

What is Computational Thinking?

Computational Thinking Characteristics

From the International Society for Technology in Education (ISTE) and the Computer Science Teachers Association (CSTA):

- Formulating problems in a way that enables us to use a **computer and other tools** to help solve them.
- **Logically** organizing and analyzing data
- Representing data through abstractions such as **models and simulations**
- Automating solutions through **algorithmic thinking** (a series of ordered steps)
- Identifying, analyzing, and implementing possible solutions with the goal of achieving the **most efficient and effective combination of steps** and resources
- Generalizing and **transferring this problem solving process to a wide variety of problems**

Computational Thinking for Teacher Education

Aman Yadav, Chris Stephenson, Hai Hong

Communications of the ACM, Vol. 60 No. 4, Pages 55-62

- Expose students to computational thinking at an early age

- Few teacher-education programs focus on training pre-service teachers to incorporate computational thinking into K-12 classrooms.
- Redesign of courses on educational technology and methods is critical to developing pre-service teacher competencies in computational thinking.
- Education and computer science faculty should work collaboratively, using their complementary expertise in computing and teacher development.

<https://cacm.acm.org/magazines/2017/4/215031-computational-thinking-for-teacher-education/fulltext>

Video

- [Computational Thinking for Teacher Education](#)

Principles of CT

- Three A's:
 - **Algorithm** – Using a sequence of steps to solve a problem
 - **Abstraction** – reducing a problem to its bare essence
 - **Automation** – Using tools to automate the solution to a problem
- “Wing said, ‘To reading, writing, and arithmetic, we should add computational thinking to every child's analytical ability.’ In summary, computational thinking is a set of problem-solving thought processes derived from computer science but applicable in any domain.”

Some Benefits of Computational Thinking

- Moves students beyond technology literacy
- Creates problem solvers instead of software users
- Lower-level processes
 - using basic facts, skills
- Higher-level processes
 - doing something complex with information
- Computational thinking is a higher-level cognitive process
 - manipulating data/information to see patterns
 - involves thinking, reasoning, and abstraction

NGSS

- What is NGSS?
- The Next Generation Science Standards (NGSS)
- Now requires teachers to incorporate Computational Thinking (CT) in K-12 education.

NGSS-Science and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
- 5. Using mathematics and computational thinking (CT)**
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

NGSS

- Using Mathematics and Computational Thinking:

<http://ngss.nsta.org/Practices.aspx?id=5>

Algorithms

- What is an **algorithm**?
 - A sequence of steps for solving a problem.
- Why is it important?
 - In daily life, we use algorithms to describe solutions to problems.
 - Computer programs execute algorithms to perform specific tasks.
 - Computers are dumb! They can only do exactly what they are told!

Algorithm Exercise

- Take out a paper.

Your Task:

- What are the steps to brush your teeth?

Materials:

- Tube of toothpaste
- toothbrush



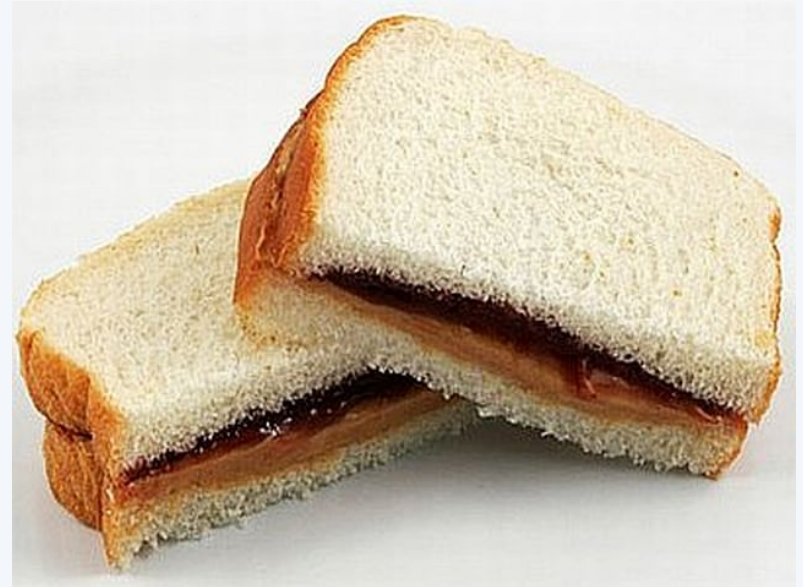
Algorithm Exercise Together

Your Task:

- What are the steps to make a peanut butter and jelly sandwich?

