Subject:
Computational Thinking & Programming

Module-1
(related to:)
Systemic Vs Computational Thinking

Sub-topics to be covered

1. Thinking
2. Thinking & problem solving models
3. Systemic Thinking (ST)
4. Computational Thinking (CT)
5. Programming and CT
6. How to use Computational Thinking to learn this programming subject
7. Home work
8. Summary

Thinking – what is it?

- **Thinking is a natural phenomenon** for human being.
- **Thinking is mostly organised** and goal directed
- **Thinking is an internal mental process**, which can be inferred from our behaviour (mental exploration)
- **Building blocks of thinking** – mental image & concept related to it
- **Types of thinking:** perceptual / concrete / reflective / abstract / logical / autistic / creative / divergent / convergent

Thinking – what is it? (2)

- **Thinking is natural, but thinking about thinking is special** – A good wisdom trains us to think about our thinking by contextualizing our thoughts

How “thinking” proceeds to problem solving?

- Problem solving is thinking that is goal-directed.
- Almost all our day-to-day activities are directed towards a goal (?)
- Some problems can be solved quickly and some may take more time & efforts (?)

How “thinking” proceeds to problem solving? (2)

- It is important to know that problems are not always in the form of obstacles or hurdles that one faces; it is the nature of that problem itself (basically) (?)
- Mental set / mind set
- Functional fixedness
- Lack of motivation
- Reasoning
- Decision making / judgement

How “thinking” proceeds to problem solving? (3)

- In problem solving there is an initial state (i.e. the problem) and there is an end state (the goal).
- These two end-points are connected by means of several steps or mental operations – thinking-driven operations.

Problem solving

- Problem solving is a process of finding and implementing a solution to a challenge or obstacle.
- In most contexts, this means going through a problem solving process that begins with identifying the issue, exploring its root causes, ideating and refining possible solutions before implementing and measuring the impact of that solution.



IDEAL model

- IDEAL gives you a complete cycle from recognizing a problem through reflecting on your solution:
- **I**dentify the problem
- **D**efine it clearly
- **E**xplore possible solutions
- **A**ct on the best option
- **L**ook back at the results

A generic model of problem solving

- Step 1: Define the Problem – Clarify scope, objectives, and impact.
- Step 2: Analyze the Problem – Gather data, identify patterns, and determine root causes.
- Step 3: Generate Potential Solutions – Brainstorm, evaluate options, and select best approaches.
- Step 4: Implement the Solution – Action planning, execution, and monitoring.
- Step 5: Evaluate & Sustain Results – Review outcomes, standardize practices, and embed improvements.
- Tools & Techniques – Fishbone diagrams, Pareto charts, and other supporting methods.
- Case Examples – Applications of the five-step approach in different industries.

Problem solving - example

Let us look at the problem of organising a play in school on the occasion of Teachers' Day. Problem solving would involve the following sequence.

	Mental operation	Nature of problem
1.	Identify the problem	A week is left for teachers' day and you are given the task of organising a play.
2.	Represent the problem	Organising a play would involve identification of an appropriate theme, screening of actors, actresses, arranging money, etc.
3.	Plan the solution: Set sub-goals	Search and survey various available themes for a play, and consult teachers and friends who have the expertise. The play to be decided, based on such considerations as cost, duration, suitability for the occasion, etc.
4.	Evaluate all solutions (plays)	Collect all the information/stage rehearsal.
5.	Select one solution and execute it	Compare and verify the various options to get the best solution (the play).
6.	Evaluate the outcome	If the play (solution) is appreciated, think about the steps you have followed for future reference for yourself as well as for your friends.
7.	Rethink and redefine problems and solutions	After this special occasion you can still think about ways to plan a better play in future.

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Why Problem-Solving Matters

- Business-driven answer - map it to a common man (?)

- Improve operational efficiency.
- Reduce unnecessary costs.
- Increase customer satisfaction.
- Minimize business risks.
- Improve collaboration.
- Support innovation.
- Strengthen business performance.

Creative Thinking

- Creative thinking is distinguished from other types of thinking by the fact that it involves the production of novel and original ideas or solutions to problems.
- Sometimes, creative thinking is understood just as a new way of thinking or thinking differently (?)
- However, it is important to know that, besides novelty, originality is also an important characteristic of creative thinking

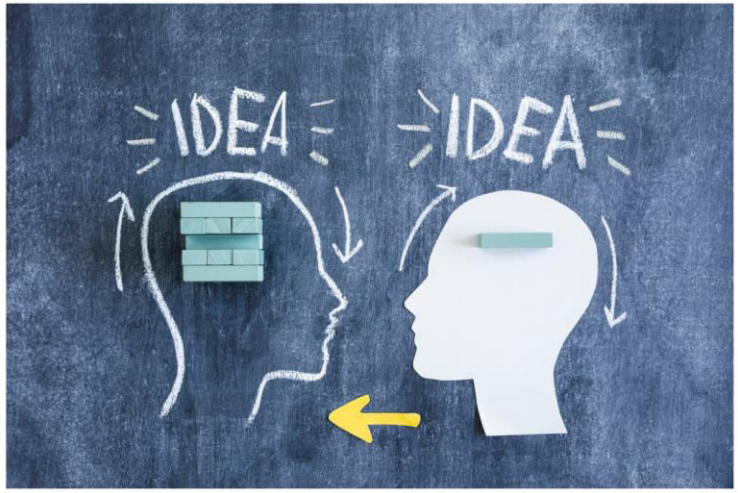
Creative thinking (2)

- Creative problem solving is a systematic approach to tackling complex challenges through innovative thinking.
- Unlike traditional problem-solving methods, which often rely on conventional solutions, the creative problem-solving process encourages individuals to think outside the box and explore alternative solutions.

Creative thinking (3)

- To work well, creative problem solving is rooted in two assumptions:
  - Everyone is creative in some manner.
  - All of use - we can learn and enhance our creative abilities.
- Curiosity, cognitive / thinking flexibility, willingness to participate, continuous learning, collaboration – are the indicators about critical thinkers

Creative thinking - steps



- Preparation / brainstorming / create ideas
- Incubation
- Illumination
- Evaluation
- Revision

- Any example / use-case / case-study?

