Teaching hands-on quantum computing to youth through workshops

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Angara et al., Teaching Quantum Computing to High-School-Aged Youth: A Hands-On Approach: https://ieeexplore.ieee.org/abstract/document/9613752

Outline

- Motivation
- Effective Teaching strategies
- Design and delivery of workshops
- Our observations
- Upcoming workshop – "Demystifying quantum enigmas: a hands-on introduction to quantum computing"

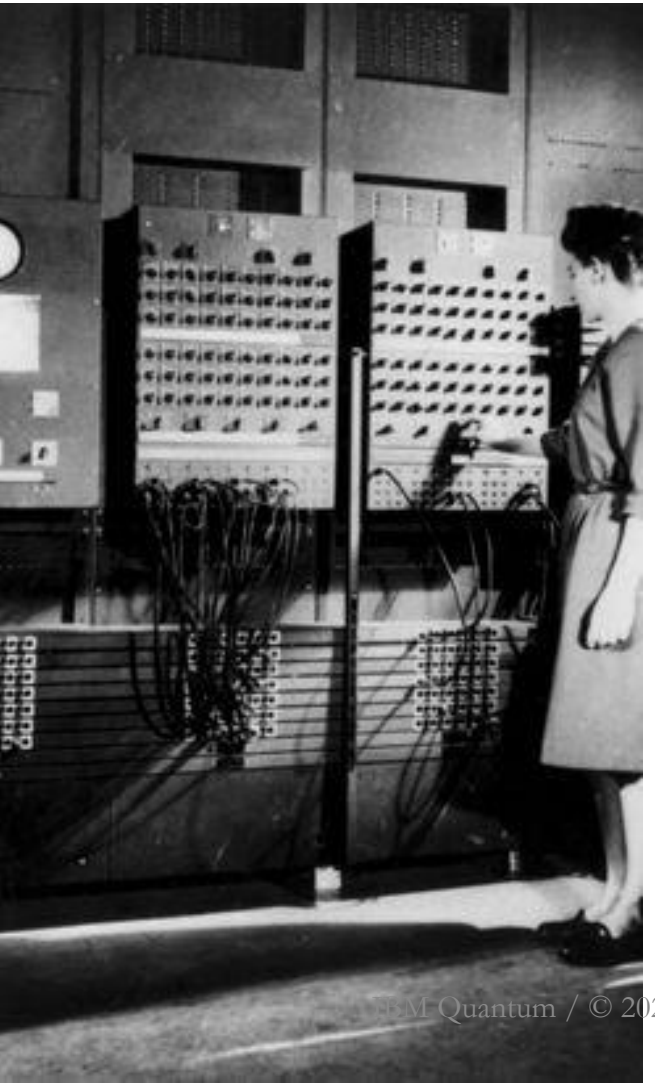
Why should we teach quantum computing at a high-school level?
Why does it matter whether people understand anything about quantum computing?

Motivation

Why is quantum computing important?

Computing

Making physics do the hard work since 1822



Computing

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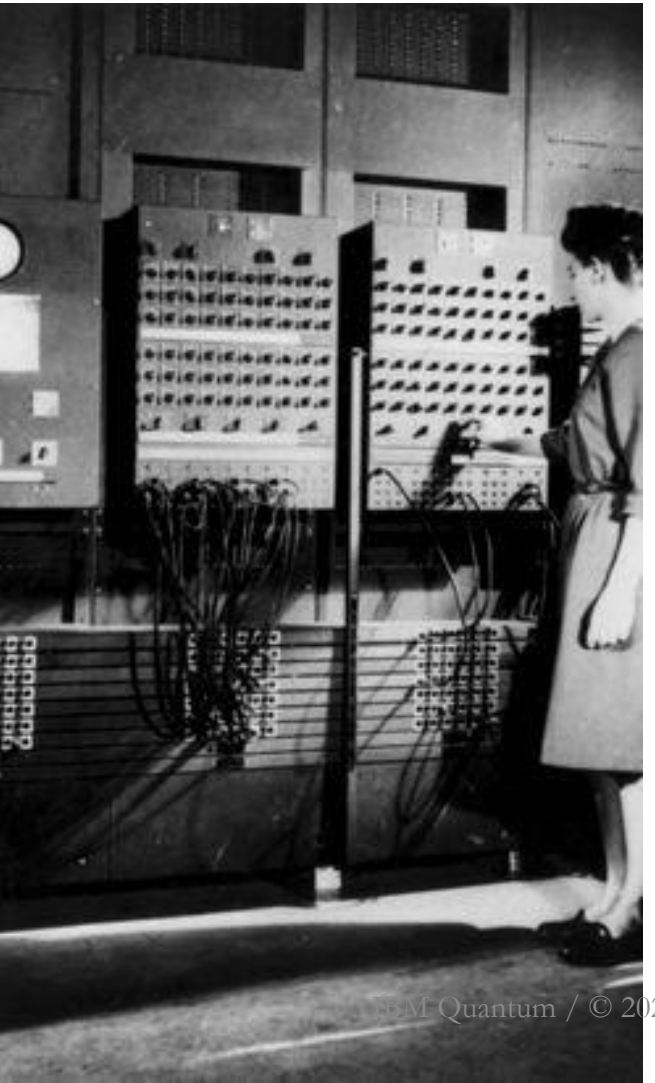

