

STEM ARDUINO PBL — PROJECT 2 | TIER 1: FOUNDATION

# Digital Temperature Monitor

Full PBL Lesson Plan, Assessment Rubric & Teaching Resources

Grades 7–9 • 2 Weeks • SDG 3, SDG 4

PROJECT SNAPSHOT	
<b>Driving Question</b>	"How can we design a smart classroom monitor that alerts teachers and students when environmental conditions become unsafe for learning and health?"
<b>Real-World Angle</b>	Environmental health monitoring for schools, clinics, and public spaces — connecting sensor data to evidence-based health thresholds and real institutional decisions
<b>Grade Level</b>	Grades 7–9 (builds directly on Project 1 skills: digital output, conditional logic, Serial Monitor — no prior sensor experience required)
<b>Duration</b>	2 weeks (10 × 45-minute lessons, or equivalent block periods)
<b>SDG Connections</b>	SDG 3 — Good Health & Well-Being   SDG 4 — Quality Education
<b>Key Components</b>	Arduino UNO · DHT11 or DHT22 sensor · 16×2 LCD (I2C) · Red LED · Green LED · Active buzzer · 10kΩ pull-up resistor (DHT11 only)
<b>Core Skills</b>	Sensor data acquisition · I2C communication protocol · Threshold logic · Real-time display · Warning system design · Library usage
<b>21st C. Skills</b>	Data literacy · Evidence-based decision making · Communication to institutional audiences · Systems thinking · Empathy for learning environment users
<b>Public Audience</b>	School nurse, facilities manager, head teacher, or school health and safety officer
<b>Entry Products</b>	Environmental health research brief + threshold justification document
<b>Final Products</b>	Working temperature/humidity monitor with alert system + data report + deployment proposal

CURRICULUM STANDARDS COVERAGE	
<b>Science / Biology</b>	Thermoregulation in humans · Effect of temperature on concentration and cognitive performance · Humidity and respiratory health · Fever thresholds and heat stress indicators
<b>Science / Physics</b>	Temperature as a measure of molecular kinetic energy · Heat transfer (conduction, convection, radiation) · Electrical resistance and how sensors exploit it · Digital vs analogue signal conversion

<b>Technology / ICT</b>	I2C serial communication protocol · Library installation and usage · Sensor interfacing and data acquisition · Threshold-based conditional programming · LCD character display control
<b>Mathematics</b>	Reading and interpreting data tables · Threshold selection using statistical reasoning · Conversion between Celsius and Fahrenheit · Graph interpretation (temperature trend over time)
<b>Health / PSHE</b>	WHO and CDC environmental health guidelines · Safe classroom temperature and humidity ranges · Effect of CO2 and humidity on alertness and learning outcomes · Student voice in school health decisions
<b>Literacy</b>	Reading scientific abstracts and health guidelines · Data presentation and interpretation · Technical report writing · Oral presentation to an institutional audience

## How This Project Builds on Project 1 and Deepens PBL Practice

Project 2 introduces two critical expansions from Project 1. First, students move from **output-only thinking** (controlling an LED) to **input-driven thinking** (reading sensor data and making decisions from it). Second, the real-world connection is no longer a story about a hypothetical user — it is data about the room they are sitting in right now. That immediacy changes everything about student engagement and the authenticity of the public audience.

PBL ELEMENT	HOW IT APPEARS IN THIS PROJECT
<b>Centrality</b>	The classroom health monitor challenge organises the full two weeks. Students learn I2C, DHT library functions, LCD control, and threshold logic because they need all four to answer the driving question — not as disconnected exercises.
<b>Driving Question</b>	The question names a real institution (the school) and a real consequence (unsafe for learning and health). Students must find out what 'unsafe' means from credible health sources — the Arduino cannot answer that part for them.
<b>Constructive Inquiry</b>	What temperature is genuinely unsafe for learning? Students cannot guess this — they must read WHO and ASHRAE guidelines, compare recommendations, and justify a specific number. That justification is a curriculum product, not homework.
<b>Student Autonomy</b>	Teams choose which conditions to monitor, what threshold values to set, which alert behaviour to implement, and how to present their findings to the school. The teacher constrains the technology; students define the health policy.
<b>Realism / Authenticity</b>	The data students collect is real. The room temperature they measure is the temperature in their actual learning environment. The audience — a school nurse or facilities manager — can actually act on the recommendation. This is not a simulation.