Benefits of creative thinking

- Finding creative solutions to complex problems
- Adapting to change
- Fuelling innovation and growth

HW Questions

- Thinking Vs Over-thinking?
- Any relationship among language and thinking?
- Culture and Thinking ?

- When will your critical thinking work / starts working?

Summary

- Thinking is a complex mental process through which we manipulate information (either acquired or stored).
- It is an internal process that can be inferred from behaviour.
- Thinking involves mental representations that are either mental images or concepts.
- Complex thought processes are problem solving, reasoning, decision-making, judgment, and creative thinking.
- Problem solving is thinking directed towards the solution of a specific problem.

References for further reading

- https://gitadaily.com/thinking-is-natural-but-thinking-about-thinking-is-special/
- https://michiganvirtual.org/blog/kinds-of-thinking
- https://www.inclusivedesigntoolkit.com/UCthinking/thinking.html
- https://asq.org/quality-resources/problem-solving?srsltid=AU7gw4VEUzD7HotcKF1pMuLFSusHirzUmUP3hZeaGBoslJiRzO9Zlye0
- https://bilginc.com/us/blog/creative-thinking-and-problem-solving-innovative-approaches-to-complex-challenges-6449/
- https://www.indeed.com/career-advice/career-development/approaches-to-problem-solving
- https://www.learningcompanions.in/wiki/components-of-problem-solving/

SYSTEMS THINKING

- SYSTEMIC THINKING (not systematic thinking) (?)
- Systems thinking is a holistic way to investigate factors and interactions that could contribute to a possible outcome.

Examples of systems

- A family unit is one system, while the community in which we live is another.
- That community is part of a bigger system of a county or city.
- All parts of a university make up different systems within the whole.
- Financial – bank, the classroom and the library make up different systems.

SYSTEMIC THINKING

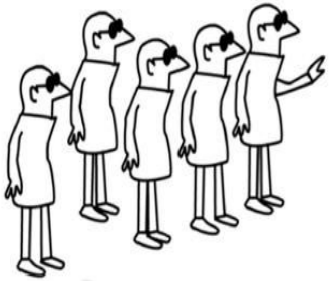
- Systems thinking is an approach that encourages people to look at behaviours and processes as parts of a system.
- Systems thinking offers several benefits, but they ultimately boil down to quick and efficient problem-solving, addressing what could be the root cause of a problem.
- From a management's viewpoint, systems thinking focuses that leaders make better decisions if they look at functions, processes, and people as part of a system. (PPT ?)
- Systems thinking is particularly useful when understanding VUCAH (volatility, uncertainty, complexity, ambiguity, hyperconnectivity) behaviours in organisations. (?)

Systemic Thinking

- We all grew up exploring our natural and social worlds and asking questions out of curiosity.
- We can look at problems, see beyond the obvious, and explore otherwise hard to see connections (?)
- The growing interest in systems thinking is that to encourage its use in both problem structuring and solution design.

Systemic Thinking (2)

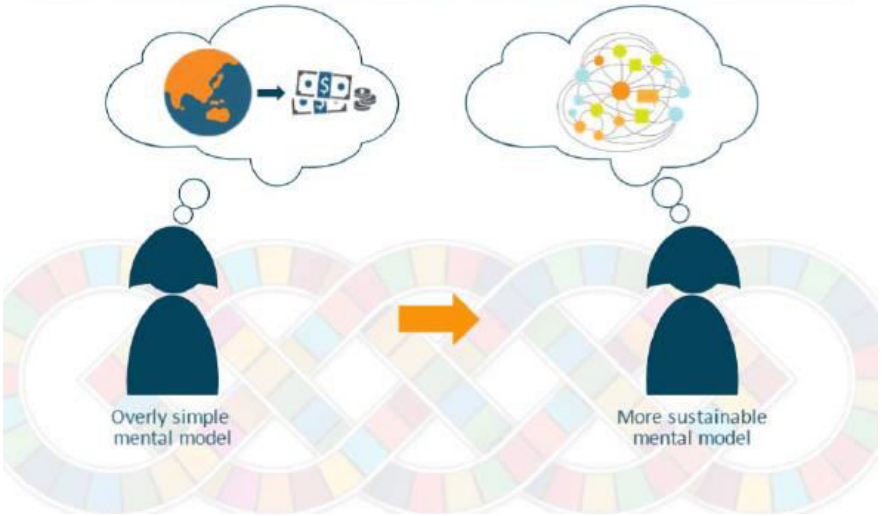
What is a Systems Perspective?







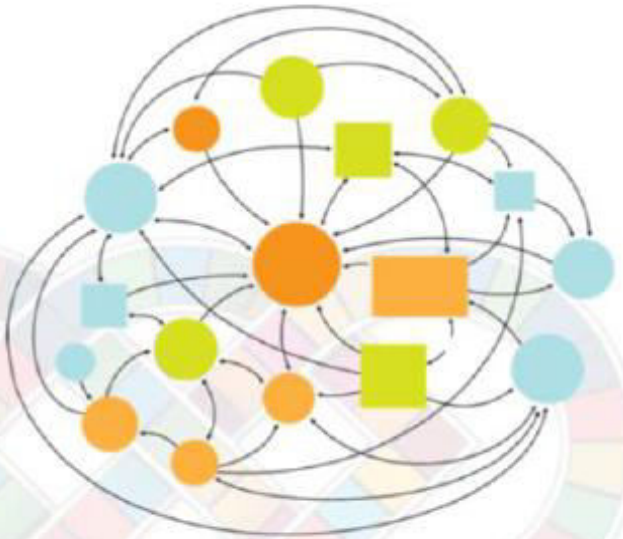
Systems thinking is the practice of examining, and improving, our mental models



Systemic Thinking (3)

"*Systems Thinking* is seeking to understand the connections among elements in a system"

- ✓ what depends on what,
- ✓ what is causing what,
- ✓ where are information flows,
- ✓ where control decisions are made,
- ✓ what information flows are critical,
- ✓ how to best engage stakeholders,
- ✓ And how best to manage or intervene in the system for desired results.



