Inputs, outputs, loops, and debugging (5 lessons)

Computing, grade 3 - by Gemini 4 Argon - status: written (unreviewed)

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Unit: Inputs, Outputs, Loops, and Debugging (Computing, Grade 3)

> **Unreviewed AI draft.** Written by Gemini 4 Argon (2026-11-04). No human teacher has reviewed this unit. All content is CC0 1.0 Public Domain.

Overview

Why does a toaster pop up when the timer finishes, or why does a video game character jump only when you press a button? Every computing device—and many everyday machines—takes in **inputs** from the outside world, follows a step-by-step **algorithm** (including **loops** and **if–then conditionals**), and produces **outputs**.

Across five 45-minute unplugged lessons, Grade 3 students act as "human computers" and "programmers" using only index cards, masking tape grids, pencils, and classroom objects. Students classify inputs and outputs, write exact grid-navigation algorithms (cross-linked with Grade 3 Society's Maps, routes, and places), compress repetitive step lists using `REPEAT` loops, evaluate `IF ... THEN ... ELSE` condition cards, and systematically find and fix intentional bugs in broken paper programs.

Prior knowledge

- Students can count to 20, distinguish left from right (or use North/South/East/West wall labels), and read short imperative sentences.
- Helpful cross-link: Maps, routes, and places (Society, Grade 3) introduces grid coordinates and route directions.
- Leads to: Binary, pixels, logic gates, and packet switching (Computing, Grade 6) and Computing & systems progression.

Learning goals

By the end of this unit, a student can:

1. Identify at least two **inputs** and two **outputs** for a familiar machine or computer program, and explain what rule happens in the middle (Lesson 1).
2. Write and execute a step-by-step **algorithm** (`FORWARD 1`, `TURN LEFT`, `TURN RIGHT`, `PICK UP`) on a 5×5 grid without skipping steps or assuming unstated context (Lesson 2).
3. Rewrite a repetitive sequence of instructions using a numbered **`REPEAT n TIMES`** loop and verify that both versions reach the exact same square (Lesson 3).
4. Trace an algorithm containing **`IF ... THEN ... ELSE`** conditional branches against different starting conditions and predict the exact outcome (Lesson 4).
5. Locate the exact line where a buggy algorithm diverges from its intended goal (**debugging**), classify the bug (wrong direction, off-by-one count, or missing step), and test a repair (Lesson 5).

Lesson sequence

Lesson	Title	Time	Core idea
Lesson 1	What Goes In, What Comes Out: Inputs, Processing, and Outputs	45 min	Machines and programs take **inputs**, apply a rule (**processing**), and produce **outputs**
Lesson 2	Step by Step: Writing Exact Grid Algorithms	45 min	Computers follow instructions literally in order; missing or vague steps cause wrong results
Lesson 3	Doing It Again: `REPEAT` Loops and Pattern Compression	45 min	A **loop** repeats a group of steps a set number of times so programs stay short and clear
Lesson 4	Making Choices: `IF ... THEN ... ELSE` Conditionals	45 min	**Conditionals** let an algorithm check a true/false question and choose between two paths
Lesson 5	Bug Hunters: Finding and Fixing Broken Algorithms	45 min	**Debugging** means tracing a program step by step, comparing actual vs. expected state, and fixing the fault

Materials for the whole unit

No computers or tablets are required. Everything runs unplugged:

- Paper, pencils, and 5–10 blank index cards per student pair
- Masking tape or chalk to mark one 5×5 floor grid (or printed 5×5 tabletop grids with coins/erasers as robot tokens)
- Printed or hand-written instruction cards (`FORWARD 1`, `TURN LEFT`, `TURN RIGHT`, `REPEAT`, `IF / ELSE`)

Assessment summary

Each lesson ends with a 3-question exit check with worked answers. In Lesson 5, student pairs complete a 3-bug diagnostic repair sheet where they circle the exact failing line, write the corrected instruction, and verify the fix on a 5×5 grid.

Sources

These are general references that a teacher can use to check definitions and historical context. All links were checked to load on 2026-11-04.

- Input–process–output (IPO) model: https://en.wikipedia.org/wiki/IPO_model
- Algorithm: https://en.wikipedia.org/wiki/Algorithm
- Control flow — Loops (`REPEAT`): https://en.wikipedia.org/wiki/Control_flow#Loops
- Conditional (`IF ... THEN ... ELSE`): https://en.wikipedia.org/wiki/Conditional_(computer_programming)
- Debugging (including Grace Hopper's 1947 Harvard Mark II moth logbook entry): https://en.wikipedia.org/wiki/Debugging
- Bell, T., Witten, I. H., & Fellows, M. (2015). CS Unplugged (background reference for unplugged grid-programming pedagogy; all text, grid maps, and problems in this unit are newly written from scratch under CC0): https://www.csunplugged.org/

Known gaps and cautions

- **Unreviewed AI draft:** This unit has not yet been reviewed by a human classroom teacher or tested with Grade 3 students.

