Quander Games: TwinTanglement

Help entangled twins Fran and Ken navigate complex mazes!

1 Player

Ages 10+

45-60 minutes

Learning Goals

Understand that entangled particles have a connection to each other.

Understand that entangled particles share a relationship even over long distances.

Quantum Computing Connection

Entangled particles share a relationship. When we measure the properties of entangled particles, the results of those measurements are correlated. Quantum computers rely on entangled particles to work, even if the particles are far apart

Game Overview

In TwinTanglement, the player controls twin monster security workers protecting a blood bank. The twins are in two separate, slightly different mazes that the player can see simultaneously. An individual twin cannot complete their respective maze without help from their sibling. Walls block the movement between the start and endpoints. In the gameplay, both twins attempt to reach the ladder in a corner of their maze.

When one twin moves, the other also moves, which symbolizes the connection shared by entangled qubits. For example, when Fran moves up and to the left, Twin 2 (Ken) will also move (and will move through a wall to do so). So, if Fran needs to move but is blocked by a wall and Ken has a clear path, the player can switch to controlling Ken and use Ken to move both twins up. In later levels, the twins' motion is still connected but incorporates rotation (i.e., when Fran moves up, Ken moves left).

The twins in this game represent qubits that are entangled. The movement of one twin is always correlated with, or entangled with, the other twin's movement. The game also aims to demonstrate that the entangled relationship holds even over large distances between qubits.
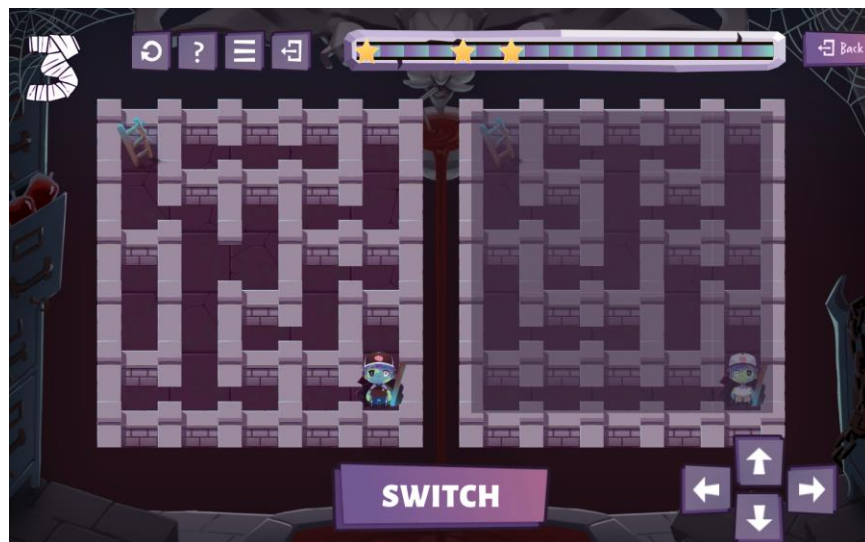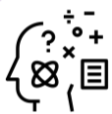
Background Knowledge for Facilitators

Entanglement: Particles, like photons, can share a uniquely quantum relationship called entanglement. Entanglement can occur naturally or can be created in a lab. Measuring one particle in an entangled pair affects the measurement result of the other particle. Quantum computers rely on using entangled particles to perform calculations.

Molly's Challenge:
What do the Franken Twins have to do to reach the highest security level of the Blood Bank and retrieve Tangle's computer parts for Molly?

Guiding Question:
How do entanglement and correlation affect the outcome of the Franken Twins' movement in the game?

Engage

1. Begin by telling your students that they will be playing a game that introduces concepts critical to quantum computing, like **correlation, qubits,** and **entanglement**.

2. Start by asking students questions about the following concepts:
    a. Has anyone heard of the term qubit?
    b. What comes to your mind when you hear the word qubit?
    c. What do you think entanglement means?
    d. What are some things you have heard about entanglement?

Explore

1. Give the students ~10 minutes to play Levels 1-5 of TwinTanglement.
    a. Once the timer is up, give students 5 minutes to discuss the following questions:

👓 Explore cont.

    i.   Did you complete the levels with all three stars? If not, did you try again? Did you try anything different?

        (Student answers may vary)

    ii.   Did you think the levels were difficult?

        (Student answers may vary)

    iii.   What did you notice about the patterns of the twins' movement?

        (Answer: When you move one twin any direction, the other twin will move in the same direction; See page 7)

    iv. **(Referencing the Terms; See page 5)** What do you think one twin represents?