To be a systems thinker you see

- Any entity as a whole – not by-parts
- Interactions between parts, not the parts themselves
- The way systems affect other systems
- Reoccurring patterns rather than just individual events.
- By learning how to continuously ask yourself how you fit as a piece into the larger whole of the systems around you, you can work together better as teammates, colleagues and stewards of your environments.

Benefits of ST

- Any one can certainly learn to become a systems thinker, however, learning how to adopt a systems thinking mindset can be a challenge.
- If you take the time to consider the systems with which you work up front, any project design will be that much stronger, with a solution that lasts longer.

Problem solving using ST

- A solution to a problem has side effects (?), which can later reinforce the problem or cause new problems.
- Therefore, we need to approach the problems that we try to tackle with a more holistic view.
- A systems mindset helps us to get an overview and to understand how everything is connected and can help us to prevent undesirable side effects.

ST – further to note

- Systems thinking is a way of seeing the world as a series of interconnected and interdependent systems rather than lots of independent parts.
- As a thinking tool, it seeks to oppose the reductionist view — the idea that a system can be understood by the sum of its isolated parts — and replace it with expansionism, the view that everything is part of a larger whole and that the connections between all elements are critical.

Case study - ST

- Healthcare: Healthcare systems consist of numerous interdependent elements, including patient care, staffing, medical supply chains, and insurance structures.
- These components are influenced by external factors such as government policies, technological advancements, and public health trends.
- By adopting a Systems Thinking approach, healthcare administrators can model how changes in one area—like staffing levels—affect patient outcomes and overall efficiency.
- Simulations through Machinations can help hospitals and organizations optimize resources, improve care, and predict the impact of policy changes.

ST – for – problem solving

- Interconnectedness Elements of a system influence one another. No part functions in isolation.
- Feedback Loops Actions create responses that loop back into the system, shaping the behavior.
- Causality Over Time Causes and effects unfold over time, often with delays that obscure their relationship.
- Emergence New properties and behaviors arise from interactions that cannot be assessed by looking at parts alone.
- Holistic View Understanding the whole system is essential to grasp how it functions and how to intervene.

ST – for – problem identification and analysis

- A systemic approach for problem identification and analysis is a holistic method that looks at an entire system, its interconnected parts, and feedback loops rather than just isolated symptoms

Problem identification (ST)

- Observe symptoms: Notice unwanted outcomes, performance gaps, or disruptions in the environment.
- Separate symptoms from causes: Recognize that a visible sign (like declining sales) is only a signal, not the core issue.
- Engage stakeholders: Talk to people inside and outside the process to gather diverse viewpoints and uncover hidden needs.
- Define boundaries: Set the limits of what the system includes (and what falls outside it) to keep the analysis focused.
- Write a clear problem statement: Document who is affected, when and where it happens, and the size of the impact

System Analysis (ST)

- Map relationships: Trace how different components, data flows, and behaviors interact with one another.
- Find root causes: drill down and find out triggers for issues
- Examine feedback loops: Identify how ongoing actions or outputs loop back to reinforce or weaken the problem over time.
- Test hypotheses: Use factual data and evidence to confirm or disprove what you believe is driving the issue
- Empirical or experimental

Systems thinking enables us to:



Change our thinking to match the interconnected, dynamic complexity of our communities and their environments



Communicate with others to create new ways of thinking and seeing - and develop shared understanding



Change our behavior to work with the complex forces in the system (instead of against them) to realize our vision



Identify and test a wider variety of **possible actions and solution pathways**



Become more aware of the potential for unintended consequences of our actions



Harness **social learning** processes to help us develop a shared understanding and take action collectively



Expand the choices available to us and identify those choices where we can **develop significant leverage**

Home work – questions (ST)

- Apply systems thinking in your own house
- How is today's Internet enabling you to think systemically about it
- Think about any social media app and tell about the systemic thinking that comes into your mind

Summary

- Systems thinking reminds us that no problem exists in isolation—where every part plays a role in a larger internal network.
- When we stop trying to 'fix' what looks broken and instead ask how it's connected, we open the door to real insight and lasting solutions.

Further reading -ST

- https://www.excella.com/insights/solving-complex-problems-with-systems-thinking
- https://drkrishnaathal.com/blog/mastering-systems-thinking-the-key-to-solving-complex-problems/
- https://medium.com/disruptive-design/problem-solving-desperately-needs-systems-thinking-607d34e4fc80
- https://www.riosalado.edu/news/2025/solve-big-problems-systems-thinking

Definitions

- A component is a single part or element that combines with other pieces to form a larger, more complex system, machine, or whole

- A boundary is a limit, dividing line, or rule that defines where one thing ends and another begins

Definitions (2)

- An input is any resource, data, energy, or information that is put into a system, machine, or organization so it can operate or produce a result
- Processes are a series of actions, steps, or changes directed toward a specific result
- An output is the direct, tangible deliverable or product that a project produces upon completing its planned activities
- Examples of outputs are the physical or digital results produced by a computer system after it processes data

Definitions (3)

- Stakeholders - any person, group, or organization that has an interest in a company or project and can affect or be affected by its decisions and operations.
- A relationship is any connection, association, or bond between two or more people / parts of systems

Definitions (4)

- Dependency is a relationship where one object, task, or software component relies on another to function or proceed.
- Cause: The reason why something happens or the trigger behind an event. It always happens first. Effect: The result, outcome, or consequence of that cause. It happens after the cause.