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Computing

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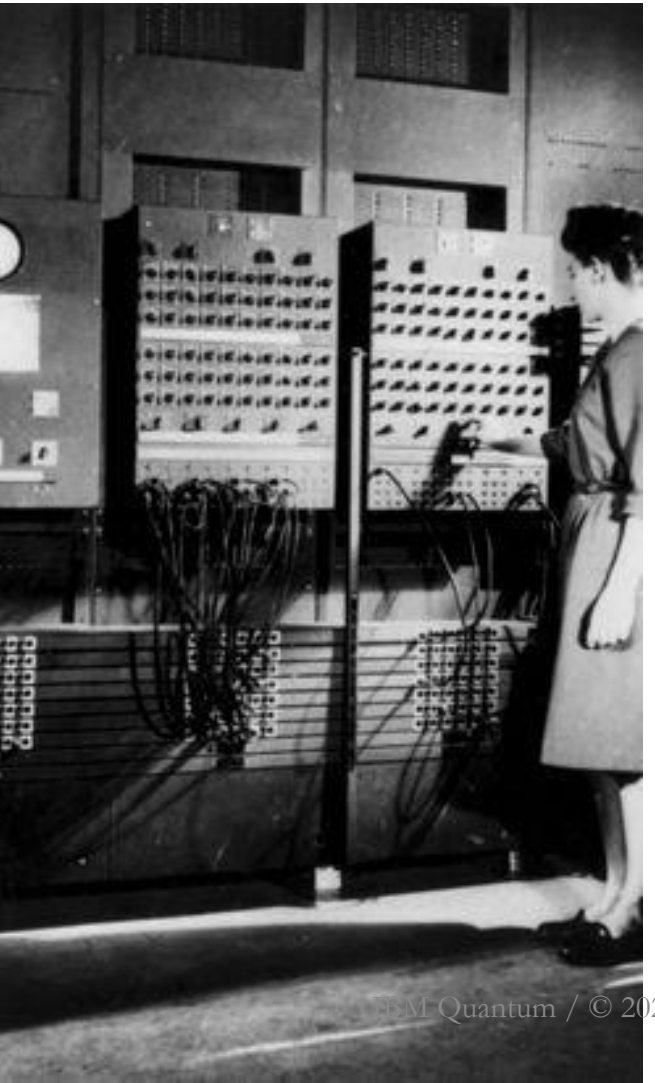