- **Relative vs. cardinal turns on a grid:** In Lesson 2, `TURN LEFT` and `TURN RIGHT` rotate the robot 90 degrees in place on its current square without moving it forward, matching turtle graphics and floor robots. Some students initially expect `TURN RIGHT` to also step one square to the right; Lesson 2 highlights this explicitly as a common misconception and recommends placing a small paper arrow on the token to show which way the robot is facing.
- **Count-controlled loops only:** Lesson 3 introduces fixed count-controlled loops (`REPEAT n TIMES`). Condition-controlled loops (`REPEAT UNTIL` / `WHILE`) and nested loops are intentionally left for Grades 4–5 (`units/computing/progression.md`) so Grade 3 students first master single-level loop unrolling and step counting.
- **Single-condition branches:** Lesson 4 uses single `IF ... THEN ... ELSE` checks evaluated at the moment the robot reaches a square. Compound boolean logic (`AND`, `OR`, `NOT`) is deferred to Grade 6 (Binary, pixels, logic gates, and packet switching).

Lesson 1: What Goes In, What Comes Out — Inputs, Processing, and Outputs

- **Unit:** Inputs, Outputs, Loops, and Debugging (Computing, Grade 3)
- **Time:** 45 minutes
- **Grouping:** Whole class and pairs

Learning objective

Students will identify the **inputs** (information or signals going in), **processing** (the rule or check inside), and **outputs** (actions, sounds, or displays coming out) for everyday devices and simple games.

Materials

- Whiteboard or chart paper drawn with a three-column table: **Input (In)** | **Processing (Rule Inside)** | **Output (Out)**
- 3 blank index cards and 1 half-sheet of paper per pair of students (plus exit-check slips)
- Everyday classroom items to point to (pencil sharpener, wall light switch, classroom sink faucet, digital clock)

Vocabulary

- **Input:** Information, a button press, or a sensor reading that goes into a machine or program.
- **Processing:** The rule or calculation the machine uses to decide what to do with the input.
- **Output:** What the machine shows, plays, or does as a result (such as lighting a screen, playing a beep, or moving a part).

Lesson flow

1. Warm-up: The Mystery Rule Box (8 min)

1. Tell the class: "I am a Mystery Rule Box. Give me a whole number between 1 and 10 (**my input**). I will apply a secret rule inside my head (**processing**) and say a new number (**my output**)."
2. Take three student inputs and respond using the rule **Input + 3 = Output**:
3. Student says `2` → Teacher says `5`
4. Student says `6` → Teacher says `9`
5. Student says `10` → Teacher says `13`
6. Ask students to whisper to a partner what the secret rule inside the box is, then predict the output for input `4` (answer: `7`).
7. Label the three parts on the board:
8. **Input:** the number spoken to the box (`4`)
9. **Processing:** add 3 (`4 + 3`)
10. **Output:** the number spoken back (`7`)

2. Direct instruction: Everyday Input–Process–Output Machines (12 min)

Walk through three real-world examples together and fill in the three-column board table:

Machine / System	Input (What goes in?)	Processing (What rule happens inside?)	Output (What comes out?)
Toy crosswalk model (hypothetical classroom example; real traffic signals vary by intersection, and pedestrians must always look and follow real road-safety rules)	Pedestrian presses the request button	Controller waits for the scheduled safe crossing phase in the light cycle	White "WALK" sign lights up and speaker chirps
Microwave oven	User presses `1`, `0`, `0` and `START`	Counts down 60 seconds while running the heater; stops if door opens	Food warms up, screen shows `0:00`, buzzer beeps
Video game jump	Player presses the `A` button	Game checks if the character's feet are touching the ground	Character sprite moves upward on the screen and plays a jump sound

> **Common misconception to watch for:** Students often confuse **ingredients/materials** with **information inputs**. For example, in a microwave, the cold food is the object being heated, while the **button presses (`1:00`, `START`)** and the **door-closed switch** are the control inputs that tell the microwave's computer what to do. Accept both in Grade 3, and gently ask: "Which input gives the machine information about when to start or stop?"