Definitions (5)

- A hierarchy system is an arrangement of items, people, or concepts ranked above, below, or at the same level as one another
- Interconnection is the state or act of connecting two or more things, systems, or networks so they can share data, traffic, or resources.
- A feedback loop is a continuous process where the output of a system circles back to influence its own input

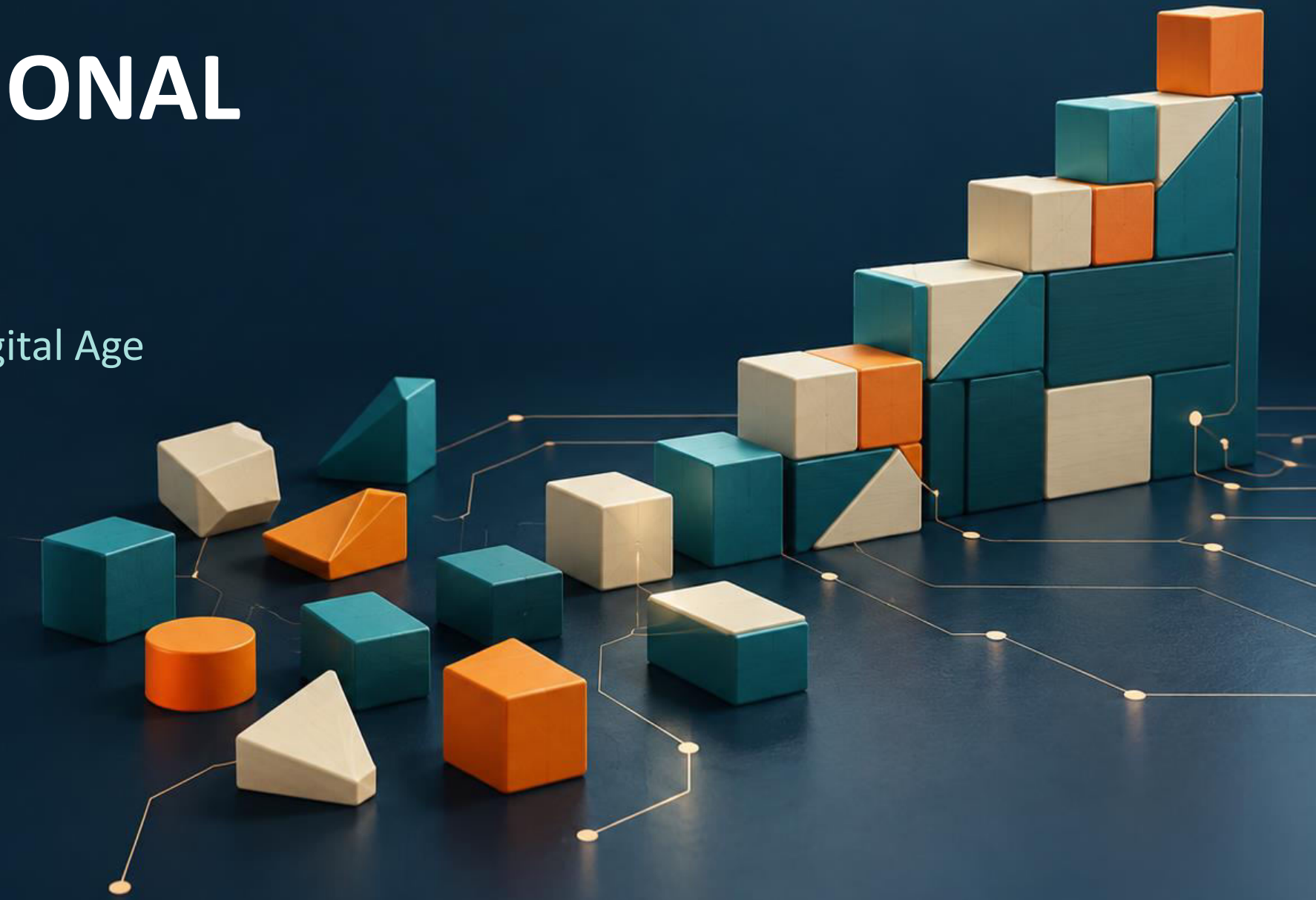
Definitions (6)

- System Behaviour – is the observable response, action, or output of a system as it interacts with internal forces and its surrounding environment.
- A pattern is a regular, repeated arrangement of sounds, shapes, numbers, or events that follow a specific and predictable rule
- A complex problem is a messy challenge with many connected parts, shifting rules, and no single clear fix

COMPUTATIONAL THINKING

Problem Solving in the Digital Age

Understanding problems.
Designing clear solutions.



What is Computational Thinking?

A systematic approach to understanding problems and designing clear, logical and efficient solutions.

A way of solving problems

Works with or without a computer

Applies beyond programming

Useful in engineering, business and daily life

The core habit

Make the problem manageable.
Make the solution precise.

Why Computational Thinking Matters

01 **Understand complexity**

Break difficult problems into manageable parts.

02 **Choose better solutions**

Compare alternatives using evidence and constraints.

03 **Use effort efficiently**

Reduce repeated work and identify tasks to automate.

04 **Explain the reasoning**

Communicate steps clearly and prepare for AI applications.

Example: the best route to college depends on time, distance, cost and traffic.

Informal and Computational Approaches

An informal approach may…	Computational thinking encourages…
Tackle the whole problem at once	Break the problem into smaller parts
Rely mainly on intuition	Make reasoning and assumptions explicit
Accept the first workable solution	Compare correctness and efficiency
Repeat the same work manually	Identify opportunities for automation
Leave the process implicit	Describe clear, repeatable steps

These approaches can overlap. Experience and intuition also help define good solutions.