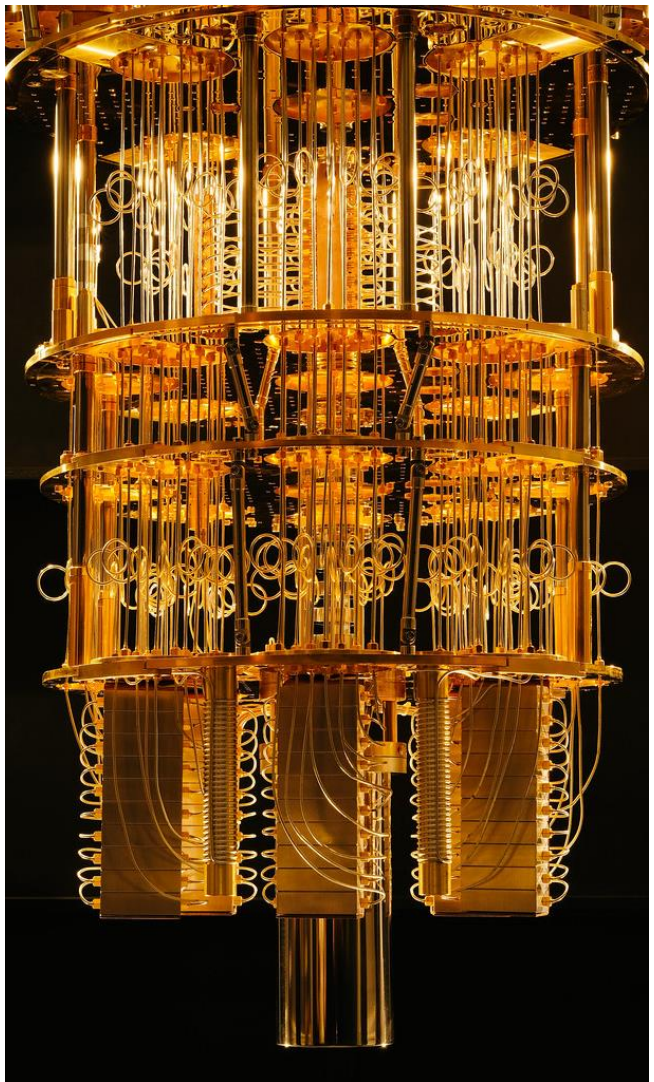

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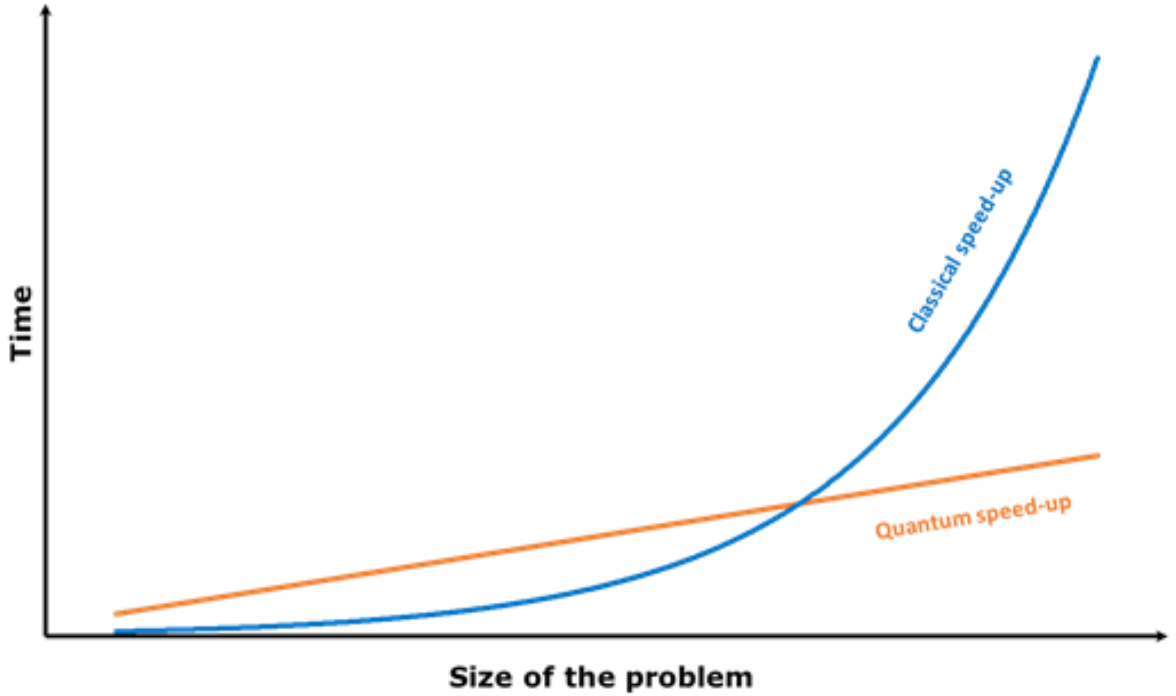
Quantum is interdisciplinary

Why does it matter whether people understand anything about quantum computing?
What changes are likely to happen due to developments in quantum computing?