        (Answer: One qubit)

    v. **(Referencing the Terms)** Where do you think entanglement is represented in the game?

        (Answer: The twins are entangled. The motion of one twin affects the motion of the other twin.)

2. Next, give the students ~10 minutes to play Levels 6-10.

    a. Once the timer is up, give students 5 minutes to discuss the following questions:

        i. Did you complete the levels with all three stars? If not, did you try again? Did you try anything different?

            (Student answers may vary)

        ii. Were these levels more challenging than previous levels? How so?

            (Student answers may vary)

        iii. What did you notice about the patterns of the twins' movement?

            (Answer: When you move one twin in any direction, the other twin will move in the opposite direction; See page 7)

        iv. **(Referencing the Terms)** What do you think the pair of twins represents?

            (Answer: A pair of entangled qubits)

👓 Explore cont.

3. Next, give the students ~10 minutes to play Levels 11-15.

    a. Once the timer is up, give students 5 minutes to discuss the following questions:

        i. Did you complete the levels with all three stars? If not, did you try again? Did you try anything different?

          (Student answers may vary)

        ii. Were these levels more challenging than previous levels? How so?

          (Student answers may vary)

        iii. What did you notice about the patterns of the twins' movement?

          (Answer; When you move one twin in any direction, the other twin will move perpendicularly. For example, when one twin moves up the other moves to the left; See page 7)

💡 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 do entanglement and correlation affect the outcome of the Franken Twins' movement in the game?

    b. Word Bank for students to use in their responses: Qubits, Entanglement, Fran, Ken, Twins, Maze, Communication, Direct, Opposite, Perpendicular.

Quantum Information Science Connections

| Concept	Definition	In-Game Representation
Entanglement	Entangled particles share a relationship. Measuring one particle's properties affects the outcome of measurements of the other.	The twins represent two entangled qubits. Moving one twin affects the motion of the other twin.
Quantum Communication	Quantum communication uses entanglement or a transmission channel, such as optical fiber, to transfer quantum information between different locations.	The twins model that entanglement exists between physically distant qubits. However, quantum communication also requires classical communication to complete.
Quantum Bit	The quantum bit, or qubit, is the fundamental unit of quantum information and is encoded in a physical system, such as polarization states of light, energy states of an atom, or spin states of an electron.	One twin represents one qubit. Together they represent two entangled qubits.
Correlation	When two things are correlated then they appear to share a connection. When you measure particles that are entangled, then you measure correlations between their properties	The twins' motion in the mazes is correlated. When one twin moves the other twin moves accordingly.

How To Play

Level select

The bar decreases each time you move. Take as few steps as possible to earn the most stars.

Restart level

Hint

Click here to switch between controlling Fran and Ken.

SWITCH
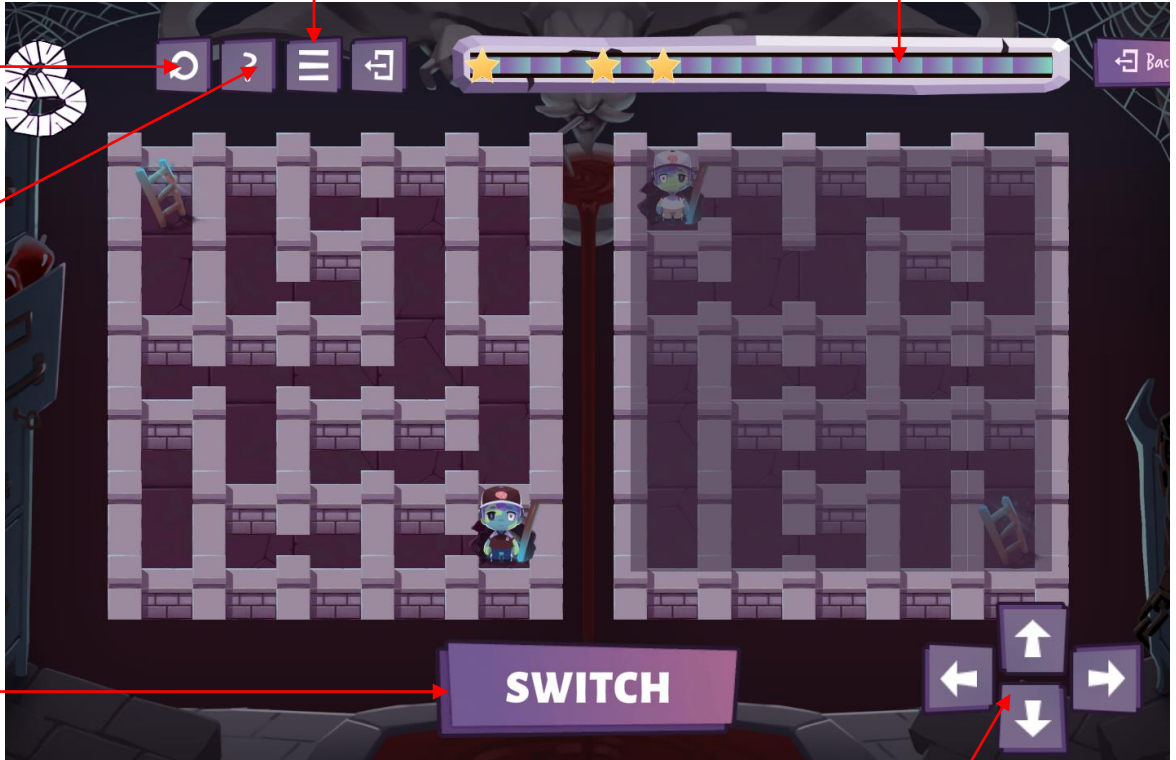
Use the arrows to control the twins' motion