3. Guided practice: Pair Card Sort & Invention (15 min)

1. Give each pair three index cards labeled **INPUT**, **PROCESSING**, and **OUTPUT**.
2. Read three short scenarios aloud. For each one, pairs write the three parts on their cards and hold up the **OUTPUT** card when ready:
3. **Scenario A (Automatic Night-Light):** A hallway light has a light sensor. When the room gets dark, it turns on the bulb.
    - Input: Room brightness measured by the light sensor.
    - Processing: Check if brightness is below the dark threshold.
    - Output: LED bulb turns on (or stays off).
4. **Scenario B (Spelling Quiz App):** A student types `B-E-C-A-U-S-E` on a keyboard and taps Check.
    - Input: Letters typed on the keyboard and the Check tap.
    - Processing: Compare typed letters against the stored word `"BECAUSE"`.
    - Output: Green checkmark on screen and "+1 point".
5. **Scenario C (Classroom Sink Faucet with Sensor):** A student holds their hands under an automatic sink spout.
    - Input: Hand-sensor reading showing hands are directly under the spout.
    - Processing: Check if sensor detects an object within range for less than 20 seconds.
    - Output: Water valve opens and water flows from the spout.
6. **Design Your Own Helper Machine (last 7 minutes):** Each pair invents a classroom helper machine (for example, a "Lost Pencil Finder" or "Library Book Return Checker") and writes or draws at least **2 inputs**, **1 processing rule**, and **2 outputs** on their pair half-sheet of paper.

✓ 4. Wrap-up & Exit check (10 min)

Students answer independently on a slip of paper:

1. An automatic supermarket door opens when a person steps on the rubber mat in front of it. What is the **input** and what is the **output**?
2. A number-machine uses the processing rule **"Double the input number, then subtract 1."** If the input is `5`, what is the output?
3. Look at a digital alarm clock. Name one **input** a human gives it, and one **output** the clock gives back.

Worked answers for exit check

1. **Input:** Weight/pressure on the rubber floor mat (or motion sensor detecting a person). **Output:** The glass doors slide open.
2. **Output:** `9` (because `5 × 2 = 10`, and `10 − 1 = 9`).
3. **Input:** Pressing the "Set Alarm" or "Snooze" buttons (or setting the time). **Output:** Glowing numbers on the screen or the buzzing sound at 7:00 AM.

Lesson 2: Step by Step — Writing Exact Grid Algorithms

- **Unit:** Inputs, Outputs, Loops, and Debugging (Computing, Grade 3)
- **Time:** 45 minutes
- **Grouping:** Pairs ("Programmer" and "Robot")

Learning objective

Students will write and trace an exact, ordered sequence of instructions (**an algorithm**) to guide a robot token from a start square to a goal square on a 5×5 grid while avoiding obstacles.

Materials

- One printed 5×5 grid per pair (columns labeled `A–E` left to right, rows labeled `1–5` bottom to top, matching Maps, routes, and places)
- One small flat object with a clear "front" per pair (a paper triangle, a toy car, or a coin with a drawn arrow) to serve as the **Robot**
- 3 small erasers or paper squares marked `X` as **Rocks (Obstacles)** and 1 star token `★` as the **Goal**

Vocabulary

- **Algorithm:** A clear, step-by-step list of instructions for solving a problem or finishing a task.
- **Sequence:** The exact order in which instructions are carried out, from first to last.
- **Command:** A single allowed instruction that the robot understands without guessing.

Allowed Robot Commands (Write on the board)

The robot **only** understands these four commands—nothing else:

1. `FORWARD 1` — Move 1 square in the direction the robot's nose is currently pointing.
2. `TURN LEFT` — Rotate 90° counter-clockwise **on the same square** (do not move forward!).
3. `TURN RIGHT` — Rotate 90° clockwise **on the same square** (do not move forward!).
4. `PICK UP` — Pick up the star `★` on the current square.

Lesson flow

1. Warm-up: The Literal Teacher Robot (8 min)

1. Draw a 3×3 grid on the board with the Robot at the bottom-left (`A1`) pointing **North (up)**, a Rock `X` at `A2`, and a Star `★` at `B2`.
2. Ask a volunteer to tell you how to get the star. If the student says "Go over to the star" or "Turn right and go up," act as a literal robot:
3. On `TURN RIGHT`, rotate your arrow to face **East (right)** while staying on `A1`!
4. Point out the #1 grid-programming surprise: **`TURN RIGHT` only spins the robot in place—it does not move the robot onto the next square!**