Potential to revolutionize

- Chemistry: simulating molecules, efficient fertilizer production, designing catalysts
- Cryptography: integer factorization, key distribution
- Optimization: Supply chain logistics, portfolio optimization
- And many other fields …



Our workshops

Goals, strategies, and observations

Goals of our workshops

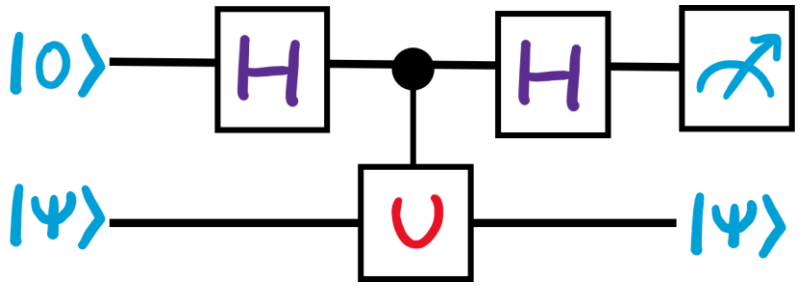
- Long-term: Expose youth to quantum computing concepts early to provide career path choices
- Increase diversity: Attracting a diverse student body remains a challenge, early education helps
- Provide training resources: a significant amount of trained personnel are needed in the coming years
- Help K-12 curriculum development: we show how to involve youth in quantum computational thinking as early as possible

Effective teaching strategies

- Unplugged activities
- Practice Sheets
- Programming
- Quantum Games

Linear algebra and complex numbers

- Prerequisites for understanding the mathematics involved in quantum computing are rarely taught in high schools
- How do we teach high-schoolers?
  - Use only real numbers
  - Use the dirac notation



States:

$|0\rangle = \begin{bmatrix} 1 \\ 0 \end{bmatrix} \quad |1\rangle = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$

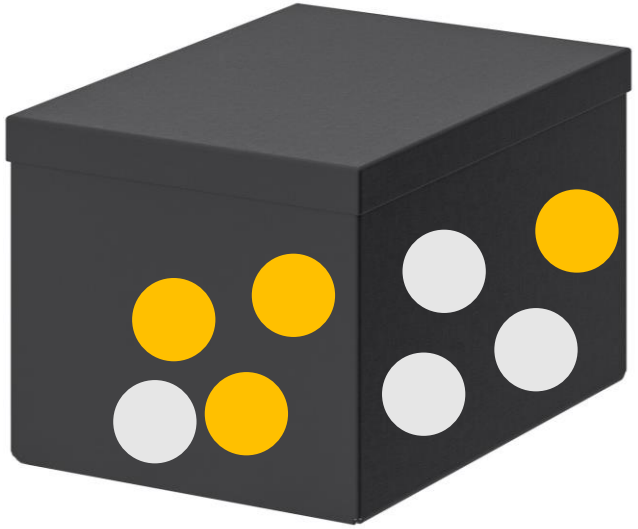
Gates:

$H = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$

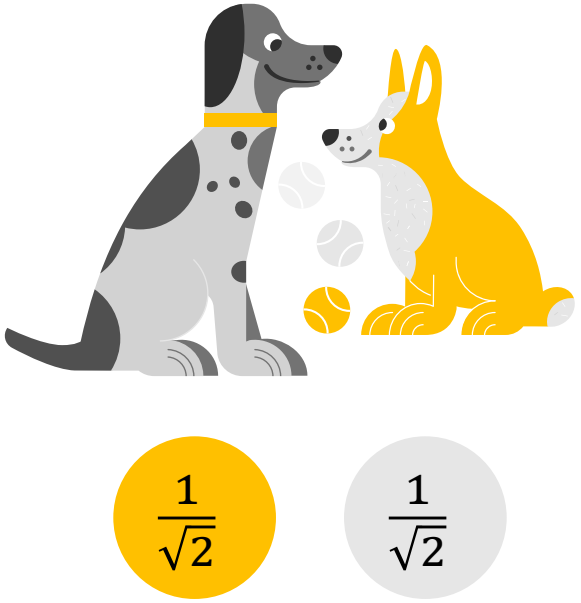
$H|0\rangle = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$

Unplugged activities

Qubit Doughnuts



Measurement black box



Find your quantum partner

Practice sheets

What is a valid quantum state?