Materials:

- A jar of peanut butter
- A jar of jelly
- A loaf of sliced bread
- One butter knife



I need one (hungry) volunteer!

Anyone allergic to peanut butter?

Algorithm Examples, cont.

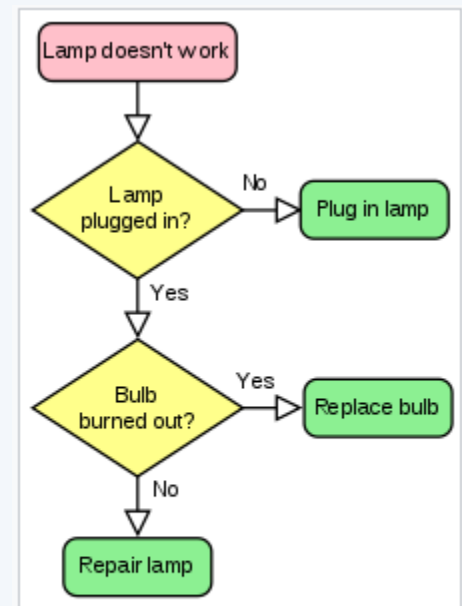
- Write an algorithm to get a computer to draw a square on the screen?
 - draw a 3 cm line
 - turn left 90 degrees
 - draw a 3 cm line
 - turn left 90 degrees
 - draw a 3 cm line
 - turn left 90 degrees
 - draw a 3 cm line

Example of an Algorithm

- **Algorithm (in simple English)**
- Problem: **Add 10 and 20**
- Initialize sum = 0
- Enter the numbers (Input)
- Add them and store the result in sum
- Print sum (output)

Flowchart

- What is a flowchart?
- A **flowchart** is a type of diagram that represents an algorithm, workflow or process, showing the steps as boxes of various kinds, and their order by connecting them with arrows. -Wikipedia

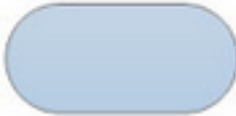






A simple flowchart representing a process for dealing with a non-functioning lamp.

Flowcharts, cont.

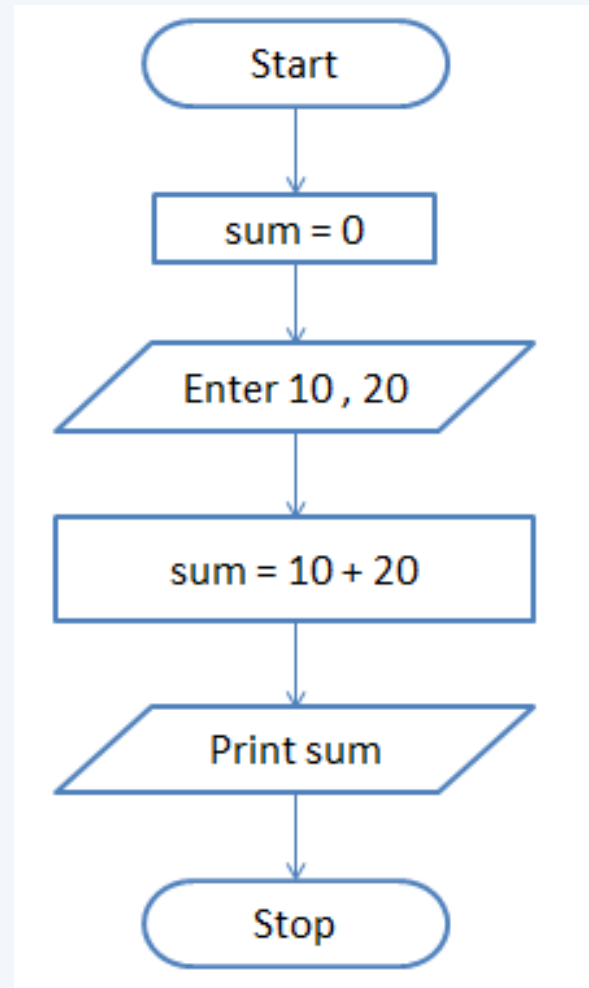
- A flowchart is a graphical representation of your thought process. It allows you to take your ideas and put them in a logical and organized fashion.
- [Funny flowcharts](#)

