Quander Games: Tangle's Lair

Simplify quantum circuits to unlock doors!

1 Player

Ages 10+

45-60 minutes

Learning Goals

Understand how to simplify quantum circuits.

Understand that simple circuits run faster and more reliably than complex ones.

## Quantum Computing Connection

Current quantum computers are fragile, and can be easily disturbed by small things like light and vibrations. Quantum programs, or circuits, have to be as short as possible so they can run quickly without errors.

Game Overview

Tangle locked herself out of her lair and she needs your help simplifying the locks. The locks are made up of kitty boxes, or gates, that combine together to make a quantum circuit. However, the circuit wont run and the door won't unlock if there are too many kitty boxes.

In Tangle's Lair the player will learn patterns of how quantum logic gates combine and reduce. Using these patterns the player will simplify each pattern as much as possible to open the doors.

Tangle's Lair slowly introduces the player to more complex gates and simplification patterns as the game progresses. Through simplifying gates, the game aims to introduce the player to various properties of logic gates.
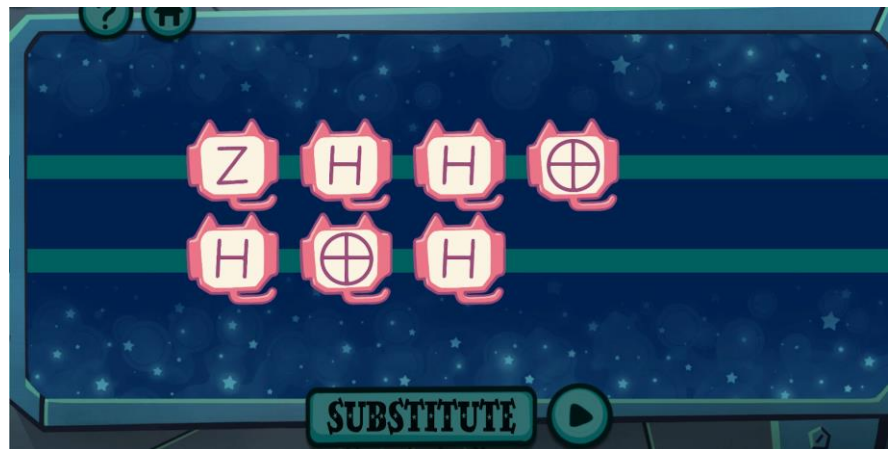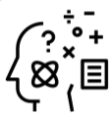
Background Knowledge for Facilitators

Fragility: Classical computers store simple values in their memory storage devices. These devices are very reliable and rarely experience errors. Quantum computers are much more fragile than classical computers. Qubits, which store information is quantum computers, can experience errors caused by light, small vibrations, sounds, or changes in temperature. Quantum programs, or circuits are made as short as possible to reduce the chances of experiencing an error.

Molly's Challenge:
What does Molly need to do to help Tangle simplify quantum circuits and unlock the doors to her Lair to retrieve her quantum computer parts?

Guiding Question:
How can Molly use the patterns of kitty boxes to simplify the circuits to open the doors?

Engage

1. Begin by telling your students that they will be playing a game that introduces concepts critical to quantum computing, like **gates** and **quantum operations**.
2. Start by asking students questions about the following concepts:
    a. Has anyone heard of the term simplification?
    b. What comes to your mind when you hear the word simplification?
    c. What do you do to simplify equations or expressions in math class?

Explore

1. Give the students ~15 minutes to play as many levels of Tangle's Lair as they can.

    Disclaimer: Students will be at various points in the game and experiences differences in levels. Levels are procedurally generated and how students choose to simplify the kitty boxes will impact their end result.

Explore cont.

    a. Once the timer is up, give students 10 minutes to discuss the following questions:

        i. Did you use any hints for any of these levels?

          (Student answers may vary)

        ii. What were some of the patterns you saw in the circuits before simplified them? (Number of kitty boxes and rows, types of boxes)

          (Students answers may vary)

        iii. **(Referencing the Terms)** What simplification patterns did you create?

          (Answer: See page X)

2. Give the students ~15 minutes to replay the last 4 levels available to them. Ask the students to try simplifying the levels multiple different ways.

    a. Once the timer is up, give students 10 minutes to discuss the following questions:

        i. What patterns did you simplify first?