5. Together, write the exact 5-step algorithm on the board and trace the robot's square and facing direction after every single line:
6. `TURN RIGHT` (at `A1`, now facing East)
7. `FORWARD 1` (moves to `B1`, still facing East)
8. `TURN LEFT` (at `B1`, now facing North)
9. `FORWARD 1` (moves to `B2`, facing North)
10. `PICK UP` (picks up `★` at `B2`)

2. Direct instruction: Why Order (Sequence) Matters (10 min)

Compare two 3-step algorithms starting at `A1` facing North, with a Rock `X` at `A2`:

- **Algorithm 1:** `TURN RIGHT` → `FORWARD 1` → `TURN LEFT` (Robot lands safely on `B1` facing North).
- **Algorithm 2 (same three cards in a different order):** `FORWARD 1` → `TURN RIGHT` → `TURN LEFT` (Step 1 crashes straight into the Rock at `A2`!).

Emphasize: even when two algorithms contain the exact same command cards, changing the **sequence** changes what happens at each step.

3. Guided practice: Programmer & Robot Grid Challenges (17 min)

Students work in pairs on their 5×5 grid (`A1` is bottom-left, `E5` is top-right):

- **Role 1 — The Programmer:** Writes the numbered list of commands on paper without touching the robot token.
- **Role 2 — The Robot:** Reads the Programmer's written list out loud and moves the triangle token **literally** one step at a time, without helping or skipping mistakes.
- After Puzzle 1, partners switch roles for Puzzle 2.

Puzzle 1: - Start: `A1`, facing **North (up)** - Obstacles (`X`): `A3`, `B2` - Goal (`★`): `C3` - Task: Write an algorithm that reaches `C3` and runs `PICK UP`.

Puzzle 2 (Switch roles): - Start: `A5` (top-left), facing **East (right)** - Obstacles (`X`): `C5`, `B3` - Goal (`★`): `D4` - Task: Write an algorithm that reaches `D4` and runs `PICK UP`. Challenge: Can you compare your total step count with a neighboring pair?

✓ 4. Wrap-up & Exit check (10 min)

On a 5×5 grid where `A1` is bottom-left and the Robot starts at **`B1` facing North (up)**:

```
Row 3:  [A3]  [B3]  [C3]  [D3★]
Row 2:  [A2]  [B2]  [C2]  [D2]
Row 1:  [A1] [B1▲]  [C1]  [D1]
```

Answer these three questions:

1. Trace this algorithm from `B1` facing North:
2. Step 1: `FORWARD 1`
3. Step 2: `TURN RIGHT`
4. Step 3: `FORWARD 1`
5. Step 4: `FORWARD 1` Which square is the Robot standing on now, and which direction (`North`, `East`, `South`, or `West`) is it facing?
6. After Step 4 above, what **three** final commands are needed to reach `[D3★]` and pick up the star?

7. Why doesn't `TURN RIGHT` move the robot from `B2` to `C2`?

Worked answers for exit check

1. After Step 1 (`FORWARD 1`), the robot is on `B2` facing North. After Step 2 (`TURN RIGHT`), it is still on `B2` facing East. After Step 3 (`FORWARD 1`), it is on `C2` facing East. After Step 4 (`FORWARD 1`), it is on **`D2` facing East**.
2. The three final commands are: Step 5: `TURN LEFT` (now at `D2` facing North), Step 6: `FORWARD 1` (moves to `D3`), and Step 7: `PICK UP`.
3. Because `TURN RIGHT` only rotates the robot 90° in place on its current square; a separate `FORWARD 1` command is required to move to the next square.

Lesson 3: Doing It Again — `REPEAT` Loops and Pattern Compression

- **Unit:** Inputs, Outputs, Loops, and Debugging (Computing, Grade 3)
- **Time:** 45 minutes
- **Grouping:** Whole class and pairs

Learning objective

Students will identify repeating patterns in an algorithm and rewrite them using **`REPEAT n TIMES`** loops, counting both single-command loops and multi-step block loops accurately.

Materials

- 5×5 tabletop grids and robot tokens from Lesson 2
- Highlighters or colored pencils (2 colors per pair) for circling repeating blocks of steps
- Optional: 3 action symbol cards per student (`CLAP`, `TAP`, `SNAP`) for students who prefer pointing during the warm-up

Vocabulary

- **Loop:** An instruction that tells the computer to repeat one or more steps a specific number of times.
- **Iteration:** One complete trip through the steps inside a loop.
- **Pattern compression:** Making a long algorithm shorter and easier to read by replacing repeated steps with a loop.