Characters & World

Molly: The main character of the Quander games.

Tangle: Molly's best friend and cat. Caused an explosion while building a quantum computer.

Fran & Ken: Entangled Franken Twins who guard the local blood bank. In TwinTanglement the player controls the twins' motion.
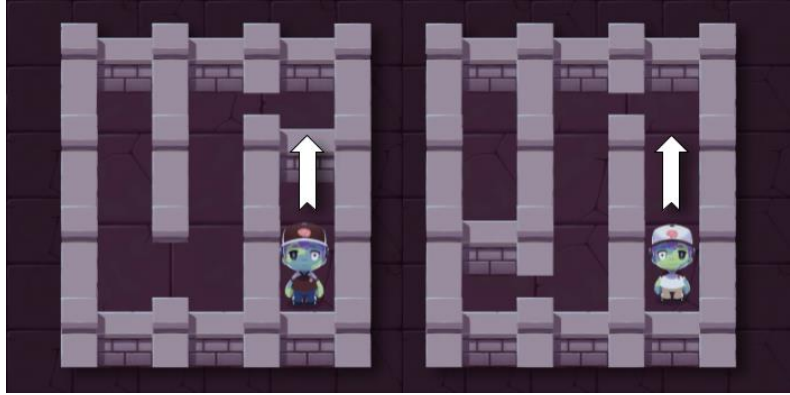
TwinTanglement game circled in red
Reward Area circled in white

TwinTanglement Reference Sheet

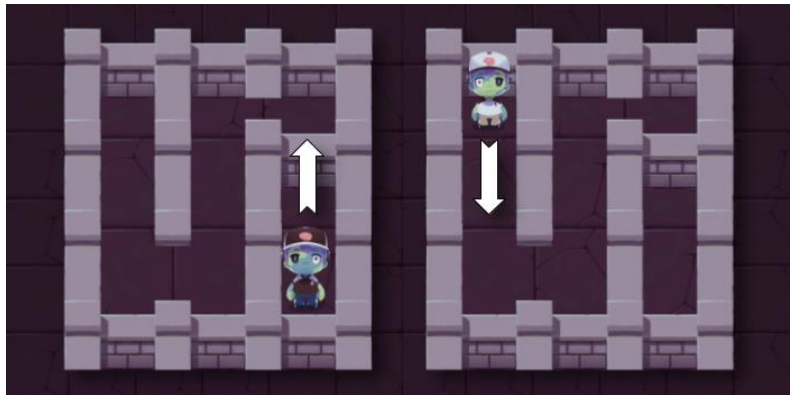## Same-Direction Motion (Levels 1-5)

When one twin moves in any direction, the other twin moves in the exact same direction.

Opposite-Direction Motion (Levels 6-10)

When one twin moves in any direction, the other twin moves in the opposite direction (See page 11).

Perpendicular-Direction Motion (Levels 11-15)

When one twin moves in any direction, the other twin moves perpendicularly (See page 11).
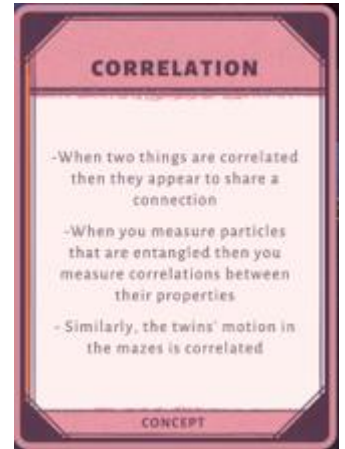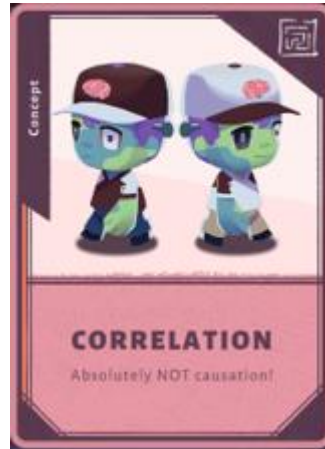
Rewards Cards (Levels 1-5)