Flowchart Symbols

Symbol	Name	Function
	Start/end	An oval represents a start or end point
	Arrows	A line is a connector that shows relationships between the representative shapes
	Input/Output	A parallelogram represents input or output
	Process	A rectangle represents a process
	Decision	A diamond indicates a decision

← conditional

Problem: $10 + 20$



Flowchart via Big Bang Theory

- [Big Bang Theory: https://www.youtube.com/watch?v=k0xgjUhEG3U](https://www.youtube.com/watch?v=k0xgjUhEG3U)

In Class Group Work

- Form a group of approximately 4 students.
- Create a flowchart of your choice to show the class.
- Some Examples (or choose your own!):
 - Whether you will pass the class?
 - Whether you should major in Computer Science, Education, or anything else.
 - How to brush your teeth
- When you are done email it to me so we can show the class!

Daily Examples of CT

- Daily Example: what is the best way to look up a name in an alphabetically sorted list?
 - e.g., 100 names per page in list of 150,000 names
 - How to minimize the number of pages to look at?

Binary Search – divide the search interval in half by choosing the middle element.
- Parallel processing:
 - Execution of multiple processes at the same time. Daily Example:
 - Cooking a gourmet meal. You don't want the meat to get cold while you're cooking the vegetables
- Traveling salesman:
 - Given cities, find the shortest possible route that visits each city and returns to the origin city. Daily Example:
 - Taking your kids to soccer, gymnastics, and swim practice

Packing Jewels into a Backpack

- A thief found a treasure chest with different sized jewels but only has a backpack of size 50!
 - She can only pack jewels resulting in a total size of at most 50
 - She wants to maximize her profit in terms of the value
- Example

Jewel	A	B	C	D	E	F
size	30	28	15	10	8	5
value	16	25	24	15	12	2

Poll

How can the thief maximize the value of what she takes?

- (A) Arrange the jewels by value, from largest to smallest, and put a jewel into the backpack if it still fits
- (B) Choose jewels in random order and put into the backpack if it still fits
- (C) Compute the ratio of "value per unit of size" and consider the jewels in order of largest ratio. Put into the backpack if it still fits
- (D) Get a larger backpack

Try out A and C

In groups of approximately 4 students, try out A and C.

For each of the below answer the following on a paper:

Which Jewels did you get?

What is the total size?

What is the total value?

(A) Arrange the jewels by value, from largest to smallest, and put a jewel into the backpack if it still fits

(C) Compute the ratio of "value per unit of size" and consider the jewels in order of largest ratio. Put into the backpack if it still fits

Jewel	A	B	C	D	E	F
size	30	28	15	10	8	5
value	16	25	24	15	12	2

Poll again!

Computational thinking can be integrated into the education of

[A] STEM (Science, Tech, Engineer and Math)

[B] English / History /Social Studies

[C] Art

[D] Physical Education

[E] All above

Example Applications of CT in K-12

- Elementary Education
 - Breaking down a simple daily task such as brushing teeth into 15 separate and distinct steps to build foundations for understanding computer performance.
- English
 - Identifying the similarities between raps and poetry, and matching rappers with poets based on their similar styles and characteristics.
- History
 - Studying historical events and statistic data to investigate what caused immigrations rates to change over time.

Another Poll!

- Which of the following is NOT like the others?
 - [A] People standing in line at the store
 - [B] List of print jobs waiting to be printed
 - [C] Set of tennis balls in their container
 - [D] Vehicles lined up behind a toll booth
 - [E] Patients waiting to see the doctor

Answers

- Which of the following is NOT like the others?
 - [A] People standing in line at the store (queue)
 - [B] List of print jobs waiting to be printed (queue)
 - [C] Set of tennis balls in their container (stack)
 - [D] Vehicles lined up behind a toll booth (queue)
 - [E] Patients waiting to see the doctor (queue)

What is Computational Thinking

[Google Computational Thinking Video](#)

Google CT, cont.