          (Student Answers may vary)

        ii. How many times did you repeat each level?

          (Student Answers may vary)

        iii. What was the least number of kitty boxes you were able to get for each level you repeated?

          (Student Answers may vary)

Explain

1. Give students ~5 minutes to explore the Reward Area (See page 6) and review the reward cards they earned while playing the game.
   a. Cards are double-sided. Students must click on the enlarged card (displayed on the right side of the screen to flip it).
2. Have students write a 3-5 sentence response to the guiding question:
   a. **Guiding Question:** How can Molly use the patterns of kitty boxes to simplify the circuits to open the doors?
   b. **Word Bank** for students to use in their responses: Molly, Tangle, Door, Gate, Kitty Box, Gate, NOT, H, Z, CZ, CNOT, SWAP.
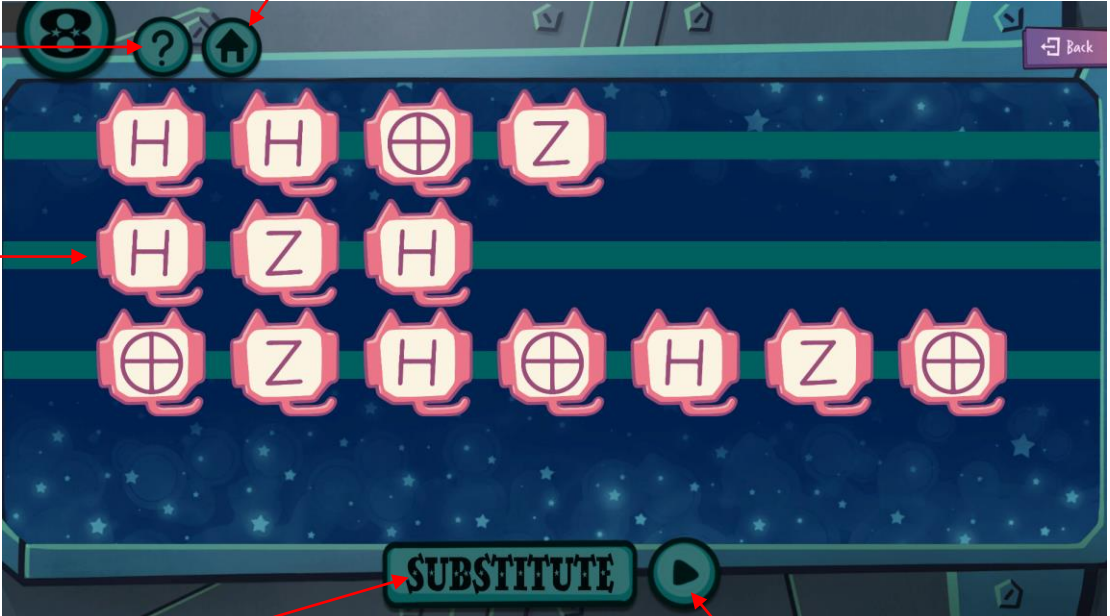
Quantum Information Science Connections

Concept	Definition	In-Game Representation
Quantum Gate	A quantum gate represents an operation that happens to a qubit.	Kitty Boxes are different quantum gates
Quantum Circuit	Quantum circuits are designed to be as short as possible (contain as few gates as possible) so they can run quickly without error.	Strings of Kitty boxes represent quantum circuits. The player simplifies these circuits so the run without errors.

How To Play

Level select

Hints

Click on kitty boxes to select them

After selecting kitty boxes, click here to simplify them

After simplifying the kitty boxes as much as possible, click here to run the circuit

Characters & World

Molly: The main character of the Quander games. In Tangle's Lair she helps Tangle unlock doors by simplifying circuits.