## Week-by-Week Lesson Calendar

**WEEK 1: ENTRY EVENT & INQUIRY**

Lesson	PBL Phase	Learning Activities	Teacher Facilitation Notes
L1	Entry Event	<ul style="list-style-type: none"> <li>• Launch: Share peer-reviewed finding that classroom temperatures above 26°C reduce cognitive performance by up to 13%</li> <li>• Ask students: 'What is the temperature in this room right now?' (They cannot answer — no instrument)</li> <li>• Pose the Driving Question. Discuss: what does 'unsafe' mean? Who decides? How do we measure it?</li> <li>• Record 'Need to Know' questions on class board — must include both health AND technology questions</li> </ul>	<p>→ The entry moment is the unanswerable question: 'What is the temperature here, right now?' Sit with the not-knowing</p> <p>→ Do NOT produce an Arduino yet — let the measurement gap drive the inquiry</p> <p>→ Listen for: students who cite body feel ('I'm hot') vs those who want objective data — that distinction is the project's central idea</p>
L2	Entry Event	<ul style="list-style-type: none"> <li>• Health guideline research: WHO, ASHRAE 55, and building regulations — what temperature and humidity are safe?</li> <li>• Students compare guidelines: why do different sources recommend different values?</li> <li>• Discuss: who is most affected by poor classroom temperature? (consider age, medical conditions, physical activity)</li> <li>• Entry product: Research brief — which guideline will your team use and why? Document the threshold values chosen.</li> </ul>	<p>→ Push beyond surface: 'The WHO says 18–24°C — but that's for a resting adult. Does that apply to an active Year 8 student?'</p> <p>→ Students often find conflicting values between sources — this is the point, not a problem</p> <p>→ Formative: research brief quality — does it cite specific sources? Does it justify the chosen threshold?</p>
L3	Inquiry — Sensor Science	<ul style="list-style-type: none"> <li>• Mini-lesson: how does the DHT11 measure temperature? (resistive/capacitive sensing, not mercury)</li> <li>• Wire DHT11 to Arduino (3-pin module); load DHT library; run basic read sketch</li> <li>• Read temperature and humidity via Serial Monitor; record 10 readings over 5 minutes</li> <li>• Compare Arduino reading to a reference thermometer — calculate the error; discuss accuracy vs precision</li> </ul>	<p>→ Ask: 'Why does the reading change slightly each second even if the room temperature hasn't changed? What does that tell us about the sensor?'</p> <p>→ Key concept: DHT11 has <math>\pm 2^\circ\text{C}</math> accuracy — significant for health threshold work; DHT22 is <math>\pm 0.5^\circ\text{C}</math></p> <p>→ Formative: accuracy test — sensor reading vs reference thermometer; difference calculated and recorded</p>
L4	Inquiry — I2C & LCD	<ul style="list-style-type: none"> <li>• Mini-lesson: what is I2C? Why does it use only 2 wires (SDA + SCL) for a display with 16 pins?</li> <li>• Use I2C scanner sketch to find the LCD's address (usually 0x27 or 0x3F)</li> <li>• Wire LCD to Arduino (VCC, GND, SDA, SCL); load LiquidCrystal_I2C library; display 'Hello World'</li> <li>• Experiment: control cursor position, clear display, scroll text — build LCD vocabulary</li> </ul>	<p>→ Ask: 'What does 0x27 mean? Why does the address use hexadecimal?' — connects back to Project 1 IR hex codes</p> <p>→ Common issue: wrong I2C address; teach I2C scanner as a diagnostic tool, not just a solution</p> <p>→ Formative: students display their name on the LCD using correct <code>setCursor()</code> positioning</p>
L5	Inquiry — Threshold Logic	<ul style="list-style-type: none"> <li>• Combine sensor + LCD: display live temperature and humidity in a formatted layout</li> <li>• Write threshold logic: if temperature &gt; chosen value → LED turns red + buzzer sounds</li> <li>• Test: what happens when the sensor is held in a warm hand? Does the alert trigger correctly?</li> </ul>	<p>→ Key question: 'Should the alert trigger the instant the threshold is crossed, or only after 30 seconds above it? Why does that matter in practice?'</p> <p>→ Students often write <code>&gt;=</code> instead of <code>&gt;</code> or vice versa — ask</p>

		<ul style="list-style-type: none"> <li>• Discuss: false alarms — what conditions could trigger the alert when it shouldn't? How would you prevent them?</li> </ul>	<p>them to test the boundary condition exactly</p> <p>→ Formative: threshold logic code review — is the condition correct? Is hysteresis considered?</p>
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**WEEK 2: BUILD, DATA COLLECTION & SHOWCASE**

Lesson	PBL Phase	Learning Activities	Teacher Facilitation Notes
L6	Build & Iterate	<ul style="list-style-type: none"> <li>• Full system assembly: DHT sensor + LCD + alert LEDs + buzzer in a single circuit</li> <li>• Refine LCD layout: design a clear two-line display (e.g. Line 1: temperature, Line 2: humidity + status)</li> <li>• First 10-minute data collection session: record readings every 2 minutes with timestamps</li> <li>• Peer circuit review: partner team checks wiring and LCD readability from 2 metres</li> </ul>	<p>→ LCD layout design is a real UX decision — ask: 'If a teacher glances at this from across the room, what should they see instantly?'</p> <p>→ Expected issue: LCD backlight works but no text — usually a contrast potentiometer issue on the I2C backpack</p> <p>→ Formative: debugging log + first data table with timestamps</p>
L7	Build & Iterate	<ul style="list-style-type: none"> <li>• Extended data collection: move monitor to different locations in the school (sunny corner, near window, near door)</li> <li>• Record: temperature, humidity, time, location, conditions (sunny/cloudy, windows open/closed)</li> <li>• Compare readings across locations — are some areas consistently hotter or more humid?</li> <li>• Identify: does any location exceed the team's chosen health threshold during normal school hours?</li> </ul>	<p>→ This lesson produces the project's most valuable data — make it feel like a real investigation, not a worksheet</p> <p>→ Prompt: 'If you were the school nurse and you saw this data, what would you do?'</p> <p>→ Formative: data table with location metadata — is context recorded, not just numbers?</p>
L8	Upgrade Challenge	<ul style="list-style-type: none"> <li>• Introduce upgrade options (differentiated by readiness):</li> <li>• Upgrade A: Dual-threshold alert — yellow LED for caution zone (e.g. 26–28°C), red LED + buzzer for danger zone (&gt;28°C)</li> <li>• Upgrade B: Heat index calculation — combine temperature and humidity to display the 'feels like' temperature</li> <li>• Upgrade C: Data logging — print a timestamped reading to Serial every 60 seconds for a complete session log</li> <li>• Teams select upgrade, plan before building, justify choice with reference to their user (school nurse, facilities team)</li> </ul>	<p>→ Upgrade B introduces the heat index formula — a real meteorological calculation used by the NWS and WHO</p> <p>→ Upgrade C produces a data artefact (the serial log) that directly feeds the deployment proposal</p> <p>→ Formative: upgrade rationale document — why this upgrade? How does it serve the stakeholder?</p>
L9	Prepare Showcase	<ul style="list-style-type: none"> <li>• Analyse collected data: calculate mean, identify peak temperature, compare to threshold</li> <li>• Draft the deployment proposal (see Handout 4): data → finding → health implication → recommendation</li> <li>• Prepare 4-minute presentation: open with the data finding, not the circuit description</li> </ul>	<p>→ Teach the presentation structure: 'Our data showed X. The WHO guideline is Y. This means Z. We recommend A.'</p> <p>→ Students often want to lead with the technology — redirect: 'Your audience does not care how it works. They care what it found.'</p>

