MASTER TEACHER'S GUIDE

Unit Title: TOY QAOA VQE BB84 Circuits (Grades 9–12)

This curriculum is designed to be a 4-week, project-based introduction to quantum fundamentals using the **IBM Qiskit Simulators AER.**

1. Curriculum Overview:

Field	Detail
Target Audience	**Tier 2: Grades 9–10 or 11 or 12 (High School)**
Design Principle	**Cross-Curricular Alignment** → Concepts are aligned with Math (CCSS-M), Science (NGSS), and Computational (CSTA) standards.
Learning Progression	**Conceptual Pre-Loading** (Engagement on Real Live phenomena model) **Applied Modeling** (Representation on phenomena math equation model) **Computational Logic** (Interaction on Qiksit-Python code environment phenomena model.).
Duration	**4 Weeks (approx. 4 x 45-60 minute sessions)**

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Teacher Guidance	**Week 5** Teleportation /Error demo **Week 6** QAOA (intuitive) Toy Low Cost **Week 7** VQE (intuitive) Compass Shaking **Week 8** Quantum Encryption (BB84) Two Measurement Basis Randomly viewed.

1. Pedagogical Framework: Multiple Shaked Quantum Compass

This unit is designed for modular deployment across different subject classrooms, ensuring high accessibility and adoption.

Focus Area	Objective (The student will be able to...)	Bloom's Level
Science/Literacy	**Define** a Quantum State Vector, understand superposition and **analyze** entanglement representation on two qbits.	Analyzing, Understanding
Mathematics	**Apply** the 100% probability rule (α%+β%=100%) to solve basic algebraic equations.	Applying
Computational	**Sequence** conceptual quantum commands (Hadamard Gate, Measurement) and understand basic **Entanglement/Correlation**. **Cost Function.**	Creating

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2. Tier 2 Curriculum Sequence (4 Weeks)

The curriculum gradually builds complexity from reading comprehension to multi-qubit logic.

Module	Weeks	Core Activity	Key Quantum Concept
5. Multi-Qubit Circuits	**Week 1**	**Simple error code** **Redundancy as detector** **Qbit correction ancilla** **From Compass to Qbit** (Jupyter Lab).	Error detection, 3 qbit cricuits, ancilla operation. .
6. QAOA (intuitive) Toy Low Cost	**Week 2**	**Cheapest electron path with QAOA** (Jupyter Lab).	Cost Function & Parameterization. Introduction to the idea of a cost function
7. VQE (intuitive) Compass Shaking	**Week 3**	**Compass Balanced** **Multiple Compass shaking** (Jupyter Lab)	Hamiltonian & Energy Minimization. Introduction to the Hamiltonian as the energy operator
8. BB84. Two Measurement Basis Randomly viewed.	**Week 4**	**Secret compass randomly viewed**	The role of the Rectilinear (Z) and Diagonal (X) bases

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3. Multiqubit Basic Literacy Units (Weeks 5-8)

These resources provide the conceptual requirements for the teacher before bringing the notebooks to the students.

Unit B: Compass on Magnetic Field (ELA/Narrative Focus)

Core Metaphor	Quantum Concept	Core Learning Idea for Students
Single qubit equilibrium	Multi-qubit gate chain.	Introduction to multi-qubit gate chain.
Compass shaking and balancing	The Hamiltonian as the energy operator.	Equilibrium on shaking and path low cost.
Two Compass 3D Entangled	The role of the Rectilinear (Z) and Diagonal (X) bases	Message spy detection

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4. Computational Logic Refinements (Weeks 5-8)

A. Tier 2 Single Qbit Equilibrium (Weeks 5-6)

Entanglement comprehension.

Gate Focus	Conceptual Model (Tier 1)	Avoided Concept (Reserved for next Tier)
CZ	Compass entanglement	Matrix Representation beyond 2 Qbits.
Rz Dials	Mixing the ZZ QAOA component	Hamiltonian build from graphs beyond 3 Edges.

B. Tier 2 VQE and BB84 Basics (Week 7-8)

Toy models to understand the VQE lowest state and how looking could alter the probabilities outcomes.

Element	Description	Computational Logic
CZ	Two compass entanglements	Introduces a controlled interaction between two qubits that generates quantum correlation on VQE required entanglement.

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Ansatz	Reach many possible spin configurations. Allow smooth, continuous adjustments. Create correlations between neighboring spins. Remain simple enough to optimize	Controlled-Z (CZ) gates introduce correlations between neighbors.

5. Tier 1 to Tier 2 Conceptual Bridge

This section clearly defines the shift in complexity required for the next tier.

Tier 1 Concept (Grade 9-12)	Bridge Explanation	Tier 3 Concept (Undergrad)
Recognizing circuits with 3+ qubits and the conceptual idea of noise as "static"	The **Compass** becoming a unstable arrow by natural noise.	Controlled Gates (Cn(U)) & OpenQASM. Using the Density Matrix (ρ)
Finding the Lowest Energy. Analogy of a ball settling at the bottom of a bowl (ground state).	All compasses dance on their shared (Hilbert) space looking for a coordinated settle point	Hamiltonian Mapping (Jordan-Wigner) & Expectation Value
Secret Code Game. Understanding the concept of a secret message.	Spied and uncovered message will be detected	BB84 Formalism & Security Proof. Formal description of the BB84 protocol using basis rotation matrices.

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6. Resources for Curriculum Implementation

The following resources are essential for deploying the Tier 1 curriculum.

Resource Name	Type	Purpose in Curriculum
Jupyter Notebook Python Qiskit 2.x	Collabs Jupyter Notebnook	Core platform designed over UDL-5E education model. That includes Pyhton code example for teacher´s further labs development..
IBM Qiskit Classroom	Educational Portal	Provides supplemental material and official documentation/tutorials on basic quantum gates for teacher background.
Qiskit Documentation	Reference (Web)	Used by the teacher to confirm gate definitions and troubleshoot expected outcomes during Composer Labs.

Conclusion and Next Steps

he immediate next phase of development will focus on **Tier 3 (Undergraduate level)**, specifically building the **Conceptual Bridge** to formally introduce the Dirac notation definition of *Phase*, while continuing the progression toward computational mastery of **QAOA**, **VQC**, and **Quantum Cryptography**. This stage will emphasize not only the formalism but also the **intuition developed within the mathematical framework**, ensuring students grasp the underlying concepts before applying them to algorithms. A **Core Matrix lecture** will be essential as a complement to strengthen this foundation.

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