Lesson flow

1. Warm-up: The Clap-Tap-Snap Loop (7 min)

1. Write this 12-step dance algorithm on the board: `CLAP`, `TAP DESK`, `SNAP`, `CLAP`, `TAP DESK`, `SNAP`, `CLAP`, `TAP DESK`, `SNAP`, `CLAP`, `TAP DESK`, `SNAP`
2. Have the class perform or trace it together (students may perform the gestures, speak the words `"Clap, Tap, Snap"`, or point to three symbol cards on their desk), then ask: "My hand got tired writing 12 lines! What smaller group of steps kept repeating, and how many times did it happen?"
3. Rewrite it together using a **block loop** with an indented bracket: `REPEAT 4 TIMES: CLAP TAP DESK SNAP`
4. Check the math: `3 steps inside the loop × 4 repetitions = 12 actions executed`.

2. Direct instruction: Single-Step vs. Staircase Block Loops on a Grid (13 min)

Show two grid examples on the board starting at **`A1` facing North**:

Example A — Crossing a straight hallway (`A1` to `A5`): - Long version (4 lines): 1. `FORWARD 1` 2. `FORWARD 1` 3. `FORWARD 1` 4. `FORWARD 1` - Looped version: `REPEAT 4 TIMES: FORWARD 1`

Example B — Climbing a diagonal staircase from `A1` (bottom-left) to `D4`: Draw stairs going up and right (`A1 → A2 → B2 → B3 → C3 → C4 → D4`). 1. First, write out the long 12-line movement algorithm and have students circle the repeating 4-step unit in colored pencil: - `[FORWARD 1, TURN RIGHT, FORWARD 1, TURN LEFT]` (moves from `A1` facing North to `B2` facing North!) - `[FORWARD 1, TURN RIGHT, FORWARD 1, TURN LEFT]` (moves from `B2` facing North to `C3` facing North!) - `[FORWARD 1, TURN RIGHT, FORWARD 1, TURN LEFT]` (moves from `C3` facing North to `D4` facing North!) 2. Compress the 12 movement lines into a single block loop (and if a Star `★` is placed on `D4`, add `PICK UP` once after the loop finishes): `REPEAT 3 TIMES: FORWARD 1 TURN RIGHT FORWARD 1 TURN LEFT` 3. **Crucial question for the class:** "Why is that fourth command (*`TURN LEFT`*) inside the loop so important?" - Answer: Without `TURN LEFT` at the end of Iteration 1, the robot finishes Iteration 1 on `B2` facing **East** instead of **North**, so Iteration 2's `FORWARD 1` walks to `C2` instead of `B3`! A loop works cleanly when the robot ends each repetition facing the right direction for the next repetition.

3. Guided practice: Loop Compression Workshop (15 min)

Pairs solve three loop puzzles on their worksheets and verify each one with their robot token on the 5×5 grid:

1. **Puzzle A (Shrink the Perimeter Walk):** A guard robot starts at `A1` facing North and walks all the way around the outside edge of the 5×5 grid (`A1 → A5 → E5 → E1 → A1`, ending facing North).
2. Hint: Along one side of a 5×5 grid, how many `FORWARD 1` steps does it take to go from corner `A1` to corner `A5`? (Answer: `4` steps, because `A1 → A2 → A3 → A4 → A5` is 4 moves!).
3. Pairs write a loop that repeats 4 times to walk all 4 sides of the square.
4. **Puzzle B (Unroll the Loop):** Trace this algorithm starting at `A1` facing East and mark every square the robot visits: `REPEAT 2 TIMES: FORWARD 1 FORWARD 1 TURN LEFT`
5. **Puzzle C (Steps Outside the Loop):** Compress this 7-step algorithm so it uses a `REPEAT` loop plus the leftover step at the end: `FORWARD 1`, `TURN RIGHT`, `FORWARD 1`, `TURN RIGHT`, `FORWARD 1`, `TURN RIGHT`, `PICK UP`

✓ 4. Wrap-up & Exit check (10 min)

1. Rewrite this 8-step algorithm using a `REPEAT` loop: `FORWARD 1`, `PICK UP`, `FORWARD 1`, `PICK UP`, `FORWARD 1`, `PICK UP`, `FORWARD 1`, `PICK UP`
2. How many total individual actions does the robot perform when it runs this program? `TURN RIGHT REPEAT 3 TIMES: FORWARD 1 TURN LEFT PICK UP`
3. A robot starts at `A1` facing **North**. It runs: `REPEAT 3 TIMES: FORWARD 1` Does it land on `A3` or `A4`? Explain why.