		<ul style="list-style-type: none"> <li>• Practice Q&amp;A: teacher poses as sceptical facilities manager — 'Why should I trust an Arduino over our building management system?'</li> </ul>	→ Formative: proposal draft review — does the recommendation follow logically from the data?
L10	Public Showcase	<ul style="list-style-type: none"> <li>• Showcase: teams present to invited institutional audience (nurse, facilities manager, or head teacher)</li> <li>• Each team: 4-minute presentation + 2-minute live demo + Q&amp;A</li> <li>• Audience completes feedback form (see Handout 5)</li> <li>• Individual reflection completed in final 10 minutes (see Handout 6)</li> </ul>	<p>→ Invite someone with real authority to act on the recommendation — this changes the presentation dynamic entirely</p> <p>→ Teacher role: facilitator only — do not rescue teams during Q&amp;A</p> <p>→ Summative: presentation rubric (criteria 4 + 5) + written proposal (criterion 6)</p>

## Detailed PBL Phase Plans

Phase 1 — Entry Event: Making the Invisible Visible		
SUB-PHASE / TASK	TEACHER ACTIONS	STUDENT ACTIONS + PRODUCTS
Entry Event Launch (Lesson 1)	Open with the unanswerable question before revealing any technology: 'Is this room at a safe temperature for learning right now? How would you know?' Sit with student uncertainty for at least 60 seconds before moving on.	Attempt to answer the temperature question using only their senses. Discuss: why is bodily sensation an unreliable instrument? What would a better instrument need to do? Generate 'Need to Know' questions covering both health science and measurement technology. Product: Need to Know board.
Health Guideline Research (Lesson 2)	Provide access to WHO, ASHRAE 55, and one national building regulation document. Do not tell students which values to use. Ask: 'These sources disagree on the upper safe limit. How do you decide which to trust?'	Research threshold values for temperature and humidity. Compare at least two sources. Identify the context dependency (resting vs active, adult vs child, healthy vs asthmatic). Justify a specific threshold value for their school context. Product: Research Brief with cited sources and justified threshold values.
Entry Assessment	Check: does the research brief cite specific documents or just 'the internet'? Does the threshold chosen reflect the specific population (students aged 11–16) rather than a generic adult standard?	Self-check: 'Can I defend my threshold choice to the school nurse using a specific published source?' If not — the threshold is not justified yet.

Phase 2 — Inquiry: Building the Measurement Capability		
SUB-PHASE / TASK	TEACHER ACTIONS	STUDENT ACTIONS + PRODUCTS

<p><b>Sensor Science (Lesson 3)</b></p>	<p>Facilitate accuracy investigation: ask students to compare their sensor reading to a reference thermometer (room thermostat, another thermometer, or the teacher's verified sensor). Do not tell them the expected error — let them find it and then ask what it means for their health threshold.</p>	<p>Wire DHT11; collect 10 serial readings; compare to reference. Calculate mean sensor error. Decide: given a <math>\pm 2^{\circ}\text{C}</math> error, should the alert threshold be set <math>2^{\circ}\text{C}</math> lower than the health guideline? Document the reasoning. Product: Sensor Accuracy Report with error calculation.</p>
<p><b>I2C Protocol &amp; LCD (Lesson 4)</b></p>	<p>Ask: 'How does the Arduino know which device to talk to on the I2C bus? What stops the LCD from answering when the Arduino is trying to talk to a sensor?' Let students reason through addressing before explaining.</p>	<p>Run I2C scanner; identify LCD address; display formatted temperature and humidity on LCD. Design the display layout on paper before coding it. Product: Working LCD display with documented layout rationale — why this information arrangement?</p>
<p><b>Threshold Logic (Lesson 5)</b></p>	<p>Pose the engineering edge case: 'What if the temperature is <math>25.9^{\circ}\text{C}</math> — exactly below your threshold? What if it spikes to <math>26.1^{\circ}\text{C}</math> for one second? Should the alert fire? Design the logic to handle these cases.'</p>	<p>Write and test threshold conditional. Test boundary conditions explicitly (at threshold, just below, just above). Consider hysteresis: alert fires at <math>26^{\circ}\text{C}</math>, clears only when temperature drops below <math>25^{\circ}\text{C}</math>. Document: why did you choose this hysteresis value? Product: Threshold logic code with boundary test evidence.</p>
<p><b>Inquiry Assessment</b></p>	<p>Update Need to Know board. Ask: 'What does I2C stand for and why does it matter that it uses only 2 wires?' 'Why did you set your threshold at that specific value rather than <math>1^{\circ}\text{C}</math> higher or lower?' If students cannot answer — these become the week 2 focus questions.</p>	<p>Peer explanation: explain the I2C protocol to your partner without using the words 'I2C' or 'two wire'. If you cannot — find a gap in your understanding and fill it before the build phase.</p>