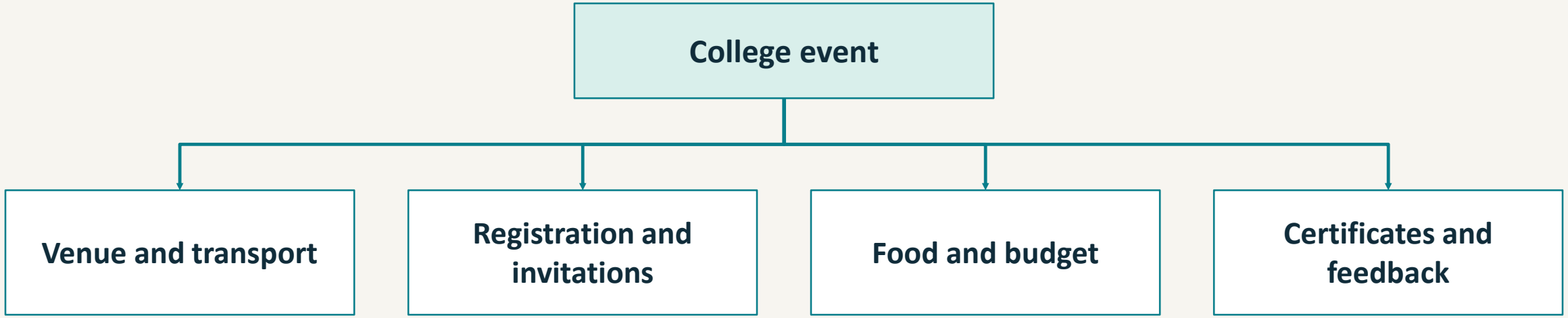
The Four Pillars

01	**Decomposition**	Break a complex problem into smaller problems.
02	**Pattern recognition**	Find similarities, repetitions and trends.
03	**Abstraction**	Keep the information that matters to the task.
04	**Algorithmic thinking**	Develop clear steps for a solution.

Decomposition

A large problem becomes easier to manage when we split it into smaller tasks.

Example: organizing a college event



Each task can have an owner, a deadline and a checklist.

Pattern Recognition

Similarities and repeated events can suggest where to look next.

“Have I seen something similar before?”

Electrical faults under similar conditions

Traffic congestion at the same time

Recurring attendance trends

Daily electricity-consumption peaks

Shared features in faces or images

A pattern is a useful clue. Test the suspected explanation.

Abstraction

Focus on essential information for the problem being solved.

A navigation map

Keeps	Usually leaves out
Location, roads and route	Building interiors
Distance and travel time	Individual trees and people
Relevant traffic information	Unrelated physical details

What counts as “essential” changes with the task.

Algorithmic Thinking

An algorithm is a finite sequence of clear, ordered steps for a task.

Example: making tea

1. Measure water, milk, tea and sugar
2. Bring the water to a boil
3. Add tea leaves
4. Add milk and sugar
5. Simmer for the chosen time
6. Strain into cups
7. Serve

Good instructions are

Clear

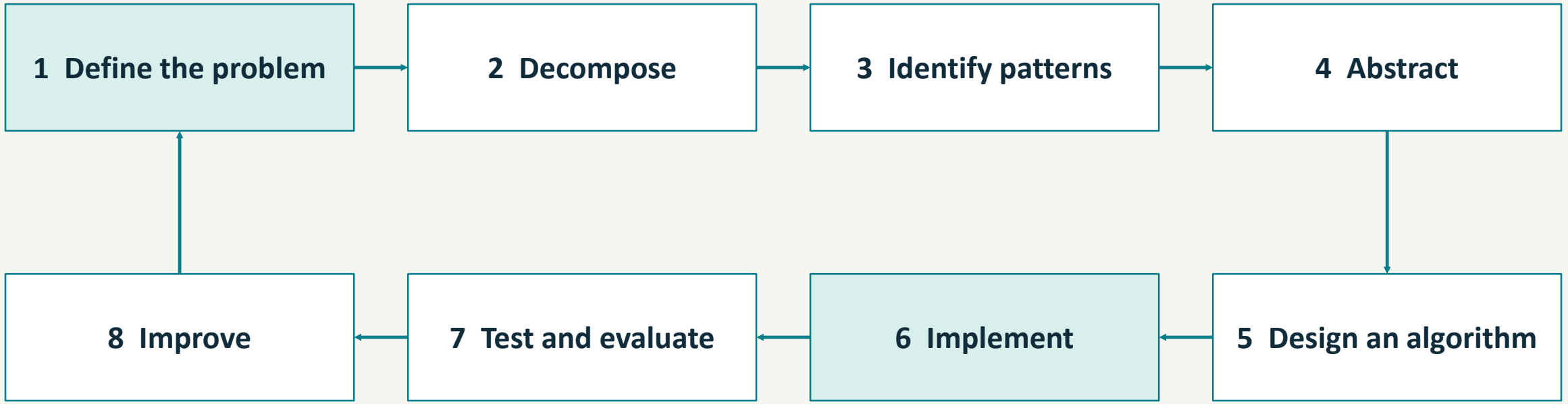
Ordered

Finite

Unambiguous

Repeatable

The Computational Thinking Process



Iteration matters: test results may send us back to any earlier step.

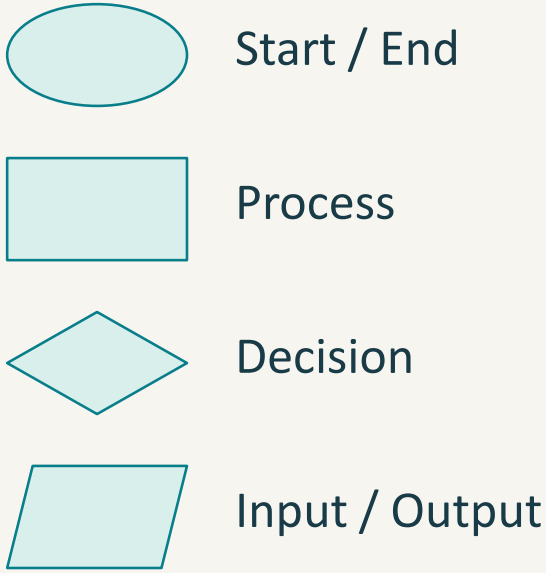
What is computational thinking?

Characteristic	Description
Abstraction	Reducing complexity to basic ideas
Algorithm	Identifying process and sequence
Decomposition	Breaking artefacts, processes or systems into component parts
Generalisation	Identifying commonalities between component parts.
Analysis	Analysing functionality of systems.
Evaluation	Systematically evaluation of the value of systems.