- Exploring Algorithms:

[https://](https://computationalthinkingcourse.withgoogle.com/unit?unit=2&lesson=23)

[computationalthinkingcourse.withgoogle.com/
unit?unit=2&lesson=23](https://computationalthinkingcourse.withgoogle.com/unit?unit=2&lesson=23)

- Finding Patterns:

[https://](https://computationalthinkingcourse.withgoogle.com/unit?unit=12&lesson=24)

[computationalthinkingcourse.withgoogle.com/
unit?unit=12&lesson=24](https://computationalthinkingcourse.withgoogle.com/unit?unit=12&lesson=24)

- Developing Algorithms:

[https://](https://computationalthinkingcourse.withgoogle.com/unit?unit=7&lesson=25)

[computationalthinkingcourse.withgoogle.com/
unit?unit=7&lesson=25](https://computationalthinkingcourse.withgoogle.com/unit?unit=7&lesson=25)

Finding Patterns

- Anyone ever play 20 questions?
- I am thinking of something (ex. airplane) and you have only 20 questions! I can only answer Yes or No.
- A recent estimate of the number of different species of life on Earth is between 8 and 9 million.
- How many questions do you think it would take to confidentially guess any species on earth I was thinking of?

Decomposition

- It's a hard problem – let's try decomposition to break the large problem into smaller problem!

Guess which organism I am thinking of?



What kind of question should you ask?

Try asking a question that removes half of the organisms:

Should I ask:

Does the organism have fins?

Would remove 2: Fish, dolphins

Does the organism have legs?

Would remove 4: Bear, bird, tiger, rooster

Does the organism have legs?

Yes!



Now I can ask either of these:

Does the organism have fur?

Or

Does the organism have wings?

Does the organism have wings?

No!

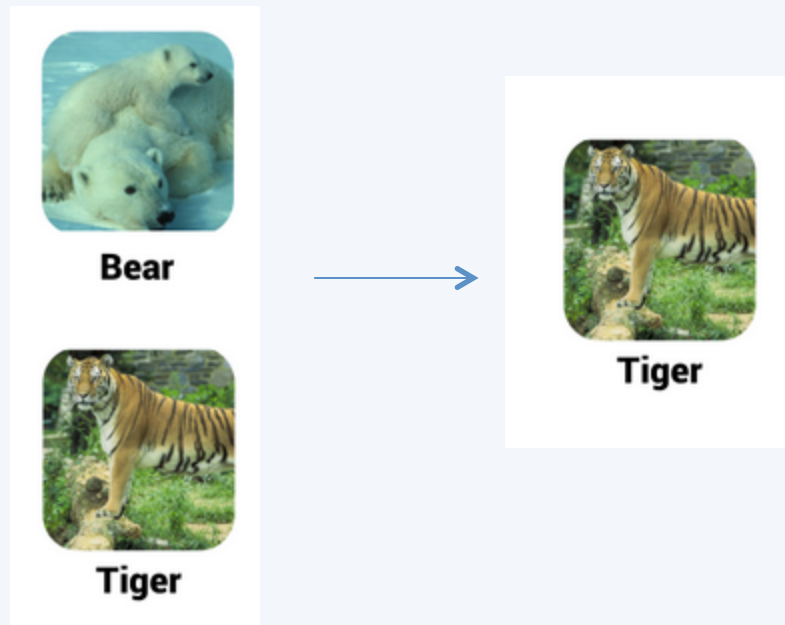


What can we ask now?

Does the organism have stripes?

Does the organism have Stripes?

Yes!



By asking good questions we were able to guess in **3** tries.

Decomposition...

- We were able to figure out which of the 8 organisms I was thinking of with only **3** questions.
- How many questions do you think it would take to guess which organism I was thinking of from 16 organisms if each of your questions removed half of the options?

Poll

- How many questions do you think it would take to guess which organism I was thinking of from 16 organisms if your question removed half of the options?
 - a) 3
 - b) 4
 - c) 5
 - d) 6
 - e) 8
 - f) 10

Pattern

- Every question has 2 possibilities, "Yes and No". For:
- 8 possibilities $2 * 2 * 2 = 2^3 = 8$
- 16 possibilities $2 * 2 * 2 * 2 = 2^4 = 16$
- 32 possibilities $2 * 2 * 2 * 2 * 2 = 2^5 = 32$

Decomposition/ Pattern, cont.

- If there were let's say 8 billion species out there – how many questions would you need to ask if each question eliminated half the options?

Abstraction

- Calculate \log_2 of all of the possibilities or
- Calculate what power of 2 is necessary to equal the number of possibilities: $2^4=16$, $2^5=32$, ..., $2^{33} \approx 8.5$ billion.
- The ability to generalize the pattern found through experimentation into a general rule, equation, or law is known as **abstraction**.

Questions for Discussion

- *What do you think Computational Thinking (CT) is?*
- *Why do you think CT is important?*
- *How would you incorporate CT in K-12?*
- *Any other questions or comments on the article or CT in general?*



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