<p><b>Phase 3 — Build &amp; Iterate: From Working Circuit to Useful Instrument</b></p>		
<p>SUB-PHASE / TASK</p>	<p>TEACHER ACTIONS</p>	<p>STUDENT ACTIONS + PRODUCTS</p>
<p><b>Full System Build (Lesson 6)</b></p>	<p>Circulate with one question: 'If a teacher walked past this display right now, what would they understand in 3 seconds?' Use the answer to guide LCD layout revisions. Do not suggest specific layouts — prompt the students' design thinking.</p>	<p>Assemble full circuit. Design and implement LCD layout. Run first 10-minute data collection session. Peer review: partner team reads the display from 2 metres — what do they see? What is missing? Product: Working prototype + first data table + peer LCD review notes.</p>
<p><b>Location Investigation (Lesson 7)</b></p>	<p>Frame this as a genuine investigation: 'You are the school's first student environmental health team. Where in this building would you deploy a</p>	<p>Systematic location testing: at least 3 locations, with timestamp, conditions, and 5-minute average reading. Identify the hottest and most humid location.</p>

	monitor, and why?' Encourage teams to have a hypothesis before moving the sensor.	Determine whether any location exceeds the threshold. Product: Location data table with hypothesis and findings.
<b>Peer Critique (Lesson 6/7)</b>	Model the critique protocol. Add a specific technical criterion: 'Does the display communicate status (safe/caution/danger) clearly without needing to know the threshold number?' This focuses critique on usability, not just functionality.	Give and receive structured critique. Revise: if the display does not clearly communicate status, redesign it. One revision minimum required. Product: Revised LCD display with documented rationale for changes.
<b>Build Assessment</b>	Assess: is the data collection systematic (consistent intervals, location metadata, conditions recorded) or ad hoc? Systematic data collection is a science skill being assessed here, not just a project task.	Self-assess: 'Would a scientist trust my data? What is missing from my data table that would make it more credible?' Completeness and rigour, not just the number of readings.

<b>Phase 4 — Upgrade Challenge: Deepening the Science</b>		
<b>SUB-PHASE / TASK</b>	<b>TEACHER ACTIONS</b>	<b>STUDENT ACTIONS + PRODUCTS</b>
<b>Upgrade A — Dual Threshold (Core+)</b>	Ask: 'Why does a hospital have a caution zone before a danger zone? Why not just alarm when things are critical?' Connect to the concept of graduated response — the same principle used in traffic lights, storm warnings, and fire evacuation systems.	Implement two threshold levels with distinct alert behaviours (e.g. yellow LED at 26°C, red LED + buzzer at 28°C). Test: does the transition between zones work reliably? Does the lower zone cancel correctly when temperature drops? Product: Dual-threshold demo with test evidence at each boundary.
<b>Upgrade B — Heat Index (Advanced)</b>	Introduce the heat index concept: 'Temperature alone does not describe how hot it feels. Why does 30°C in Qatar feel different from 30°C in London?' Let students discover the humidity factor before presenting the formula.	Research the NOAA heat index formula or simplified version ( $HI = T - 0.55(1 - RH/100)(T - 58)$ in Fahrenheit, converted). Implement in code; display 'Feels like: X°C' on the LCD. Test: does the heat index increase with humidity as expected? Product: Heat index calculation with formula derivation documented.
<b>Upgrade C — Serial Data Log (Extended)</b>	Introduce the data logging concept: 'Scientists don't watch a sensor all day — they record it and analyse it later. How would you structure your data so that a spreadsheet could import it automatically?'	Implement CSV-formatted serial output: timestamp (millis()/1000), temperature, humidity, status (OK/CAUTION/DANGER). Run a 15-minute logging session. Export the data and open in a spreadsheet. Graph temperature over time. Product: CSV data log file + spreadsheet graph + trend analysis paragraph.

<p><b>Upgrade Assessment</b></p>	<p>Upgrade A assessed on boundary condition reliability. Upgrade B assessed on formula accuracy and display clarity. Upgrade C assessed on data format consistency and the quality of the subsequent graph and analysis.</p>	<p>Design decision document: which upgrade chosen, why (must reference the stakeholder need, not just technical interest), how tested, what was revised. One failed approach documented with learning extracted.</p>
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<p><b>Phase 5 — Showcase: Data Speaks to Decision-Makers</b></p>		
<p><b>SUB-PHASE / TASK</b></p>	<p><b>TEACHER ACTIONS</b></p>	<p><b>STUDENT ACTIONS + PRODUCTS</b></p>
<p><b>Data Analysis (Lesson 9)</b></p>	<p>Teach the move from data to argument: 'You have numbers. Numbers alone do not persuade a head teacher. What turns your data into a recommendation?' Model: 'Our highest reading was 28.3°C at 13:45 in Room 14. The ASHRAE 55 guideline is 24°C for seated light activity. This exceeds the guideline by 4.3°C.'</p>	<p>Calculate mean, peak, and time-above-threshold for collected data. Write one evidence paragraph per significant finding. Draft deployment proposal using the structure in Handout 4. Product: Annotated data table + proposal draft.</p>
<p><b>Showcase Preparation (Lesson 9)</b></p>	<p>Challenge: 'Your audience has 4 minutes and zero interest in how I2C works. Design your presentation so that a facilities manager who has never heard of Arduino leaves knowing exactly what they should do on Monday morning.'</p>	<p>Prepare 4-minute presentation starting with the data finding, not the circuit. Practice with the specific Q&amp;A questions in Handout 3. Prepare live demo contingency. Product: Presentation outline with opening data statement.</p>
<p><b>Public Showcase (Lesson 10)</b></p>	<p>Introduce the stakeholder audience before teams begin. Remind students: data is their credibility. Do not intervene during Q&amp;A — the discomfort of being challenged by a real decision-maker is a core learning experience.</p>	<p>Present to institutional audience. Lead with data. Demonstrate live system. Field questions with evidence. Note two pieces of feedback that were not anticipated during practice. Product: Showcase delivery + audience feedback forms.</p>
<p><b>Reflection (Lesson 10)</b></p>	<p>10 quiet minutes for individual written reflection. No teacher prompting during this time — let the experience settle before analysis begins.</p>	<p>Complete Handout 6. Required: one thing the data revealed that you did not expect; one decision you would change about your threshold and why; one question the audience asked that you could not answer and what you would need to know to answer it. Product: Individual Reflection Document.</p>