Worked answers for exit check

1. Loop version: `REPEAT 4 TIMES: FORWARD 1 PICK UP`
2. **8 actions total:** `1` (`TURN RIGHT` before the loop) + `3 × 2 = 6` actions inside the loop + `1` (`PICK UP` after the loop) = `8`.
3. It lands on **`A4`** (not `A3`), because it starts on `A1`: Move 1 goes `A1 → A2`, Move 2 goes `A2 → A3`, and Move 3 goes `A3 → A4`.

Lesson 4: Making Choices — `IF ... THEN ... ELSE` Conditionals

- **Unit:** Inputs, Outputs, Loops, and Debugging (Computing, Grade 3)
- **Time:** 45 minutes
- **Grouping:** Whole class and pairs

Learning objective

Students will evaluate true/false **conditions** and trace algorithms that use **`IF ... THEN`** and **`IF ... THEN ... ELSE`** branches to adapt to changing obstacles or treasures on a grid.

Materials

- 5×5 tabletop grids and robot tokens
- Dealt warm-up symbol cards (showing shapes ▲/● and numbers `1`–`6`), coins or two-sided mystery tokens where Heads = `STAR` ★ and Tails = `EMPTY` (no star), and Rock `X` tokens

Vocabulary

- **Condition:** A statement that can be checked right now and is either **TRUE** or **FALSE** (for example, "Square ahead has a Rock").
- **Conditional (`IF ... THEN ... ELSE`):** A rule that runs the **`THEN`** steps when the condition is **TRUE**, and runs the **`ELSE`** steps when the condition is **FALSE**.

Lesson flow

1. Warm-up: Card Check Conditionals (8 min)

1. Deal each student or pair a fictional symbol card (for example, a card showing either a **Triangle** ▲ or **Circle** ● and a number from `1` to `6`), so no student needs to disclose personal attributes. Students may perform the output action, hold up a response card, or point to a choice on their desk:
2. **Rule 1 (`IF ... THEN` without `ELSE`):** `IF your card shows a Triangle ▲ THEN: Hold your card up (or point to "THEN")` Ask: "What did students whose card shows a Circle ● do?" (Nothing—because there was no `ELSE` branch!).
3. **Rule 2 (`IF ... THEN ... ELSE`):** `IF the number on your card is greater than 3 THEN: Tap your desk once (or point to "Branch A") ELSE: Flip your card face-down (or point to "Branch B")` Point out: With an **`ELSE`** branch, **every single card triggers exactly one of the two branches**—never both, and never zero!
4. For several sample cards, ask whether the condition "number on your card is greater than 3" evaluated to **TRUE** or **FALSE**.

2. Direct instruction: Smart Robots that Check Before Stepping (12 min)

Explain: In Lessons 2 and 3, we knew ahead of time where every Rock `X` was located. What if a rock falls onto the path **after** we write our program? A robot equipped with a **downward sensor**

(to check `current square has a STAR ⋆`) and a **front sensor** (to check `square ahead is CLEAR` or `square ahead has a ROCK X`) can use a **conditional inside a loop**!

Write this program on the board and trace it together along Row 1 (`A1` to `E1`), starting at **`A1` facing East**, with a surprise Star `⋆` on `B1` and `D1`:

```
REPEAT 4 TIMES:
    FORWARD 1
    IF current square has a STAR ⋆ THEN:
        PICK UP
```

Trace all 4 iterations together in a table on the board:

Iteration	After `FORWARD 1`, robot is on...	Is `current square has a STAR ⋆` TRUE or FALSE?	Does `PICK UP` run?
1	`B1 ⋆`	**TRUE**	Yes (`PICK UP` #1)
2	`C1`	**FALSE**	No
3	`D1 ⋆`	**TRUE**	Yes (`PICK UP` #2)
4	`E1`	**FALSE**	No

Now show an `IF ... THEN ... ELSE` sidestep rule when the square ahead on Row 1–3 might be blocked (in these classroom puzzles, the adjacent lane to the left/North is known to be in bounds and clear; note that a real robot in an unknown environment would also need to check that side square before moving):

```
IF square ahead is CLEAR THEN:
    FORWARD 1
ELSE:
    TURN LEFT
    FORWARD 1
```

3. Guided practice: Mystery Token Corridor (15 min)

1. Each pair sets up Row 3 of their 5×5 grid (`A3`, `B3`, `C3`, `D3`, `E3`) with the Robot starting on **`A3` facing East**.
2. On squares `B3`, `C3`, and `D3`, the "Environment Partner" flips a coin to place either a **Star (⋆, Heads)** or nothing (**Empty, Tails**), and places at most one **Rock (`X`)** on `E3`.
3. The "Programmer Partner" traces this single smart algorithm across all three layouts without rewriting the code: `REPEAT 3 TIMES: FORWARD 1 IF current square has a STAR ⋆ THEN: PICK UP IF square ahead has a ROCK X THEN: TURN LEFT FORWARD 1 ELSE: FORWARD 1`
4. Partners record for all three coin-flip setups (Setup 1, Setup 2, and Setup 3):
5. How many stars were picked up?
6. Which square (`E3` or `D4`) did the robot finish on?