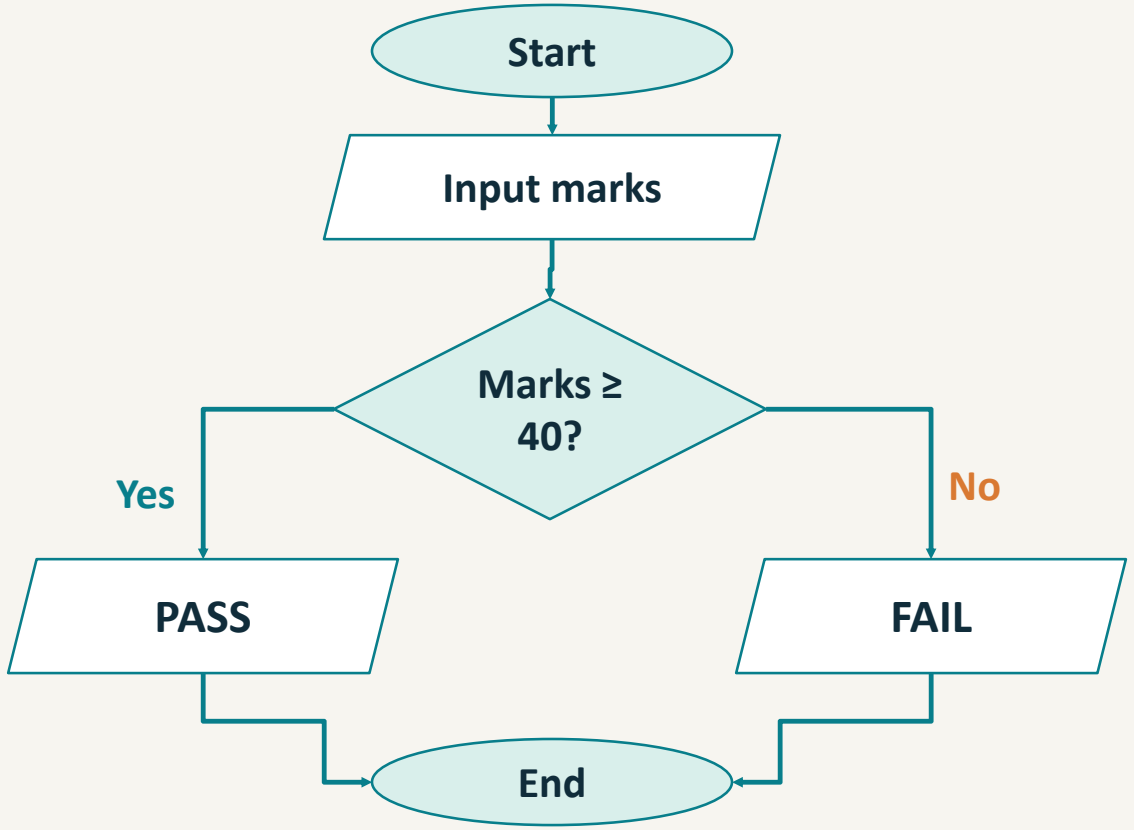


Algorithms and Flowcharts

An algorithm describes the steps. A flowchart shows their order and decisions.



Arrows show flow direction.



Illustrative rule: one score out of 100

Worked Example: Student Result

Simplified rule: five subjects, each out of 100. Pass if overall percentage ≥ 40%.

Subject	1	2	3	4	5
Marks	62	58	71	49	60

Total = 300 out of 500

Percentage = (300 ÷ 500) × 100 = 60%

PASS

60% ≥ 40%

Input marks → Add marks → Calculate percentage → Apply rule → Display result

Computational Thinking in Engineering

Electrical engineering applications

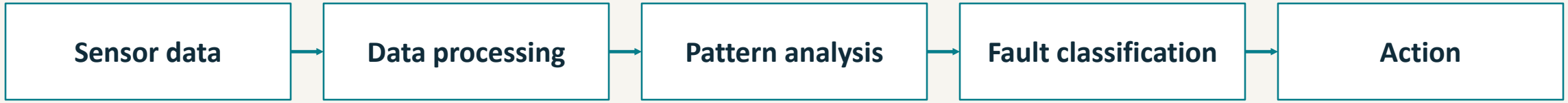
Power-system analysis and circuit simulation

Load forecasting and energy planning

Fault detection and protection systems

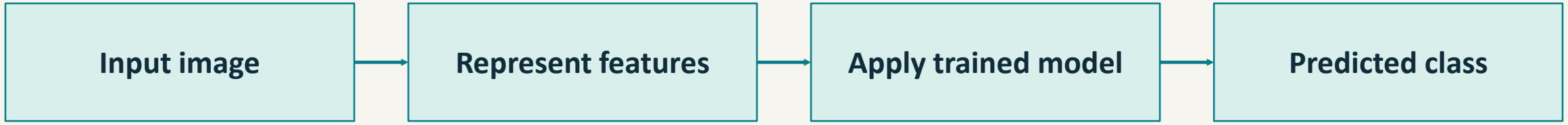
Motor control and renewable-energy optimization

Example: fault detection



Computational Thinking in Artificial Intelligence

Example: image classification



CT helps structure the task, select relevant information and test the result.

Applications

Face and speech recognition
Medical-image analysis
Autonomous-vehicle perception
Recommendation systems
Fraud detection
Image and document classification

Computational Thinking in Everyday Life

Cooking	Follow a clear sequence with specified quantities.
Travel planning	Compare routes using time, distance and cost.
Shopping	Compare options against needs, price and quality.
Time management	Divide a large task into smaller scheduled activities.
Troubleshooting	Identify symptoms, isolate a cause and test a solution.

We often use these habits before we learn their names.

Benefits of Computational Thinking

For students

Logical thinking

Problem-solving skills

Creativity

Analytical ability

Programming readiness

For professionals

Better decisions

Process improvement

Useful automation

Manageable tasks

Data-informed reasoning

For society

Digital transformation

Smarter systems

Better public services

Solutions to complex

real-world problems

The shared benefit: a solution that others can understand, test and improve.