**Project 2 Assessment Rubric**

Distribute on Lesson 1. *Level 3 (Proficient) is the expected standard. Level 4 is characterised by the move from description to argument — students who reach Level 4 use their data to make a case that a real institution could act on.*

CRITERION	1 — Beginning	2 — Developing	3 — Proficient ✓	4 — Exemplary
<b>Technical Functionality (25%)</b>	System does not function; sensor not reading or returning NaN; LCD shows nothing or garbled text; no alert system present.	System partially functions; temperature or humidity displays but readings are inaccurate or unstable; alert triggers at wrong threshold or does not trigger at all.	System functions reliably; temperature and humidity display correctly on LCD; alert system (LED and/or buzzer) triggers consistently when readings exceed defined threshold; readings are stable and match a reference thermometer within $\pm 2^{\circ}\text{C}$ .	System exceeds brief; includes dual thresholds (caution and danger zones with different alert behaviours); displays trend indicator (rising/falling); readings verified against a calibrated reference; system handles sensor read failures gracefully (NaN check with fallback message).
<b>Threshold Justification &amp; Scientific Reasoning (20%)</b>	Threshold values chosen arbitrarily with no reference to health guidelines or evidence; student cannot explain why their threshold was set where it was.	Thresholds chosen with some reference to a source, but the source is not credible or the values are misread; student can state the threshold but not justify it in terms of health impact.	Thresholds for both temperature and humidity are justified with reference to at least one credible source (WHO, CDC, ASHRAE 55, or national building standards); student can explain the health consequence of exceeding the threshold for their specific school context.	Thresholds justified with multiple sources; student compares differing recommendations and justifies their chosen value; considers age-specific effects on children; proposes different thresholds for different room types (lab vs sports hall vs office); includes humidity and heat index cross-reference.
<b>Data Collection &amp; Interpretation (20%)</b>	No data collected during the project; readings noted ad hoc with no structure; no attempt to interpret readings in context.	Some data collected but inconsistently; readings noted without timestamps or context; no comparison to thresholds; no interpretation of what the data means.	Systematic data collection over at least two sessions; readings recorded with timestamps and room context; data displayed in a table and graph; interpretation connects readings to threshold and identifies at least one actionable finding.	Extended data collection across multiple times of day and conditions; statistical analysis (mean, range, peaks); comparative data (two rooms or two days); findings presented as evidence-based recommendations in the deployment proposal; data integrity maintained (NaN values excluded and noted).
<b>Collaboration &amp; Team Process (15%)</b>	Limited contribution; student relied on others for circuit and code; no evidence of	Contributed to some aspects; needed prompting; some evidence of role-	Consistent equitable contribution; roles shared; team resolved disagreements about	Led or co-led team effectively; facilitated structured debate about threshold

	team decision-making in work or reflection.	sharing but collaboration was uneven.	threshold values or alert design productively; peer feedback incorporated into revised design.	selection using evidence; documented team decisions and rationale; supported teammates to understand I2C and sensor concepts, not just to copy code.
<b>Communication &amp; Presentation (20%)</b>	Presentation absent, unclear, or directed at a technical audience; data not presented; no recommendation to the stakeholder.	Presentation covers the project but does not translate technical findings into actionable institutional language; data shown but not interpreted; recommendation absent or vague.	Clear presentation to a non-technical institutional audience; data visualised and interpreted; threshold justification communicated accessibly; specific, evidence-based recommendation made to the named stakeholder (nurse, facilities manager, etc.).	Compelling presentation that moves from data to decision: 'Our monitor found X, which exceeds the WHO guideline for Y, which means Z should happen.' Handles challenging questions from the audience with evidence. Proposal is specific enough that the school could act on it immediately.
<b>Written Deployment Proposal (20%)</b>	Proposal absent or lists only components; no data, no recommendation, no audience awareness.	Proposal present but reads as a technical description rather than an institutional recommendation; data listed without interpretation; recommendation is generic.	Proposal addressed to a named decision-maker; includes observed data, threshold comparison, health implications, cost of the system, and a specific recommended action (e.g. 'Install a monitor in Room 14 and set the ventilation to trigger at 26°C').	Proposal is publication-quality; uses data to build a persuasive case for policy change; includes cost-benefit comparison (this system vs commercial alternatives vs doing nothing); addresses implementation questions (who monitors the alerts? what is the escalation path?); written at the right register for a head teacher or health and safety officer.