✓ 4. Wrap-up & Exit check (10 min)

A robot starts on **`A2` facing East**. Square `B2` is **EMPTY**, and square `C2` has a **ROCK `X`**. The robot runs:

```
Step 1:
IF square ahead has a ROCK X THEN:
    TURN LEFT
ELSE:
    FORWARD 1
```

```
Step 2:
IF square ahead has a ROCK X THEN:
    TURN LEFT
    FORWARD 1
ELSE:
    FORWARD 1
```

Answer these three questions:

1. In **Step 1**, the robot is at `A2` looking at `B2`. Is the condition `square ahead has a ROCK X` **TRUE** or **FALSE**? Which square does the robot end Step 1 on?
2. In **Step 2**, the robot is on `B2` facing East and looking at `C2` (which has a Rock `X`). Is the condition **TRUE** or **FALSE**? Which branch (`THEN` or `ELSE`) runs?
3. What square is the robot standing on after Step 2 finishes (`B3`, `C2`, or `B1`)?

Worked answers for exit check

1. **FALSE** (because `B2` is empty). The `ELSE` branch runs (`FORWARD 1`), so the robot ends Step 1 on **`B2` facing East**.
2. **TRUE** (because `C2` has a Rock `X`). The **`THEN`** branch runs (`TURN LEFT`, then `FORWARD 1`).
3. **`B3`** (from `B2` facing East, `TURN LEFT` faces North, and `FORWARD 1` steps onto `B3`).

Lesson 5: Bug Hunters — Finding and Fixing Broken Algorithms

- **Unit:** Inputs, Outputs, Loops, and Debugging (Computing, Grade 3)
- **Time:** 45 minutes
- **Grouping:** Whole class and pairs

Learning objective

Students will systematically **debug** broken grid algorithms (including sequences, `REPEAT` loops, and `IF` conditionals) by tracing step by step to find the exact line where actual state diverges from expected state, classifying the bug, and testing a fix.

Materials

- 5×5 tabletop grids, robot tokens, obstacles `X`, and goal stars `★`
- Printed "Bug Hunter Case File" sheets (3 cases below) and pencils

Vocabulary

- **Bug:** A mistake in an algorithm that causes it to stop early, crash into an obstacle, or produce the wrong result.
- **Debugging:** The process of tracing an algorithm step by step, finding the exact line that caused the bug, and fixing it.
- **Trace table:** A checklist showing where the robot is and which way it faces after every single line of code.

Lesson flow

1. Warm-up: Why Do We Call It a "Bug"? & The Three Classic Bug Types (8 min)

1. Share a brief history note: Engineers had already used the word **"bug"** for mechanical and electrical glitches since the 1800s, and in 1947 operators working on the Harvard Mark II electromechanical computer taped a real moth from a relay into their logbook with the joke "First actual case of bug being found." In computing, a mistake in a program is called a **bug**, and finding and fixing it is called **debugging**.
2. Introduce the **Three Classic Grid Bugs** on the board:
3. **Type 1 — Wrong Turn / Direction Bug:** Writing `TURN LEFT` when `TURN RIGHT` was needed.
4. **Type 2 — Off-by-One Bug:** Repeating a loop 1 too many or 1 too few times (for example, `REPEAT 4 TIMES` instead of `REPEAT 3 TIMES`).
5. **Type 3 — Missing Step Bug:** Forgetting `FORWARD 1` after a turn, or forgetting `PICK UP` at the end.

2. Direct instruction: The Golden Rule of Debugging (10 min)

Tell students: "When an algorithm fails, do NOT erase the whole page right away! Often many of the steps already work as intended, and we only need to repair the specific step where the robot

goes off track. Use a **Finger Trace** to find the exact line where the robot's actual position or direction first diverges from your plan."