Tangle: Molly's best friend and cat. Caused an explosion while building a quantum computer and locked herself out of her lair.
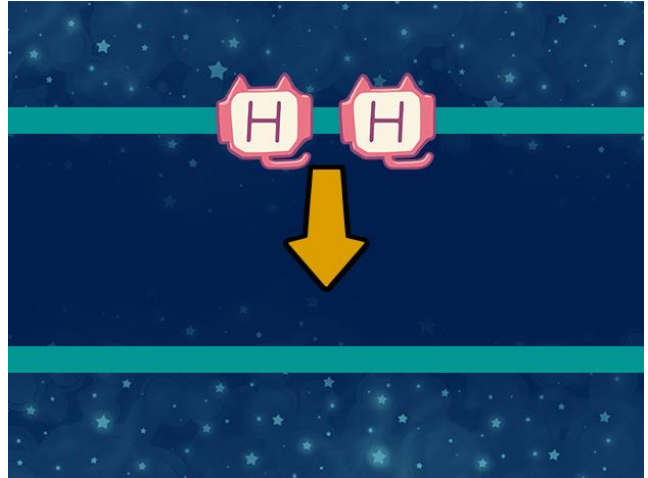

Tangle's Lair game circled in red
Reward Area circled in white

Gate Simplification Reference Sheet
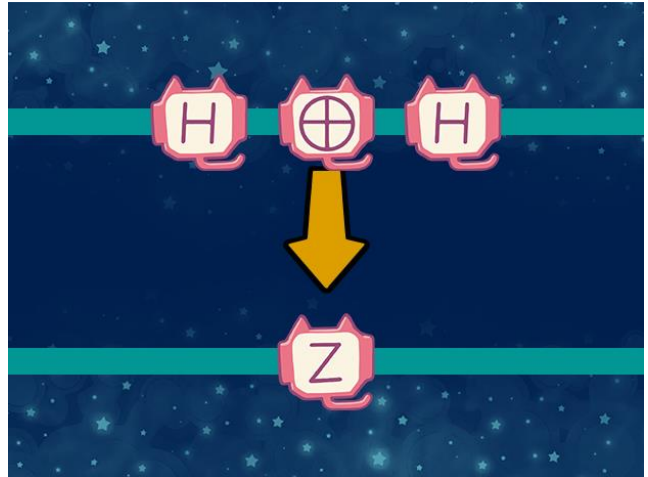
H-H Simplification

Two H kitty boxes next to each other cancels both boxes out.
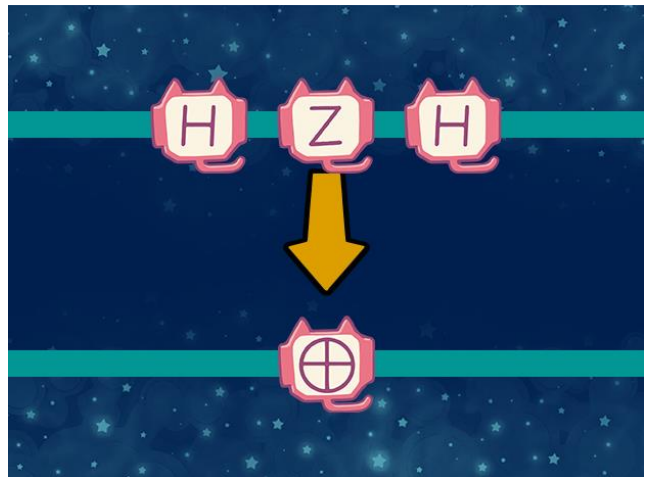

H-NOT-H Simplification

The H-NOT-H pattern simplifies to one Z kitty box.

H-Z-H Simplification

The H-Z-H pattern simplifies to one NOT kitty box.

Gate Simplification Reference Sheet

NOT-NOT Simplification

Two NOT kitty boxes next to each other cancels both boxes out.