CRITERION	WEIGHTING	ASSESSED WHEN
<b>Technical Functionality</b>	25%	Lessons 6–8 (formative) + Lesson 10 (summative demo)
<b>Threshold Justification &amp; Scientific Reasoning</b>	20%	Lesson 2 (research brief) + Lesson 10 (Q&A)
<b>Data Collection &amp; Interpretation</b>	20%	Lessons 7–8 (data tables) + Lesson 9 (analysis)

<b>Collaboration &amp; Team Process</b>	15%	Ongoing observation + Lesson 6 peer circuit review
<b>Communication &amp; Presentation</b>	20%	Lesson 9 (practice run) + Lesson 10 (summative)
<b>Written Deployment Proposal</b>	20% (see note)	Lesson 10 final submission
<b>TOTAL</b>	<b>120% → normalised to 100%</b>	<b>Portfolio submitted Lesson 10</b>

Note: Weightings sum to 120%. Divide raw total by 1.2 to get a percentage score out of 100.

## Student Handouts

### Handout 1 — 'Need to Know' Starter Questions

WHAT DO I NEED TO KNOW TO ANSWER THE DRIVING QUESTION?

You cannot design an evidence-based classroom monitor without understanding both the health science AND the technology. Work through both columns.

**About the Health Science:**

- What temperature range does the WHO recommend for indoor working and learning environments?
- What humidity range is recommended for respiratory health? What happens at extremes (too dry or too damp)?
- What is the heat index? Why does humidity affect how hot we feel?
- At what temperature does cognitive performance (concentration, memory, reaction time) begin to decline? Find a peer-reviewed source.
- Who is most vulnerable to poor classroom temperature? (consider age, asthma, physical activity level)
- What do different sources say? ASHRAE 55, WHO, your country's building regulations — do they agree?

**About the Technology:**

- What does DHT stand for? How does the DHT11 sensor measure temperature and humidity?
- What is the accuracy of the DHT11 vs the DHT22? Why does accuracy matter for a health monitor?
- What is I2C? What does SDA stand for? What does SCL stand for?
- Why does an I2C LCD only need 2 data wires when it has 16 pins?
- What is a library in Arduino? How do you install one? What would happen if you tried to use a DHT sensor without the library?

- What is hysteresis in a threshold system? Why is it useful for an alert system?

**About the Design:**

- If your sensor has  $\pm 2^{\circ}\text{C}$  accuracy, how should that affect where you set your alert threshold?
- What information should a teacher be able to read from your display in 3 seconds?
- How will you collect data systematically — not just glance at the screen?

*Add your own questions:*

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_

**Handout 2 — Systematic Data Collection Sheet**

**DATA COLLECTION — record every reading here, not on a scrap of paper**

Team name: \_\_\_\_\_ Monitor location: \_\_\_\_\_ Date: \_\_\_\_\_

Chosen temperature threshold: \_\_\_\_\_  $^{\circ}\text{C}$  Chosen humidity threshold: \_\_\_\_\_ % Source: \_\_\_\_\_

Reading #	Time	Temperature ( $^{\circ}\text{C}$ )	Humidity (%)	Status	Conditions (windows open/closed, sun, crowded, etc.)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					

12					
13					
14					
15					

**Data analysis (complete after collection):**

Mean temperature: \_\_\_\_\_ °C Peak temperature: \_\_\_\_\_ °C at \_\_\_\_\_ Lowest: \_\_\_\_\_ °C

Number of readings above threshold: \_\_\_\_\_ out of \_\_\_\_\_ total readings

Most affected location/time: \_\_\_\_\_

**Key finding (one sentence):** \_\_\_\_\_

**Handout 3 — Showcase Preparation: Anticipated Q&A**

**PRACTISE THESE QUESTIONS BEFORE THE SHOWCASE — your audience will ask them**

Your audience is a school facilities manager, nurse, or head teacher. They are non-technical but will ask sharp questions about credibility and practicality. Prepare a specific answer — supported by your data or research — for each question below.

**'How accurate is your sensor? Can I trust these readings?'**

**Preparation hint:** Reference: your accuracy test from Lesson 3. State the error margin. Explain how you accounted for it in your threshold setting.

Your prepared answer: \_\_\_\_\_

**'Our school already has a heating/cooling system. Why do we need this?'**

**Preparation hint:** Reference: your location data. Were there spots where the temperature exceeded the guideline even when the HVAC was running? What does the HVAC not detect?

Your prepared answer: \_\_\_\_\_

**'What do I actually DO when the alarm goes off? Is there a protocol?'**

**Preparation hint:** This is in your proposal. Be specific: 'We recommend that the facilities team is alerted and the window is opened. If temperature remains above threshold after 10 minutes, we recommend moving the class.'

Your prepared answer: \_\_\_\_\_

**'An Arduino seems unreliable. What happens if it crashes?'**

**Preparation hint:** Address: how often did your system crash during testing? What is the consequence of a missed reading vs a false alarm? How could reliability be improved in a permanent installation?

Your prepared answer: \_\_\_\_\_

**'This is a student project. Why should the school take it seriously?'**

**Preparation hint:** Reference: the WHO or ASHRAE source you cited. The data speaks regardless of who collected it. Your readings are either above the guideline or they are not.

Your prepared answer: \_\_\_\_\_

**'How much would this cost to install in every classroom?'**

**Preparation hint:** From your proposal: total component cost × number of classrooms. Compare to a commercial CO2/temperature monitor (typical cost: £50–200 per unit). Your system: approximately £8–15 per unit.

