and review of programs. 8.1.8.DA.2: Explain the difference between how the computer stores data as bits and how the data is displayed

Introduction

This four-lesson unit introduces middle school students to the fundamental ideas behind how computers work. Through a series of puzzles, simulations, and interactive activities, students explore computational thinking, algorithms, computer systems, and binary representation. Each lesson builds on the previous one, helping students understand how computers solve problems by following precise instructions and processing information step by step.

Students begin by developing logical problem-solving strategies and learning about computational thinking. They then explore how algorithms are used to solve problems and how careful observation and precise instructions are essential in programming. In later lessons, students investigate how computers process information through input, storage, processing, and output, and how data is represented using binary.

By the end of the unit, students will have a foundational understanding of how computers solve problems, how information is processed within a computer system, and how computational thinking strategies can be applied to complex challenges.

This lesson package includes:

- Presentation slides
- Cut Block Logic Puzzle Worksheets and Answer Keys
- Spot the Difference Worksheets (Robots and Fish)
- Bubble Sorting Number Cards (#1-6)
- Traveling Salesman Printable Activity Image
- "How Computers Work" Activity Sheets (CPU 1 & 2, ALU, Display)
- "How Computers Work" Activity Instructor Information Sheet
- "How Computers Work" Video Student Worksheet
- Computational Thinking (CT) Printable Skills Quadrant

Lesson Agenda

Class 1 – Introduction to Computational Thinking
Objective: Students will use logic and problem-solving strategies to explore how complex problems can be solved step by step, introducing key ideas behind computational thinking.

5 mins	Warm up: Discuss in Small Groups	"Think back to a large problem you have had lately. How did you solve it? How did you discover the solution? Did you get help?"
20 mins	Activity: Eight Queens	This puzzle is a classic problem in which the goal is to place eight queens on an 8x8 chessboard such that no two queens threaten each other. 1. First explain how a queen can move (vertically, horizontally, and diagonally) 2. Model how to create two safe queens (in the first example the two queens will not be safe). 3. When you start this activity, also start a stopwatch and wait until you hear someone say this is impossible or I give up. Give them a pep talk about academic rigor and encourage them. o After 2 -5 minutes, you can quickly walk through a few of the hints, then you can post all of them. Try making this a challenge. How many people can do it? 4. Show slides of potential solutions, discuss briefly before moving on to the video (up next). *Refer to the PPT slides and list below for student hints.*
~8 mins	Video: Watch a Computer Solve the 8 Queens Problem	https://www.youtube.com/watch?v=YdU7kIhObps
5 mins	Wrap up: Discussion (Whole Class)	*See below for discussion questions.*

Eight Queens Hints

- **Knight's Move:** Think about how knights move in an "L" shape: two squares in one direction and then one square perpendicular to that. While this doesn't directly solve the queen's placement problem, it can help in visualizing non-linear movements on the board.
- **Zig-Zag Pattern:** Encourage them to try placing queens in a zig-zag pattern, moving diagonally up and down as they place each new queen. This helps avoid conflicts in both rows and columns.
- **Mirroring:** Place the first few queens in one half of the board, and then try to mirror that pattern on the other half. This can create symmetrical patterns that help avoid conflicts.
- **Diagonals First:** Focus on placing queens along the main diagonals first. Once the main diagonals are populated, it becomes easier to see safe spots for the remaining queens.

- **Corners and Edges:** Start by placing queens in the corners or along the edges of the board. This reduces the number of squares that are threatened and can help in visualizing safe spots.
- **Layering:** Think of placing queens in layers. First, place a queen, then imagine that the board is layered, with each subsequent queen placed in a higher layer, avoiding the positions threatened by queens in the lower layers.
- **Divide and Conquer:** Divide the board into smaller sections and solve for each section independently. For example, treat the board as four 4x4 sections and place queens in each section ensuring they don't conflict.

Class 1 Discussion (Wrap up)

- **Concept Check:** What are the main rules that each queen must follow to ensure they are not attacking each other on the chessboard?
- **Pattern Recognition:** How many different solutions did you find for placing the 8 queens on the board? Did you notice any patterns or similarities among the solutions?
- **Strategy:** What strategies did you use to figure out where to place each queen? How did you determine whether a placement was safe or not?
- **Problem Solving:** If you had to place 9 queens on a chessboard instead of 8, what changes would you need to make to your approach? How might the problem become more complex?
- **Visualization:** How did visualizing the chessboard and the positions of the queens help you in solving the problem? Did drawing out the board or using physical pieces make a difference?
- **Reflection:** What was the most challenging part of solving the 8 Queens problem for you, and how did you overcome it? What did you learn from this activity about problem-solving and strategy?
- **Learning Experience:** How did working on the 8 Queens problem change the way you think about puzzles and challenges? Did it help you develop any new skills or approaches that you can use in other areas?
- **Teamwork and Collaboration:** If you worked on this problem in pairs or groups, how did collaborating with others affect your approach to finding solutions? What did you learn from your peers, and how did working together impact the overall process?