Algorithms

- A tool for solving a well-specified computational problem



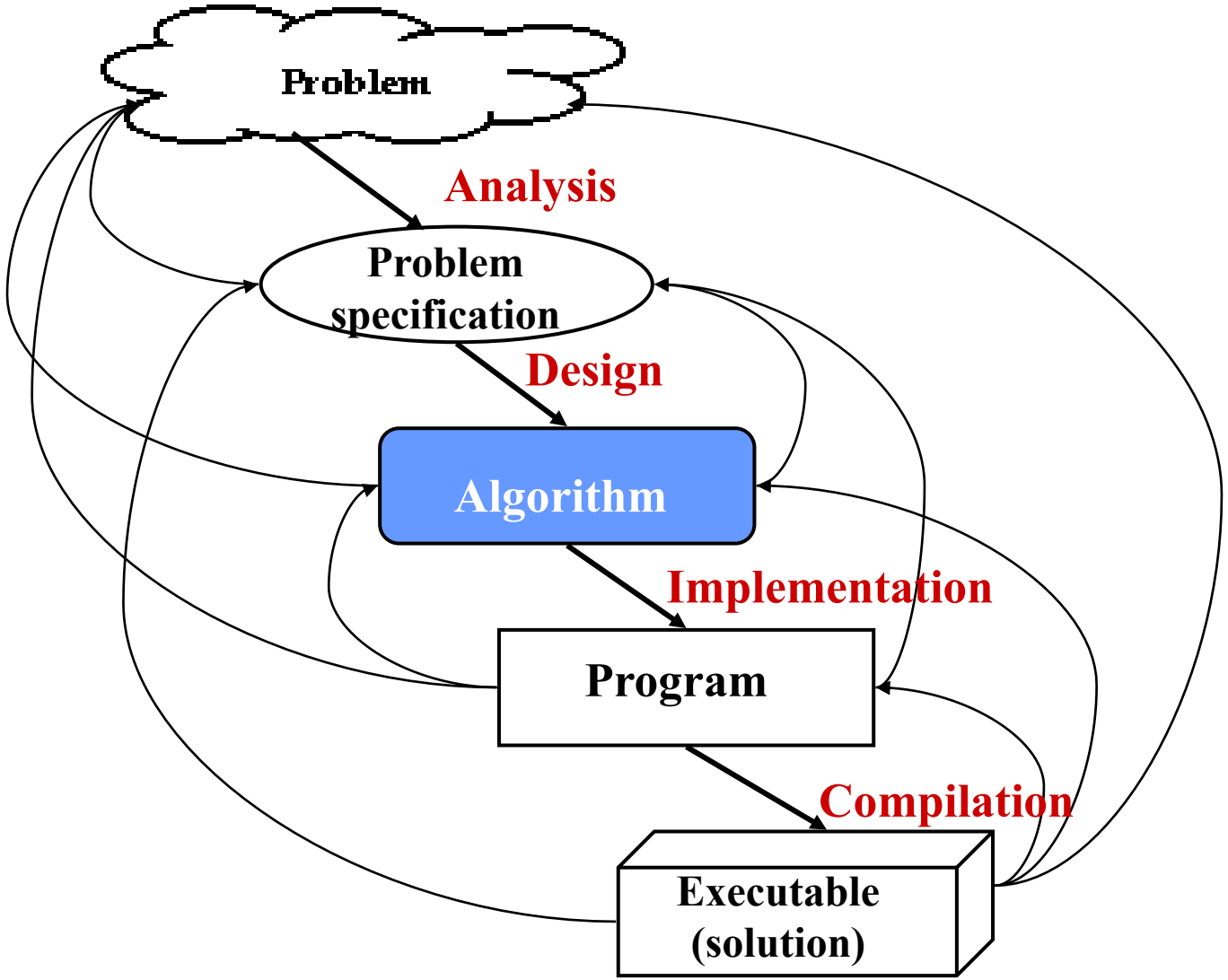
- Algorithms must be:
  - Correct: For each input produce an appropriate output
  - Efficient: run as quickly as possible, and use as little memory as possible – more about this later

Algorithm & Computing

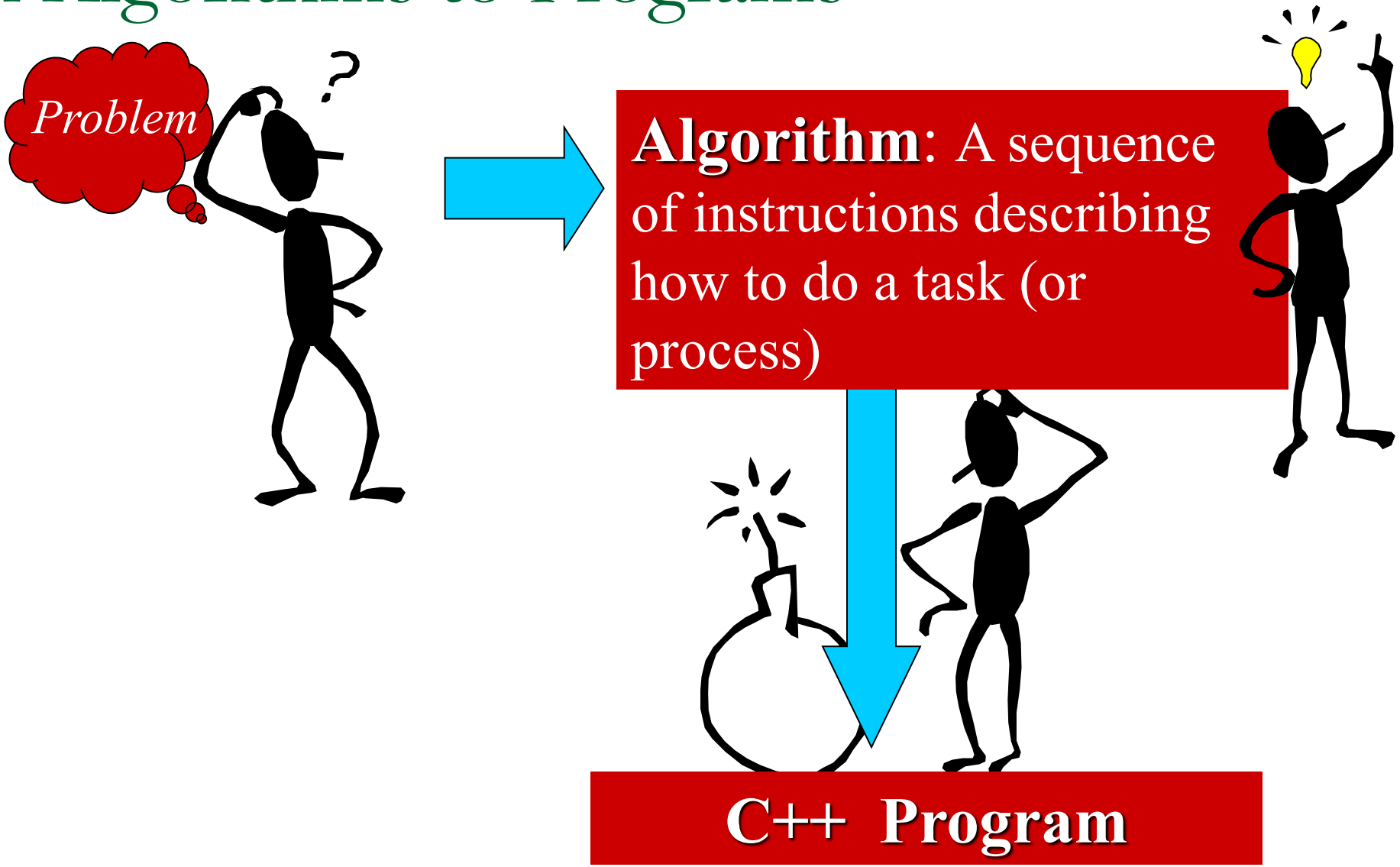
- The word "**algorithm**" comes from the Latinized name of the 9th-century Persian mathematician **Muḥammad ibn Mūsā al-Khwārizmī**