H-CNOT-H Simplification

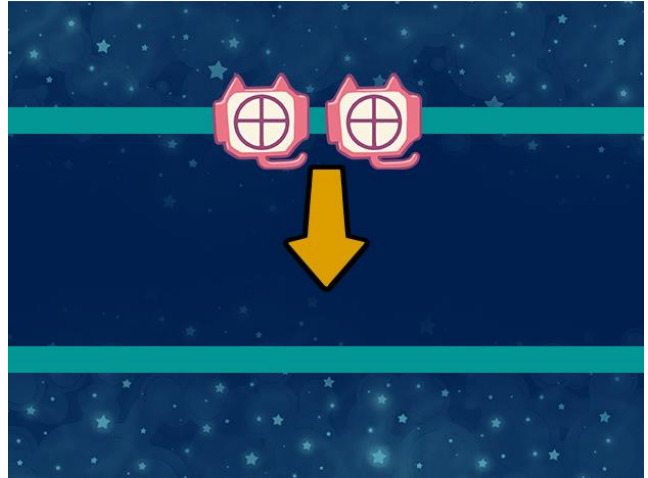The H-CNOT-H pattern simplifies to one CZ kitty box as long as the H kitty boxes are on the same row as the NOT portion of the CNOT kitty box.
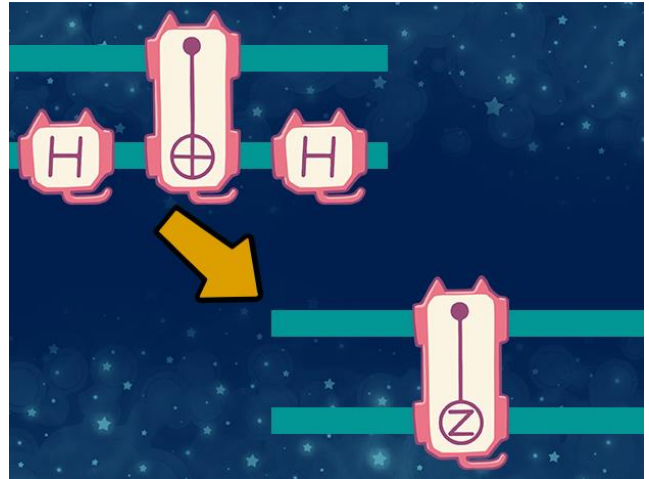
H-CZ-H Simplification

The H-CZ-H pattern simplifies to one CNOT kitty box as long as the H kitty boxes are on the same row as the Z portion of the CZ kitty box.

Gate Simplification Reference Sheet

H-H-CNOT-H-H Simplification

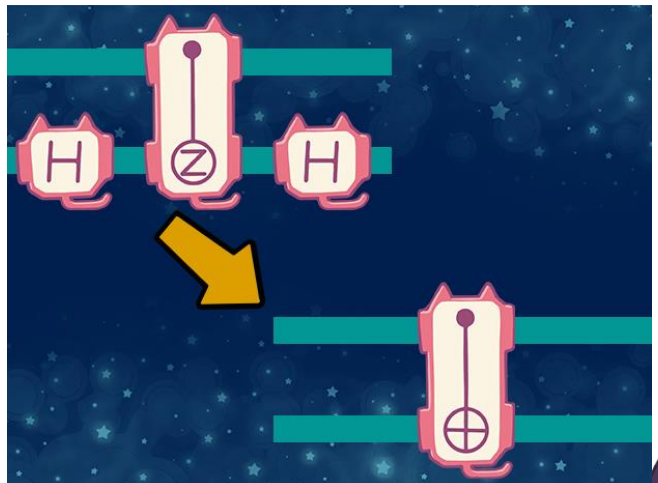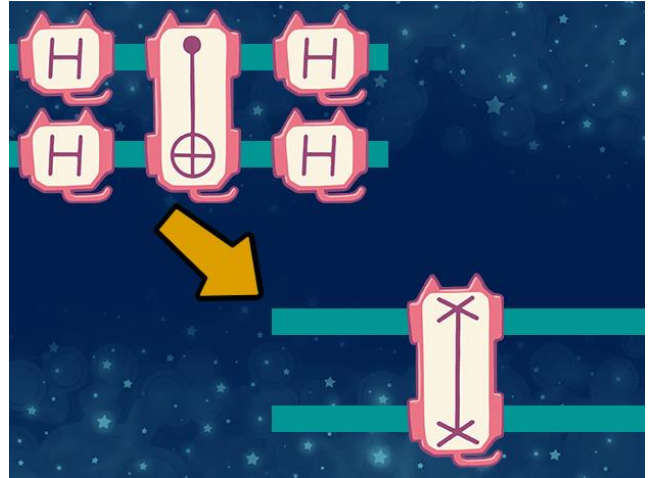The H-H-CNOT-H-H pattern simplifies to one SWAP kitty box. This simplification needs one H on the top row and one H on the bottom row on both sides next to the CNOT box.