Your prepared answer: \_\_\_\_\_

## Handout 4 — Deployment Proposal Structure

### YOUR DEPLOYMENT PROPOSAL — addressed to a named decision-maker at your school

Address this to a real person — your school nurse, facilities manager, or head teacher. Use their name. Write in formal but accessible English.

#### 1. The Problem (75 words)

- What environmental health issue did your monitor investigate?
- Why does it matter for students and staff at this school?
- What does the research say about the consequences of poor classroom temperature or humidity?

#### 2. What We Found (data summary + 1 graph)

- State your most significant finding in one sentence: 'On [date], Room [X] reached [Y]°C at [time], exceeding the [source] guideline of [Z]°C.'
- Include your data table summary: mean, peak, number of readings above threshold
- Include one graph: temperature over time (from your data log or manual readings)

#### 3. What This Means (health interpretation)

- What does exceeding the threshold mean for the people in that room? Cite your source.
- Which students or staff members are most at risk?

**4. Our System (brief description + cost)**

- What does your monitor do? (2 sentences, plain English)
- Component cost per unit: £\_\_\_ (list components and prices)
- Comparison: a commercial equivalent costs £\_\_\_ (cite a real product)

**5. Our Recommendation (specific and actionable)**

- Where exactly should a monitor be installed? (name the room)
- Who should receive the alert? What should they do? What is the escalation protocol?
- What should happen first, second, and third when the alert triggers?

**6. Next Steps**

- What would need to happen for this to become a permanent installation?
- What one thing do you need from the decision-maker to move forward?

**Handout 5 — Stakeholder Audience Feedback Form**

**AUDIENCE FEEDBACK FORM (for invited stakeholders)**

Team name / number: \_\_\_\_\_ Date: \_\_\_\_\_

**1. Credibility of the data**

*Did the team collect data systematically? Did they account for sensor accuracy? Do you trust their findings?*

Rating: 1 — Needs work    2 — Adequate    3 — Good    4 — Excellent

Comments: \_\_\_\_\_

**2. Relevance of the health threshold**

*Was the threshold they set based on credible evidence? Did they explain why that specific value matters for this school context?*

Rating: 1 — Needs work    2 — Adequate    3 — Good    4 — Excellent

Comments: \_\_\_\_\_

**3. Clarity of the recommendation**

*Could you act on their recommendation immediately? Was it specific enough — naming a room, a response protocol, a person responsible?*

Rating: 1 — Needs work    2 — Adequate    3 — Good    4 — Excellent

Comments: \_\_\_\_\_

**4. Communication quality**

*Did the team explain their findings without unnecessary technical jargon? Could a non-technical colleague follow this presentation?*

Rating: 1 — Needs work   2 — Adequate   3 — Good   4 — Excellent

Comments: \_\_\_\_\_

**5. Practicality of the system**

*Does this seem like something that could realistically be deployed in a school? What concerns would you raise before approving installation?*

Rating: 1 — Needs work   2 — Adequate   3 — Good   4 — Excellent

Comments: \_\_\_\_\_

**Would you act on this recommendation?** Yes / No / With more information

If 'With more information': what would you need to know? \_\_\_\_\_

**Handout 6 — Individual Reflection Prompts**

**REFLECTION — write with specificity; general answers will not receive credit**

Complete this individually in the final 10 minutes of the showcase lesson. Reference specific readings, moments, or conversations from your project.

**Data surprise:**

*Describe one reading or trend in your data that genuinely surprised you. What did you expect to find, and what did you find instead? What explains the difference?*

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Threshold decision:**

*Looking at your data now, was your threshold set in the right place? If you were deploying this monitor permanently, would you adjust it? By how much, and why?*

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Technical concept:**

*Describe one moment when you understood I2C communication more deeply than before. What was the specific thing you understood? What had you misunderstood before?*

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Audience challenge:**

Write down one question from the showcase audience that you could not fully answer. What would you need to know or research to answer it? Where would you find that information?

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**From data to decision:**

In one paragraph: what does your data say, what health guideline does it reference, and what specific action do you recommend the school take? Write this as if the head teacher will read it tomorrow.

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**Project 1 → Project 2:**

How did what you learned in Project 1 (IR remote, LED control) help you in this project? Identify one specific skill or habit that transferred — and one thing about Project 2 that felt genuinely new.

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## Teacher Reference: Common Misconceptions & Facilitation Moves

Project 2 shifts students from controlling outputs to interpreting inputs — a conceptual move that many find more challenging than the circuit work itself. The misconceptions below reflect that shift.

STUDENT MISCONCEPTION	CORRECT UNDERSTANDING	TEACHER FACILITATION MOVE
'NaN means something is broken'	NaN (Not a Number) is the DHT library's return value when the sensor fails to complete a reading — caused by timing issues, insufficient power, or a loose connection. It is normal to see occasional NaN values, especially at startup. It does not mean the sensor is dead.	Ask: 'What does NaN stand for? When would a number genuinely not exist?' Then: 'How would you write code that checks for NaN before displaying a reading?' Introduce <code>isnan()</code> as both a debugging tool and a production safeguard.
'My threshold should be 30°C because that's when it feels really hot'	Subjective perception of heat is not the basis for a health or safety threshold. Published guidelines (ASHRAE 55: 20–26°C for sedentary	Ask: 'Where did you get that number? What evidence supports it?' If students cannot cite a source, the threshold is not justified. Return to the research

