Week 1 — Qubits & Measurement (Tier 1, Grades 6–8)

Welcome! This Week-1 guide gives you a simple, classroom-ready way to introduce qubits using IBM Quantum Composer and one clear metaphor—the Quantum Compass. Think of a qubit as an arrow you can point and rotate. When we flip the arrow straight from North to South (X gate), students see a guaranteed outcome—our “bit” moment. When we turn the arrow 90° to East (H gate), checks along the N/S axis become probabilistic (~50/50)—our first “qubit” moment. We’ll run short experiments, read histograms, and talk about why repeated measurements estimate probability and how a tiny wobble (noise) can shift results. No prior quantum experience is needed; follow the steps, keep the compass image on the board, and let the data drive the discussion.

Quantum Compass — quick reference for teachers

State picture: a qubit is an arrow on a compass/sphere. Direction encodes the state.

Measurement: “checking on the N/S ruler” returns 0 or 1 with probabilities set by the arrow’s direction.

X (bit-flip): N ↔ S flip → deterministic change (like toggling a bit).

H (basis change): 90° turn to East (from $|0\rangle$) or West (from $|1\rangle$) → puts the arrow on the equator; repeated N/S checks give ~50/50.

Noise: tiny angle jitter (wobble) → small, explainable shifts in the observed counts.

Why this metaphor: it matches the Bloch sphere you’ll use next week (rotations = gates; axes = measurement bases) while staying easy to sketch and explain.

Tip: Keep a quick sketch on the board (↑ N, ↓ S, → E). When students report histograms, point back to the arrow and ask, “Where is the compass pointing now, and what should that mean for our N/S checks?”

Big idea: A qubit is like an arrow on a compass.

X gate = flip the arrow N ↔ S → deterministic.

H gate = 90° turn to East → probabilistic (~50/50).

Noise = a tiny wobble in the arrow.

Prior / Next:

Before: none (web browser only).

Next week: Bloch sphere & rotations (Rx/Ry/Rz) = compass rotations in 3D.

Goals (students will be able to…)

Build and run X+Measure and H+Measure in Composer.

Explain the difference between deterministic and probabilistic outcomes.

Use shot counts to estimate probability and describe noise vs sampling randomness.

Standards

CSTA 2-AP-10, 2-AP-13 (decompose & test).

NGSS MS-PS4-2 (wave/measurement model; evidence).

CCSS-M 7.SP (probability from data).

CCSS-ELA RST.6-8.1 (cite evidence).

Materials

1 device per pair with internet; IBM Quantum Composer.

Projector/board.

Optional: a printed compass rose or quick sketch on board.

Vocabulary

bit — The smallest piece of computer info. It's either 0 or 1, like a light switch off/on.

In our lab: the X gate makes the bit read 1.

qubit — A "quantum bit." It can be 0, 1, or a blend of both until we check it.

In our lab: after H, the qubit is in a blend that gives about 50% 0 / 50% 1.

gate — An instruction that changes a qubit. (Think: a button that rotates or flips the qubit.)

In our lab: we use the X and H gates.

X (gate) — The flip gate. It turns 0 → 1 and 1 → 0.

Compass idea: flips the arrow North ↔ South.

H (Hadamard gate) — The mix gate. It puts the qubit into an even blend of 0 and 1.

Compass idea: a 90° turn to East.

measurement — Checking the qubit to see 0 or 1. After we measure, the blend is gone and we keep that result.

In our lab: we measure at the end of the circuit.

shots — How many times we repeat the same experiment. More shots = better data.

In our lab: we might run 100 or 1000 shots.

histogram — A simple bar chart that shows how many times we got 0 and how many times we got 1.

In our lab: the H gate should make the bars about the same height.

probability — How likely an outcome is. We estimate it by counts ÷ shots.

Example: 500 out of 1000 shots = 0.5 (50%).

noise — Small, unwanted changes that nudge results away from the ideal.

Compass idea: a tiny wobble in the arrow; results won't be exactly 50/50.

Timing (45–60 min)

Do Now/Hook – 5

Lab 1: X (flip N↔S) – 10

Quick Check – 3

Lab 2: H (turn to E) – 20

Noise Challenge – 7

Exit Ticket – 5

(If you only have 45 minutes: trim Lab 2 runs from 1000 to 500 shots.)

Classroom setup (pairs)

Roles: Driver (mouse/drag) & Navigator (reads steps, records results). Swap for Lab 2.

Teacher talk track (scripted & concise)

Hook (1 min)

“Picture a compass arrow. If I flip it from North to South, the result is guaranteed—like a bit. If I turn it 90° to East, a check on the N/S axis will sometimes read N and sometimes S—like a qubit in a new basis.”

Draw: ↑ N, ↓ S, → E on the board.

Lab 1 — X + Measure (flip)

Composer steps: new circuit → on q0 add X → add Measure to c0 → 100 shots → run.

Expected: histogram ~100% 1.

Check-for-understanding (pair share):

When is the outcome guaranteed?

Why do we call this “classical”?

Common pitfall: measurement not connected to classical bit → fix wiring.

Lab 2 — H + Measure (superposition/basis change)

Composer steps: remove X → add H on q0 → Measure → 1000 shots → run.

Expected: near 50% 0 / 50% 1.

Prompt:

What changed when we moved from X to H? (Flip vs basis change)

Why aren’t the results identical every run? (sampling randomness)

Math mini-link: turn counts into percentages; write as P(0) and P(1).

Noise Challenge — The Wobble

Framing: real devices have noise; even simulators show non-exact splits due to randomness.

Task: run H+Measure three times at 1000 shots; record each histogram.

Discuss: Did you ever get exactly 500/500? How would a tiny angle wobble (noise) shift probabilities?

Exit Ticket (2–3 sentences)

Where did we see bit behavior (deterministic) and qubit behavior (probabilistic)?

Explain using the compass idea.

Assessment

Formative: two quick checks (after X; after H).

Summative (today): Exit Ticket using a 3-point CER rubric:

3 = clear claim + correct evidence from histogram + correct compass explanation.

2 = correct claim, partial evidence/explanation.

1 = claim or evidence missing/incorrect.

Misconceptions & fixes

"50/50 means every run is the same." → No, probability describes long-run frequency.

"Noise = simulator is broken." → Separate sampling randomness (this lab) from device noise (later with AER).

"H is a flip." → Contrast flip (X) vs basis change (H) using the compass drawing.

Differentiation

Support: provide a sentence frame—"When we applied X, the result was ___. When we applied H, the histogram showed ___ because ___."

Challenge: ask students to predict the histogram for two H gates (H then H) before running (should recover |0⟩).

Tech fallback (no Composer)

Show a static image of X circuit and H circuit; use an online coin-toss sim to approximate shots; keep the compass explanation and discussion.

Teacher checklist (prep)

Test Composer login.

Create a blank circuit and run once.

Draw ↑, ↓, → on a whiteboard slide.

Print/prepare exit ticket prompt.

Copy blocks you can paste into your student sheet

Q1: “Flip Test (X): When is the outcome guaranteed? Why is that classical?”

Q2: “Equal Mix (H): What does turning the arrow to East mean? Why aren’t runs identical?”

Noise: “Run H three times at 1000 shots. Did you see 500/500? Explain with the compass wobble.”