Rewards Cards (Levels 1-6)

Card: Gate Simplification

Type: Concept

Level Earned: 2

GATE SIMPLIFICATION

Gate simplification is as easy as 7-(2*3), 2+4-4, 3*(4-3)

GATE SIMPLIFICATION

- There are different ways to make a circuit do the same thing to qubits

- Doing things with the least amount of gates is what we call the simplest circuit

- Simplifying circuits is similar to simplifying math equations

- For example, 2+(1+4-4) can be simplified to 2+1

CONCEPT

Card: Zombie Boss Brad

Type: Character

Level Earned: 4

ZOMBIE BOSS

"Morning Brad!"
"Hey Chef, got any brains?"
"Brad, we make Qupcakes."
"Oh, right. Uhh, two then."

ZOMBIE BOSS

Name: Brad

Role: A Qupcakery regular who stops by every day on his way to work

Hobbies: Working, spending money, eating, trying to feel something

Favorite Foods: Brains, guts, qupcakes, expense reports

Birthday: October 13th

CHARACTER

Card: H Gate

Type: Visual Representation

Level Earned: 6

H GATE

Prior to the H gate, DeeCee wanted cheese not batteries. Now he wants cheese and batteries

H GATE

- The "H" in H gate stands for "Hadamard"

- The H gate acts on only one qubit at a time

- Two H gates destroy one another

- The H gate creates a superposition or undoes it, depending on the input
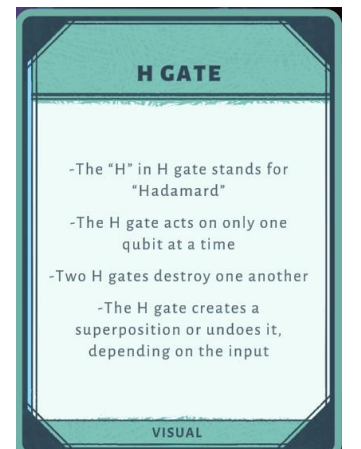
VISUAL

Rewards Cards (Levels 7-15)

Card: Quantum Processor

Type: Concept

Level Earned: 9

QUANTUM PROCESSOR

-A quantum processor is only good for solving certain problems, like searching a database or simulating a chemical reaction

-You need a regular computer to program a quantum computer

- A quantum processor is made from gates and qubits

CONCEPT
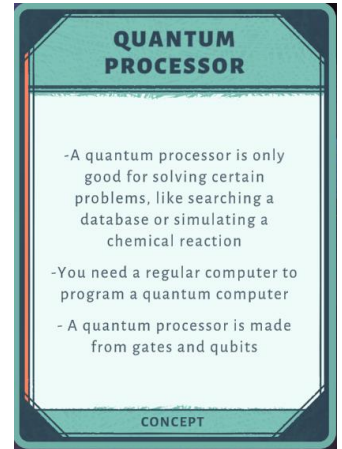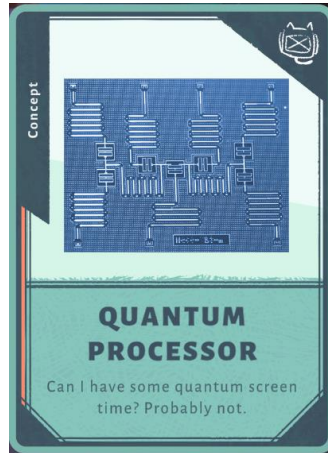
Card: CNOT Gate

Type: Visual Representation

Level Earned: 12

CNOT GATE

-The "C" in CNOT gate stands for "Controlled"

-The CNOT gate needs two qubits to work: The first qubit "controls" the second "target" qubit

-The CNOT gate flips the target (second) qubit if and only if the control qubit (first) is 1