	activity; WHO: 18–24°C for learning environments) are derived from controlled studies of performance and health outcomes. 30°C already represents significant heat stress for children.	<i>brief activity — a health monitor with an unjustified threshold is potentially dangerous, not just wrong.</i>
<b>'The LCD is displaying garbled characters — the library is broken'</b>	Garbled LCD characters almost always indicate a contrast problem (potentiometer on I2C backpack needs adjustment), a wrong I2C address (scanner shows 0x3F not 0x27), an insufficient power supply, or missing <code>lcd.begin()</code> in <code>setup()</code> . Libraries are very rarely the cause.	<i>Teach the diagnostic sequence: (1) Is the backlight on? (2) Is the contrast adjusted? (3) Does the I2C scanner find the address? (4) Is <code>lcd.begin(16,2)</code> in <code>setup()</code>? (5) Is the power supply adequate? Model systematic elimination of causes — not random code changes.</i>
<b>'We only need to check temperature, not humidity'</b>	Temperature and humidity interact to determine actual thermal comfort and health risk. The heat index formula shows that 30°C at 90% humidity is equivalent to 40°C at 40% humidity in terms of physiological stress. A monitor that ignores humidity gives an incomplete picture — especially relevant in Qatar's climate.	<i>Show the NOAA heat index table: find a cell where moderate temperature plus high humidity equals 'danger'. Ask: 'Is it possible for a room to be within the safe temperature range but still be hazardous? When?' Students often discover Qatar's context independently.</i>
<b>'Once the alert triggers, we're done — the monitor works'</b>	A single successful alert trigger tests one code path once. Reliability requires: testing at the exact threshold boundary, testing that the alert clears when conditions improve, testing behaviour over extended periods (does it drift?), and testing edge cases (what if the sensor returns NaN during an alert condition?).	<i>After the first successful alert: 'Great — now test what happens when the temperature drops back below the threshold. Does the alert clear? Does it clear immediately or after a delay? Is immediate clearing actually what you want?' These questions drive the hysteresis concept.</i>
<b>'Our data proves the classroom is dangerous'</b>	Student data is evidence, not proof. Proof requires controlled conditions, calibrated instruments, statistical significance, and peer review. Student data from an uncalibrated DHT11 is valuable preliminary evidence that warrants further investigation — but claiming it 'proves' danger overstates what a school project can establish.	<i>Teach the language of evidence: 'Our data suggests... Our readings indicate... This is consistent with... Further investigation using calibrated instruments would be needed to confirm...' This is also the right language for the deployment proposal — it is more persuasive, not less, because it is honest.</i>

## Differentiation Strategies

LEARNER PROFILE	SUPPORT SCAFFOLDS	EXTENSION CHALLENGES
<b>Learners needing additional support</b>	Pre-identified I2C address (skip scanner step) · DHT11 wiring guide with colour-coded diagram · Code template with sensor read and display sections pre-	Core system only: temperature display + one threshold alert · Data collection at one location · Research brief citing one source · Proposal with 4 sections only

	written as stubs · Research brief sentence starters provided · Proposal template with paragraph openers · Partner pairing for circuit build, independent for data collection and analysis	(problem, finding, system, recommendation) · Verbal presentation with visual aids accepted
<b>On-track learners</b>	Standard project brief · BIE phase check-ins · All 6 rubric criteria targeted · Peer critique at Lesson 6	Temperature + humidity display · Threshold alert for both conditions · Data from 3+ locations · Complete 6-section proposal · One upgrade chosen and completed · 4-minute presentation with live demo and Q&A
<b>Advanced learners</b>	Minimal scaffolding · Self-directed threshold research from primary sources · Design own LCD layout from user requirements · Identify own data collection protocol	All three upgrades (dual threshold + heat index + data logging) · Extended data collection over 3+ days at 5+ locations · Statistical analysis (mean, SD, peak) · Proposal including cost-benefit comparison to 3 commercial products · Presentation of findings at a real school health meeting or staff briefing

## Materials List & Approximate Costs

COMPONENT	QTY (per team)	UNIT COST (USD approx.)	NOTES
Arduino UNO (or Nano)	1	\$4–8	UNO recommended for Project 2; easier I2C pin labelling (A4=SDA, A5=SCL marked on board)
DHT11 sensor module (3-pin)	1	\$1–2	Module preferred over bare sensor — includes pull-up resistor; DHT22 if budget allows ( $\pm 0.5^{\circ}\text{C}$ vs $\pm 2^{\circ}\text{C}$ )
DHT22 sensor module (upgrade option)	1	\$3–5	Higher accuracy; strongly recommended for health monitoring contexts; replace DHT11 if possible
16x2 LCD with I2C backpack	1	\$2–4	Ensure I2C backpack is included; check contrast potentiometer is accessible
Red LED (5mm)	1	\$0.10–0.20	For danger/threshold alert
Green LED (5mm)	1	\$0.10–0.20	For safe status indicator
Yellow LED (5mm) — Upgrade A	1	\$0.10–0.20	Optional; for dual-threshold caution zone

Active buzzer (5V)	1	\$0.30–0.80	Active = buzzes on HIGH without tone(); simpler for threshold alerts
220Ω resistors (1/4W)	2–3	\$0.05 each	For LEDs; one per LED
Breadboard (half-size)	1	\$1–2	One per team
Jumper wires (assorted)	15–20	\$0.50 pack	Include 4 female-to-male for I2C LCD connection
Reference thermometer (shared)	1 per class	\$5–15	For accuracy calibration in Lesson 3; one per class is sufficient
TOTAL per team (core kit)	—	≈ \$10–18	DHT22 version adds approximately \$2–3 — recommended investment for health monitoring accuracy