Class 2 – How Algorithms Solve Problems

Objective: Students will apply computational thinking by using algorithms to solve problems and recognizing the importance of precise instructions and careful observation.

Time	Activity	Notes
10 mins	Warm up: Discuss in Small Groups	1. Ask: "Do you know how to solve a Rubik's Cube? How do you do it? What is the strategy? Is math involved?" Briefly discuss. 2. Play video on how to solve a Rubik's Cube (watch until 3:11): https://www.youtube.com/watch?v=PW2J8IblczM 3. Even though the Rubik's Cube looks random, people solve it using specific sequences of moves. These sequences are called algorithms. a. Briefly reflect and ask the class: i. What is an algorithm? ii. Do you remember either of the two algorithms from the video?
20 mins	Activity: bubble	1. Post the directions on the board or use provided PPT slide. 2. Students will sort number cards using different algorithmic methods of sorting (15 mins):

10 mins	Activity: Spot the Difference (Independent)	1. Give students puzzles 2 and 3 (robots and fish) and have them circle differences they notice in the second image. 2. Explain to students that this activity is helping them to think more like programmers, who need attention to detail when writing programs and debugging software. o These skills are important in computer science because programmers must carefully examine code to identify errors (bugs) and ensure instructions are written correctly. *Student worksheets and answer keys available separately in package.*
10 mins	Wrap-up Discussion (Whole Class)	Throughout the lesson, students explored how problems can be solved using algorithms: clear, step-by-step instructions that can be repeated and followed precisely. This discussion should help students connect the Rubik's Cube example, the sorting activity, and the spot-the-difference exercise to the way computers solve problems by following instructions, repeating steps, and requiring careful attention to detail. *See below for discussion questions bank.*

Bubble Sort Activity

Objective: In this activity, students act out a sorting algorithm used by computers to organize data.

- **Materials:**
  - Each group receives one shuffled set of six number cards labeled 1–6.
  - Cards may be printed number cards (provided), index cards, or playing cards with numbers written clearly.
  - See "Bubble Sort Cards – Printable" within lesson package.
- **Bubble Sort Activity #1: Put in number order**
  - Students will:
    - Place all cards face down
    - Flip first 2 cards over. Move the lower number to the left.
    - Flip both cards back face down.
    - Now flip cards 2 and 3 over. Move the lower number to the left.
    - Flip both cards back face down.
    - Now flip cards 3 and 4 over.
    - Flip both cards back face down.
    - Now repeat. Start from the step 1 with flipping over cards 1 and 2.
  - Repeat this process until the cards are in number order. Continue making passes until the list is sorted.
    - *Teacher note: When a full pass results in zero swaps, the list is sorted.*
- **Bubble Sort Activity #2: take the larger number with you**
  - Students will:

        - Place all cards face down
        - Flip first 2 cards over. Move the lower number to the left.
        - Flip over the smaller number and take the larger number with you.
        - Now compare the card you are holding with card 3. Move the lower number to the left.
        - Flip over the smaller number and take the larger number with you (leave face up).
        - Now flip card 4 over. Move the lower number to the left.
        - Flip over the smaller number and take the larger number with you (leave face up).
        - Now repeat. Start from the step 1 with flipping over cards 1 and 2.
        - Repeat this process until the cards are in number order.
    - Repeat passes (ignoring sorted cards at the end) until no swaps are needed.
        - *Teacher note: The largest number "travels" to the right during the pass.*
- **Activity Discussion Questions bank:**
    - What steps did your group follow to sort the numbers?
    - Did every group follow the same steps, or did some groups do it differently?
    - What happened to the largest number during each pass through the cards?
    - Why did we have to repeat the steps more than once?
    - What might happen if one of the instructions was skipped or done out of order?
    - How is sorting the cards like giving instructions to a computer?
    - Why do computers use algorithms to sort information?

Class 2 Discussion Bank (Wrap-up)

- What did the Rubik's Cube, the sorting activity, and the spot-the-difference puzzle have in common?
- What does the word algorithm mean?
- Why did we have to repeat the same steps several times to sort the cards?
- What happened to the largest number during each pass through the row?
- Why was it important to look carefully at the pictures in the spot-the-difference activity?
- How might missing a small detail affect a computer program?
- Why do computers need very clear instructions?
- How are computers similar to what you did during the sorting activity?
- If someone asked you how computers solve problems, what would you say?

Class 3 – How Computers Process Information

Objective: Students will explore how computers process information by examining the roles of input, storage, processing, and output within a computer system.

Time	Activity	Notes
5 mins	Warm up: Question	"If your class had to plan a school event like a talent show, how could the four computational thinking skills help organize the work?" • Keep PPT slide with definitions up as you discuss with the class. *See below for some discussion question prompts.*
10 mins	Activity: Traveling Salesman	In this activity, students will explore how computers evaluate different possibilities to find the best solution to a problem. Students do not need to find the exact shortest route as this activity is about exploring possible paths.