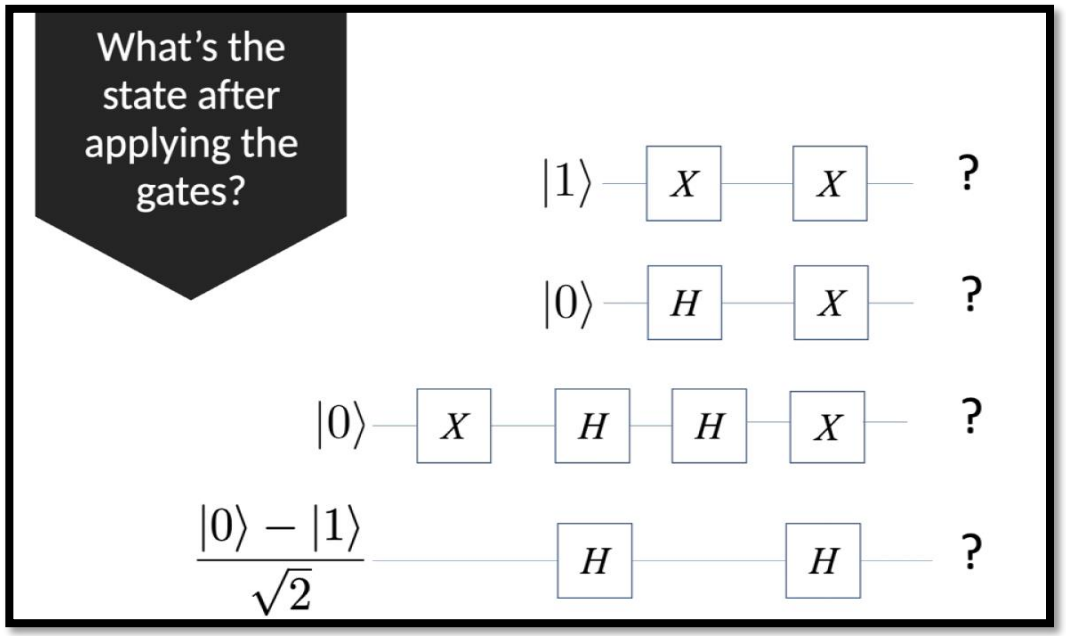
$$|\psi\rangle = \frac{1}{\sqrt{2}}|0\rangle + \frac{1}{\sqrt{2}}|1\rangle$$

$$|\psi\rangle = \frac{1}{4}|0\rangle + \frac{3}{4}|1\rangle$$

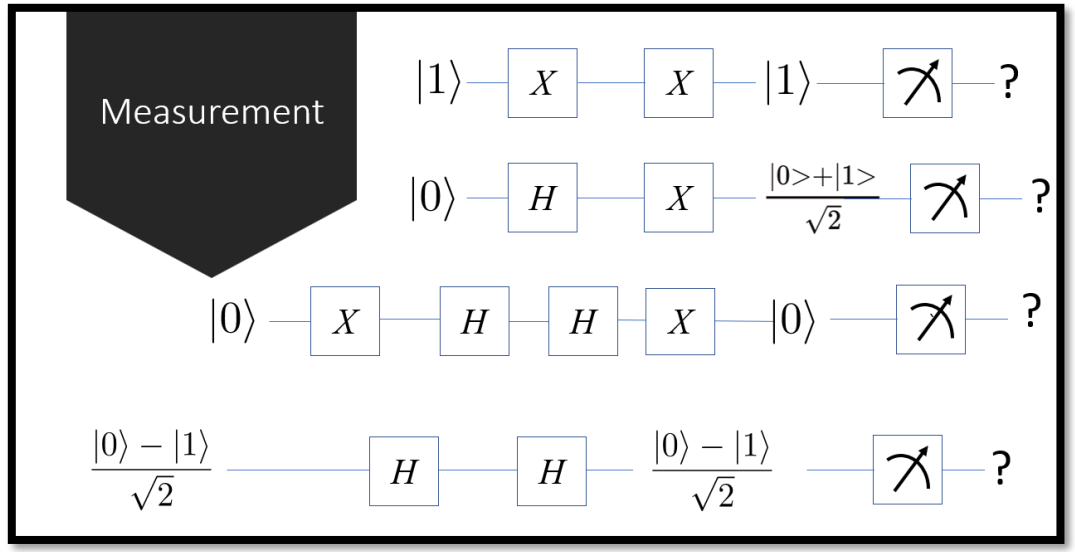
$$|\psi\rangle = \frac{12}{13}|0\rangle + \frac{5}{13}|1\rangle$$

$$|\psi\rangle = \frac{4}{5}|0\rangle + \frac{2}{5}|1\rangle$$

What's the state after applying the gates?