Model **Case 0** on the board: - **Setup:** Start at `A1` facing **North**. Goal star `★` is at `B3`. Rock `X` is at `A3`. - **Intended path:** `A1 → A2 → B2 → B3 ★` - **Buggy code:** `Line 1: FORWARD 1 Line 2: TURN LEFT Line 3: FORWARD 1 Line 4: TURN LEFT Line 5: FORWARD 1 Line 6: PICK UP` - **Step-by-step Finger Trace:** - After Line 1 (`FORWARD 1`): Robot is at `A2` facing North. (Matches plan!) - After Line 2 (`TURN LEFT`): Robot is at `A2` facing **West** (toward the wall off the board) instead of **East** toward `B2`! (Divergence found on Line 2!) - **Fix:** Change **Line 2** from `TURN LEFT` to **`TURN RIGHT`**. Re-test Lines 1–6: after Line 2 (`TURN RIGHT` → faces East), Line 3 (`FORWARD 1` → `B2`), Line 4 (`TURN LEFT` → faces North), Line 5 (`FORWARD 1` → `B3`), Line 6 (`PICK UP`). Success!

3. Guided practice: Three Bug Hunter Case Files (17 min)

Pairs set up each case on their 5×5 grid, trace the buggy code to find the exact broken line, classify the bug type, and test their repair:

Case File 1: The Overshot Treasure (Off-by-One Bug)

- **Setup:** Start at `A1` facing **East**. Star `★` is on `D1`.
- **Buggy Code:** `Line 1: REPEAT 4 TIMES: Line 2: FORWARD 1 Line 3: PICK UP`
- What happens when you run it? The robot walks `A1 → B1 → C1 → D1 → E1` and tries to `PICK UP` on `E1` (1 square past `D1`!).
- Fix: Change Line 1 from `REPEAT 4 TIMES:` to **`REPEAT 3 TIMES:`**.

Case File 2: The Spin-In-Place Trap (Missing Step Bug)

- **Setup:** Start at `B1` facing **North**. Rock `X` is on `B2`. Star `★` is on `C2`.
- **Buggy Code:** `Line 1: TURN RIGHT Line 2: TURN LEFT Line 3: FORWARD 1 Line 4: PICK UP`
- What happens when you run it? Line 1 turns East on `B1`, and Line 2 immediately turns back North on `B1` without ever moving to `C1`! Then Line 3 crashes into the Rock at `B2`.
- Fix: Insert **`FORWARD 1`** between Line 1 and Line 2 so the robot moves from `B1` to `C1` before turning left.

Case File 3: The Backwards Sensor (Conditional Bug)

- **Setup:** Start at `A2` facing **East**. Square `B2` has a **Rock `X`**. Goal is to step safely onto `A3`.
- **Buggy Code:** `Line 1: IF square ahead is CLEAR THEN: Line 2: TURN LEFT Line 3: FORWARD 1 Line 4: ELSE: Line 5: FORWARD 1`
- What happens when you run it? Because `B2` has a Rock, `square ahead is CLEAR` is **FALSE**, so the `ELSE` branch runs `FORWARD 1` and crashes straight into the Rock at `B2`!
- Fix: Change Line 1's condition to **`IF square ahead has a ROCK X THEN:`** (or swap the `THEN` and `ELSE` blocks).

✓ 4. Wrap-up & Unit Exit Check (10 min)

A robot starts at **`A1` facing North**. The Star `★` is at **`C2`**. There are no rocks. A student wrote this 5-line program:

```
Line 1: FORWARD 1
Line 2: TURN RIGHT
Line 3: REPEAT 3 TIMES:
```

```
Line 4:     FORWARD 1
Line 5: PICK UP
```

Answer these three questions:

1. Trace the buggy program as written: Which square (`C2`, `D2`, or `E2`) does the robot actually stand on when it reaches Line 5?
2. Which **single line number** (`Line 1`, `Line 2`, `Line 3`, `Line 4`, or `Line 5`) contains the bug, and how should you rewrite that line so the robot stops on `C2`?
3. Is this bug a **Wrong Turn Bug**, an **Off-by-One Bug**, or a **Missing Step Bug**?

Worked answers for exit check

1. After Line 1 (`FORWARD 1`), the robot is on `A2` facing North. After Line 2 (`TURN RIGHT`), it is on `A2` facing East. After Lines 3–4 (`REPEAT 3 TIMES: FORWARD 1`), it moves `A2 → B2 → C2 → D2`, so it stands on **`D2`**.
2. **Line 3** has the bug. Rewrite Line 3 as **`REPEAT 2 TIMES:`** (so it moves `A2 → B2 → C2` and stops on `C2`).
3. It is an **Off-by-One Bug** (the loop repeated 3 times instead of 2 times).