		1. Show the graph of connected nodes (cities) on the PPT slide. a. This can be done as a class or by printing the included traveling salesman figure for independent or group work. 2. Explain that each circle represents a city and each line is a possible route between cities. 3. Tell students they are a traveling salesperson who must visit each city once. 4. Working individually or in small groups, students trace possible routes between the cities. 5. Ask students to try to determine: a. The shortest route they can find that visits all cities. b. The longest route they can find that still visits all cities. 6. Have students compare their routes with classmates. 7. To help transition to the video (up next), explain to the class that: a. Problems like this can have many possible solutions, and checking all of them can be difficult for humans. Computers are powerful because they can follow instructions quickly and test many possibilities. Let's watch a short video to see how computers perform these tasks. *A printable traveling salesman figure (same as in PPT) is available separately.*
10	Video: How Computers Work	Watch the video and have students answer these questions concurrently. https://www.youtube.com/watch?v=mCq8-xTH7jA&t=8s ○ What are the four main tasks that computers need to perform to be considered a "thinking machine"? ○ Describe how the input, storage, processing, and output stages work together in a computer system. ○ How have computers evolved from the earliest "thinking machines" to the modern devices we use today? Provide examples of how they have changed. • Before moving on, engage the students in a brief discussion reviewing their answers. *See below for answers. An optional student worksheet included separately.*
20 mins	Activity: How Computers Work (Groups of 3)	In this activity each student takes on the role of a different part of a simplified computer (Display, ALU/Memory and the CPU) and they work in groups of 3 to run a simple program. The result of this program is to draw a picture on a simulated computer display. ○ https://cse4k12.org/how_computers_work/index.html *See below for more information.*
2 mins	Wrap-up: Riddle	• Riddle: "I am the brains of the device you use every day, handling tasks in an organized way. What am I?" ○ Answer: CPU (Central Processing Unit)

Warm-up Discussion Question Prompts

- How could you break the problem into smaller tasks? (Decomposition)
- What patterns or similarities might you notice? (Pattern Recognition)
- What steps would you follow to organize everything? (Algorithm)

- What details matter most, and which can you ignore? (Abstraction)

How Computers Work Video Answers

1. The four main tasks computers need to perform are: taking input, storing information, processing the information, and outputting the results. <00:01:29 - 00:01:54>
2. Computers take in information through various input devices like keyboards, mice, microphones, and cameras. This input data is then stored in the computer's memory. The computer's processor manipulates and processes the stored information using algorithms, and then sends the processed data back to be stored again. This cycle continues until the information is ready to be output through displays, speakers, or other devices. (00:03:28 - 00:03:55)
3. Early computers were large, clunky machines made of wood, metal, and mechanical parts. They were slow and could only perform basic mathematical calculations. Over time, computers evolved to use electrical components and became much smaller and faster. Today's computers can do a wide variety of tasks like communication, gaming, robotics, and virtual reality. (00:01:54 - 00:02:43)

Class 4 – Understanding the Binary System
Objective: Students will explore how computers represent numbers using binary and apply computational thinking skills to identify patterns, strategies, and problem-solving methods used during the activity.

Time	Activity	Notes
5 mins	Warm-up: class question	"If you wanted a computer to draw a picture or move a character on the screen, what instructions would you need to give it?" Encourage students to think about step-by-step instructions. Emphasize that computers can only perform actions when given clear commands.
20 mins	Activity: Binary	1. Explain that computers store numbers using binary, a system that uses only two digits: 0 and 1. In this activity, each column represents a value (1, 2, 4, and 8). By turning columns on or off, students can create different numbers. 2. Have students complete the 4-bit binary Scratch activity a. https://scratch.mit.edu/projects/614413974/ 3. Pass out small pieces of paper. On these, students will write patterns they noticed, strategies they used, or observations about how the binary system works. Encourage students to generate several slips. a. E.g. If a student identifies 4 observations and 6 strategies, they should write 10 separate slips (one idea per slip). This activity will help students see that problem solving involves multiple strategies, which connects directly to computational thinking.
10 mins	Activity: Computational thinking Skills (Small-Group Reflection)	1. Using more slips of paper, students will write down notes on the four computational thinking skills. Ask students to write one idea per slip of paper related to computational thinking. 2. At their table, they will place each piece of paper on the correct square of the larger paper. The chart paper will be broken up into four quadrants; 1 per CT skill. 3. After writing them down, have students add each to the quadrant that best represents each CT skill. Students are sorting examples of computational thinking into categories

		Printable CT quadrants sheet provided separately.
15 mins	Wrap-up Discussion (Whole Class)	Ask questions to help students reflect on the binary activity and connect it to computational thinking. The goal is for students to recognize how pattern recognition, step-by-step strategies, and clear instructions help both people and computers solve problems. *See guidance document for discussion questions bank.*

Preparation:

Cut small slips of paper or secure post its for use during the Binary and CT reflection activities.

Class 4 Discussion Bank (Wrap-up)

- What patterns did you notice in the binary numbers?
- How did recognizing patterns help you figure out how the binary system worked?
- Which computational thinking skills did you use during the binary activity?
- Why is breaking a problem into smaller parts helpful when solving a challenge like this?
- Why do computers use binary instead of regular numbers?
- How do clear instructions help computers perform tasks like drawing pictures or running programs?