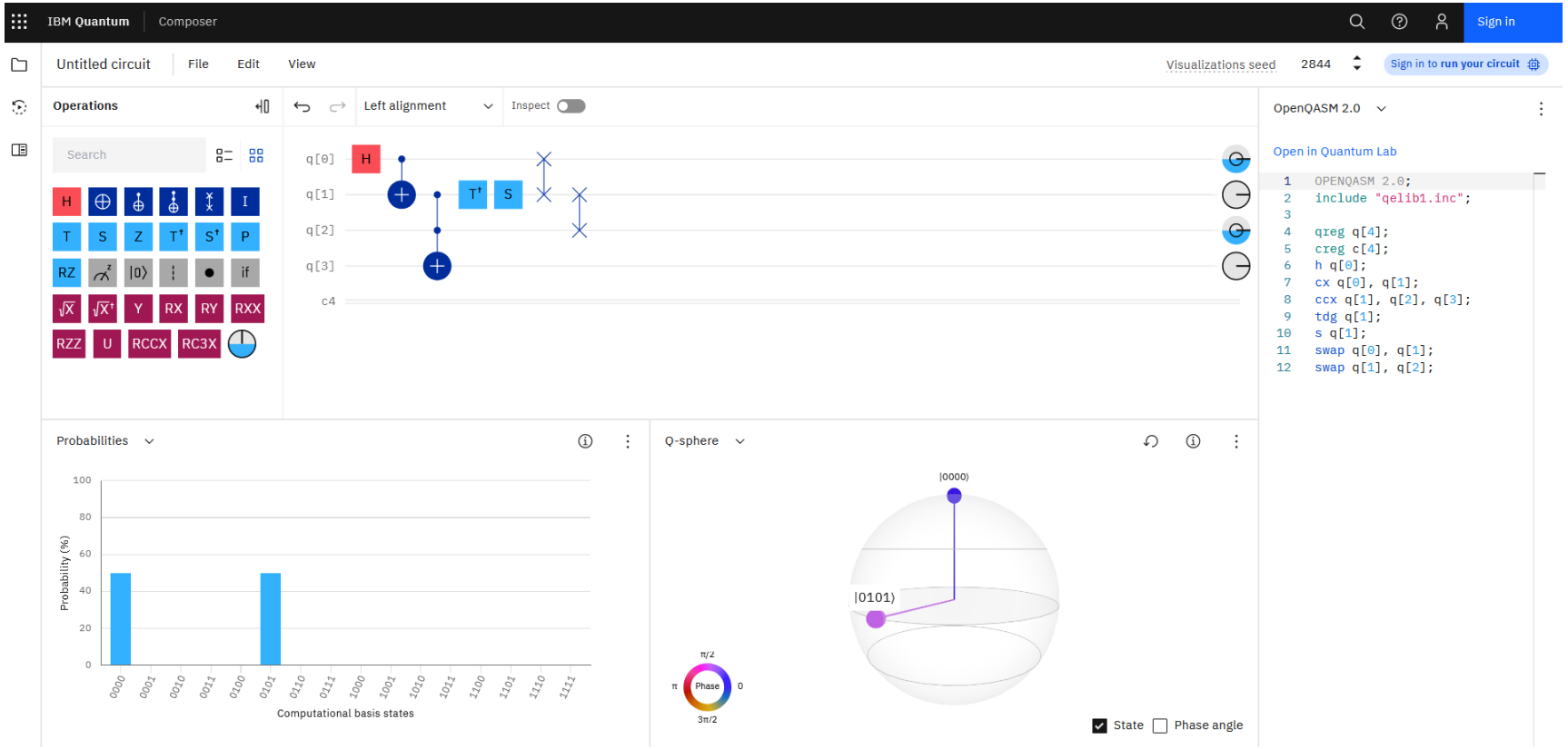


Measurement



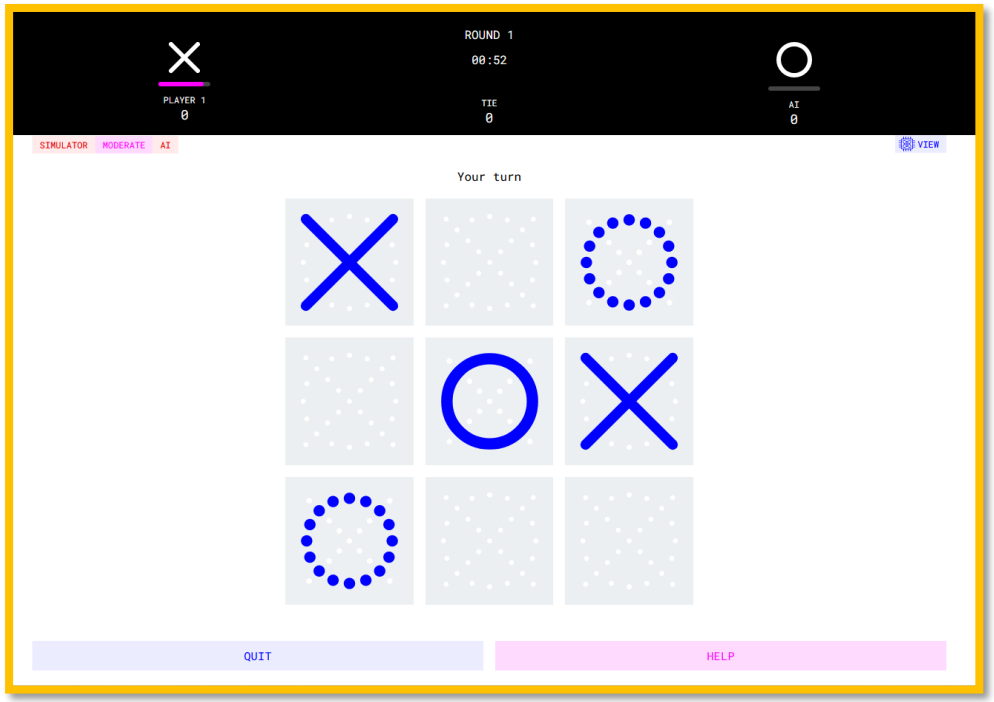
Programming

- IBM Circuit Composer
  - Python + Qiskit



Quantum Games

[Entanglion]



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Design and delivery of workshops

Introduction	Journey of a qubit: A quick introduction Main concepts: Qubits, Superposition, Entanglement, Measurement, Quantum Gates Create IBM accounts, setup environment Hands On: Circuit Composer
Journey through the quantum stack	Quantum Software: Hands On: Quantum gates and circuits Quantum applications with a focus on hybrid quantum-classical techniques
Pathways into Quantum Computing	Panel Discussion: How did you get into quantum computing? Q & A with students

Sample of a one day workshop schedule

Our observations

Teaching strategies: A mix of strategies helped for an interactive learning experience.

Engagement and participation: Interaction among participants lead to high student satisfaction.

Diversity: Attracted interest from various age groups, promoting collaboration and synergy.

Our observations

Props and handouts: unplugged activities and practice sheets for reinforced learning.

Programming: The composer was easy to use, Jupyter notebooks and python had lower levels of comfort

