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 won’t 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.
Quander Games: Quantime Edition

Additional Information

Disclaimer: The Quantime Quander Games are a limited access version of Quander.

The Quander games are based upon work supported by the National Science Foundation under Grant No. 2115780 and 2115843 at the University of Chicago, University of Illinois Urbana-Champaign, and University of California Santa Barbara. Access to the full games requires parental or legal guardian consent for people under the age of 18. To access the full games with parental or guardian consent visit http://quander-consent.s3website.us-east-2.amazonaws.com/.

Downloading the games can take up to 10 minutes.

Downloading Quander for Quantime can take up to 10 minutes. The download provides access to four limited access Quander games; TwinTanglement, QueueBits, Tangle’s Lair, and Qupcakery. We recommend facilitators use the time the game is downloading to begin the Engage section (see page 3) of the facilitation guide. Facilitators can return to Molly’s Challenge (page 3) and the Guiding Question (page 3) after completing the Engage section of the guide.

How do I mute the games?

There is no in-game option to mute the games. To mute the games turn off the sound on the individual devices you are using.
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 in 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 ~20 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; See Page 6) What simplification patterns did you create?  
      (Answer: See pages 8-9)

2. Give the students ~10 minutes to replay levels 12-16. 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 7) 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.
# Quantum Information Science Connections

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

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.
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.
Rewards Cards (Levels 1-6)

Card: Quantum Circuit
Type: Computer Part
Level Earned: 1

- 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 measures them at output.

Card: 2 Entangled Qubits
Type: Computer Part
Level Earned: 4

- 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.

Card: Tangle
Type: Character
Level Earned: 6

- 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
Rewards Cards (Levels 7-16)

Card: Zombie Boss Brad
Type: Character
Level Earned: 9

Card: H Gate
Type: Visual Representation
Level Earned: 12

Card: CNOT Gate
Type: Visual Representation
Level Earned: 15
## Level Summary (1-16)

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

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<th># simplifications needed</th>
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