VISUAL
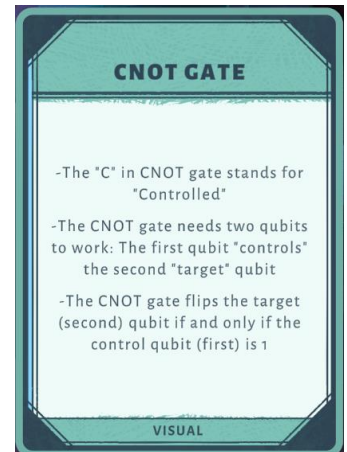
Card: Quantum Circuit

Type: Computer Part

Level Earned: 15

QUANTUM CIRCUIT

-It's a program that runs on a quantum computer

-A quantum circuit contains gates

-Order matters! The gates need to be in a particular order so that the circuit does what you want

-A quantum circuit takes quantum bits (qubits) as inputs and measure them at output
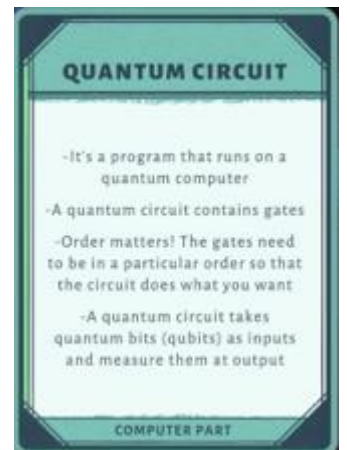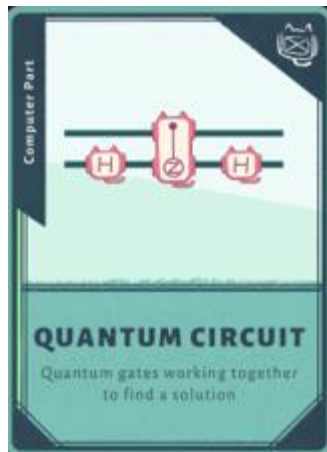
COMPUTER PART

Rewards Cards (Levels 16-24)

Card: Tangle

Type: Character

Level Earned: 17

TANGLE

What's it called when you stack two cats on top of each other? Supurrposition

TANGLE

Name: Tangle

Role: A wonderful quantum computing mastermind

Hobbies: Being simultaneously inside and outside of boxes, beating Byte in a game of QueueBits, receiving the correct number of belly rubs

Favorite Toys: Laser (coolers), Schroedinger boxes

Birthday: March 17th

CHARACTER

Card: 2 Entangled Qubits

Type: Computer Part

Level Earned: 22

2 ENTANGLED QUBITS

Fragile: Handle with care!

2 ENTANGLED QUBITS

-Entangled qubits are delicate

-Tangle's quantum computer works more efficiently with these entangled qubits

-Two entangled qubits can be far apart or close together

- Measuring one entangled qubit can affect the other no matter how far apart they are

COMPUTER PART

Level Summary (1-18)

Note: Levels are procedurally generated and substitutions can happen in any order. Numbers below may not match for all participants.

Level	# starting gates	# simplifications needed	# ending gates
0	2	1	0
1	3	1	1
2	4	1	2
3	4	1	2
4	7	2	3
5	11	3	5
6	12	2	8
7	10	3	4
8	14	3	8
9	13	6	1
10	25	8	9
11	27	9	9
12	24	7	10
13	27	8	11
14	21	4	13
15	22	4	14
16	27	6	15
17	22	5	12

*Only levels 1-12 available for Quantime participants
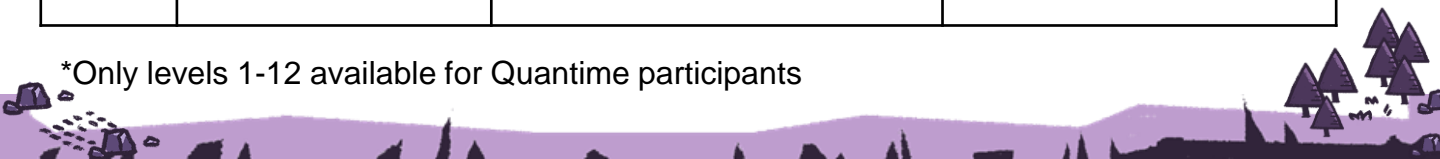
Level Summary (1-18)

Level	# starting gates	# simplifications needed	# ending gates
18	26	7	12
19	29	8	13
20	31	7	17
21	25	5	15
22	33	8	15
23	31	7	17
24	36	9	18

*Only levels 1-12 available for Quantime participants