- **An algorithm is a step-by-set of instructions for solving a problem, while computing is the actual process of running those instructions using a computer system.**

The Problem-solving Process



From Algorithms to Programs



Key Takeaways

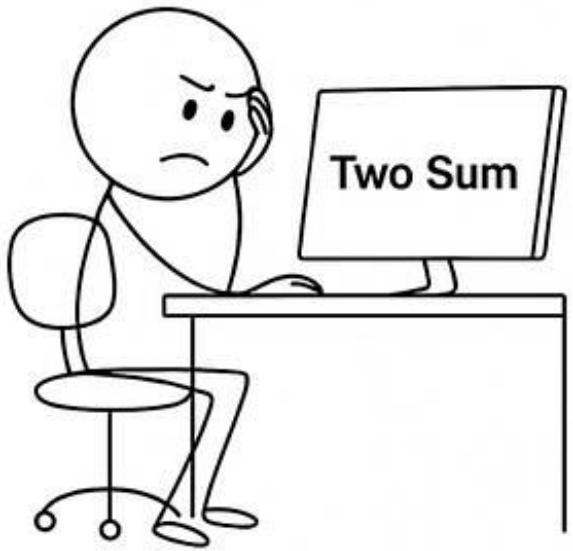
Decomposition	Break the problem
Pattern recognition	Find similarities
Abstraction	Focus on essentials
Algorithmic thinking	Create clear steps

Computational thinking helps us solve problems systematically.

Subject:
Computational Thinking & Programming

Tutorial

- Simple problem taken up – to add TWO numbers


Two Sum

Simple C code

```
#include <stdio.h>
int main() {

    int number1, number2, sum;

    printf("Enter two integers: ");
    scanf("%d %d", &number1, &number2);

    // calculate the sum
    sum = number1 + number2;

    printf("%d + %d = %d", number1, number2, sum);
    return 0;
}
```

Thinking

- How to add two numbers?

- There are multiple approaches / solutions / issues – even in this simplest computing problem

Thinking.. Building blocks..

- Two numbers – how do we write?
- Concept related to it?

- Perceptual thinking.. About two numbers..

- Thinking about thinking – contextualizing.. (may be applications domain)

Time and effort / accuracy

- Quick addition Vs Long addition?
- For what purpose?

- Mindset / functional fixedness?
- Reasoning / decision making?

Sample issues in adding two numbers

- **Integer Overflow:** The sum exceeds the maximum limit that a data type or computer memory can store, causing incorrect or negative results.
- **Carry Generation (Regrouping):** The sum of digits in a place value reaches 10 or more, requiring you to carry over a value to the next column.
- **Floating-Point Precision Loss:** Adding decimals with computers can lead to tiny rounding errors (e.g., \(0.1 + 0.2 \neq 0.3\) precisely in binary floating-point math).

Any other issues?

- ?

Problem solving models

- IDEAL model
  - Identify the problem (?)
  - Define it clearly
  - Explore possible solutions
  - Act on the best option
  - Look back at the results

Effectiveness

- Business driver?
- Common man issue?

Creative thinking

- Creative thinking issues related to adding two numbers involve breaking past rigid procedural habits—like standard vertical column carrying—to explore flexible relationships, alternative definitions, and non-routine contexts.

Creative thinking here?

- Two numbers – add?
- When 1 + 1 = 24?
- When does 7+ 60 = 8?

Systems / systemic thinking?

- Place Value Misalignment: Failing to align columns by magnitude (e.g., adding tens to ones) causes structural calculation errors.

- The Carry Operation Breakdown

Problem?

- **Dyscalculia** is a real, recognized neurodevelopmental condition that affects a person's ability to understand numbers and learn math

Computational thinking..

- Data Type Mismatch and Precision Loss: Adding floating-point numbers introduces rounding and precision issues due to binary representation limits (IEEE 754 standard), meaning \(0.1 + 0.2\) may not precisely equal \(0.3\) in computational memory.

- Integer Overflow (Data Constraints): Fixed-width data types (such as 32-bit or 64-bit integers) possess hard upper and lower boundaries. When the sum of two numbers exceeds the maximum capacity of the allocated memory container, an overflow occurs, wrapping the value into an incorrect (and often sign-flipped) result.

Read this document for further understanding..

- https://medium.com/@ayaan-javed/deconstructing-two-sum-the-complete-thought-process-ac0182c3d993