Gamification: "Entanglion" game enjoyed by students, although its complexity and timing posed challenges in identifying learned concepts.

Panel discussion: Rich discussion into careers in quantum

Take home messages

Why should we teach quantum computing at a high-school level?
Why does it matter whether people understand anything about quantum computing?

- Preparing for the future
- Developing critical thinking and problem-solving skills
- Introducing interdisciplinary connections
- Broadening perspectives
- Encouraging creativity and innovation

Take home messages

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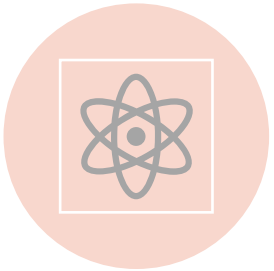
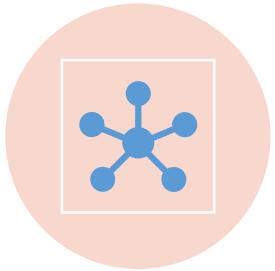


COMPUTING + QUANTUM COMPUTING = A GREAT TOOLKIT!

LEARN QUANTUM PHYSICS AND MATHEMATICS THROUGH QUANTUM COMPUTING



PROVIDE OPPORTUNITIES TO ENGAGE IN THE LOCAL QUANTUM ECOSYSTEM

Resources

- Perry et al., Quantum computing as a high school module: https://www.osti.gov/biblio/1527395
- Qubit by Qubit: https://www.qubitbyqubit.org/
- Angara et al., Teaching Quantum Computing to High-School-Aged Youth: A Hands-On Approach: https://ieeexplore.ieee.org/abstract/document/9613752

Upcoming workshop

https://qce.quantum.ieee.org/2023/