TIERS Based Concepts Checklist

Week	Topic	Tier 1 (Grade 6–8) Conceptual Focus	ier 2 (Grade 9–11) Interm. Math & Visuals	3 (Undergrad) Qiskit Developer Focus	Tier 4 (Adv. Encryption) Qiskit Advocate Focus
1	**Qubits & Measurement**	Qubit States, H Gates. Flipping a coin in the air (superposition). Deterministic vs. Probabilistic Outcomes (Histogram focus).	State Vectors & Amplitudes. Calculating simple probabilities from α and β.	The Formal State Vector, Dirac Notation, & Born Rule. Use Statevector Simulator and Density Matrix (ρ).	Quantum Postulates & No-Cloning Theorem. Formal proof that arbitrary state copying is impossible.
2	**Single-Qubit Rotations**	Direction & Spin (Analogy). Visualization of states as directions (up/down, left/right). Simple rotations as flips (X,Z).	Bloch Sphere Mapping & Pauli Gates. Visualizing X,Y, Z rotations (π radians). Using Qiskit's plot_bloch_vector.	Unitary Evolution, Euler Angles, & Ry,Rz Matrices. Formal definition of all single-qubit unitaries and decomposition.	Basis Transformation for Measurement. Mathematical derivation of the transformation matrix required to switch between measurement bases.
3	**Entanglement & Bell States**	Magic Dice & Perfect Link (Analogy). Entanglement as a perfect, non-local connection. Outcomes are always 00 or 11.	CNOT Gate Function & State Composition. Building the circuit. Visualizing the unpolarized individual qubit on the Bloch Sphere.	Tensor Product & Non-Separability Proof. Formal matrix construction of the Bell state. Running the CHSH Game/Inequality.	EPR Pairs for QKD (Ekert 91). Using entanglement as the fundamental cryptographic resource. Security relies on Eve breaking the correlation.
4	**Mini-project: Teleportation**	"Un-Flip" Game. Using the perfect link to perfectly "guess" the state of a distant particle (Teleportation concept via analogy).	Teleportation Circuit Logic. Understanding the roles of the Bell State and measurement results in determining the final correction gates.	Formal Teleportation Derivation. Mathematical derivation of the full Teleportation protocol. Using conditional logic to apply X and Z gates in Qiskit.	Superdense Coding vs. Teleportation. Compare and contrast the two protocols. Analysis of the classical channel requirement.

5	**Multi-qubit Circuits & Noise**	Circuit Complexity. Recognizing circuits with 3+ qubits and the conceptual idea of noise as "static" on the signal that corrupts the outcome.	SWAP Gate and Toffoli Gate. Introduction to these multi-qubit gates and their matrix representation. Noise as an "Error Rate."	Controlled Gates (Cn(U)) & OpenQASM. Using the Density Matrix (ρ) to model simple noise channels (e.g., Depolarizing Channel) applied to a circuit.	Quantum Error Correction (Conceptual). Introduction to the Stabilizer Formalism via the 3-qubit bit-flip code and its Qiskit implementation.
6	**QAOA (Intuitive)**	Optimization as Pathfinding. Conceptual understanding of finding the "best path" in a network. QAOA as a guided search for the lowest point.	Cost Function & Parameterization. Introduction to the idea of a cost function and the classical parameter tuning (β,γ).	Variational Algorithms & Qiskit Primitives. Formal structure of the QAOA Ansatz. Using the Qiskit Estimator primitive.	Optimization for Cryptography/Resource Allocation. Use QAOA for specific constrained optimization problems relevant to secure routing.
7	**VQE (Intuitive)**	Finding the Lowest Energy. Analogy of a ball settling at the bottom of a bowl (ground state). VQE as a method to find the most stable position.	Hamiltonian & Energy Minimization. Introduction to the Hamiltonian as the energy operator. VQE's goal: minimizing the expected value of the Hamiltonian.	Hamiltonian Mapping (Jordan-Wigner) & Expectation Value. Formal mapping of chemical structures to qubits. Practical calculation of ⟨H⟩ using the Qiskit Estimator.	VQE for Material Science/Chemistry. Advanced applications in chemistry (e.g., LiH molecule). Discuss resource estimation and NISQ limitations.
8	**Quantum Encryption (BB84)**	Secret Code Game. Understanding the concept of a secret, uncopyable message. BB84 as a "send, check, discard" protocol.	Two Measurement Bases. The role of the Rectilinear (Z) and Diagonal (X) bases. The high probability of detection when Eve uses the wrong basis.	BB84 Formalism & Security Proof. Formal description of the BB84 protocol using basis rotation matrices. Proof of Eve's inevitable disturbance (error rate).	QKD Post-Processing & Key Rate Analysis. Full simulation including Sifting, Error Reconciliation, and Privacy Amplification. Analyze the final secure key rate.