Card: Correlation

Type: Concept

Level Earned: 3

CORRELATION

CORRELATION

Absolutely NOT causation!

- When two things are correlated then they appear to share a connection
- When you measure particles that are entangled then you measure correlations between their properties
- Similarly, the twins' motion in the mazes is correlated

CONCEPT

Card: Fran

Type: Character

Level Earned: 4

FRAN

Despite whatever physical distances, Ken and I are never truly apart.

FRAN

Name: Fran

Role: Cautious security guard of the regional blood bank, Ken's responsible older twin sister

Hobbies: Synchronized swimming and tandem bicycling

Favorite games: Seesaw, hide-and-seek

Birthday: Jan 1, 1818

CHARACTER

Card: Photons

Type: Computer Part

Level Earned: 5

PHOTONS

A photon is a bit of light energy

PHOTONS

- Waves, not particles? But, not not particles? Not just waves though? Yes that's all correct
- Light is made of photons
- Quantum computers can use a single photon as a qubit
- Photons can carry information between quantum processors

COMPUTER PART
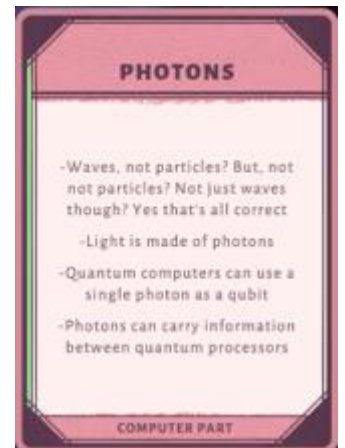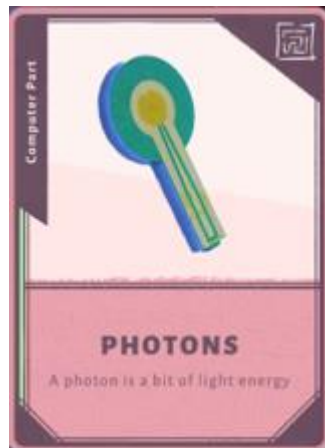
Rewards Cards (Levels 6-10)

Card: Entanglement

Type: Concept

Level Earned: 8

ENTANGLEMENT
Entanglement is a power boost for quantum computers

ENTANGLEMENT

-Entangled particles share a relationship. Measuring one particle's properties affects the outcome of measurements of the other

-Occurs naturally or in a lab, and particles can be far apart

-You need entanglement for getting the most out of quantum computers

CONCEPT
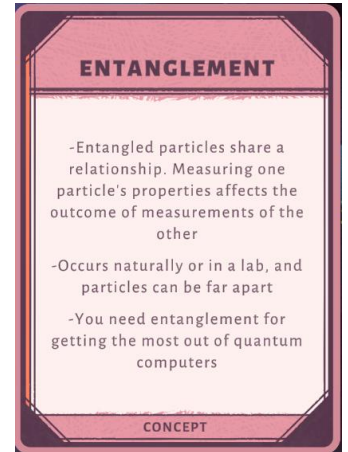
Card: Maze

Type: Visual Representation

Level Earned: 9

MAZE
Quantum computers are aMAZEing

MAZE

-The twins represent two entangled qubits

-The mazes are an analogy for two possible locations for qubits in a quantum computer

-Entangled qubits affect one another, even if they are at different locations

-Entanglement is part of what makes quantum computers useful
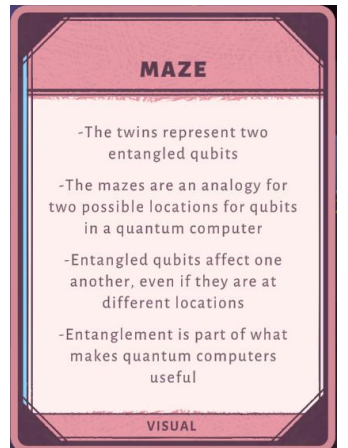
VISUAL

Card: Ladder

Type: Visual Representation

Level Earned: 10

LADDER
Tunnels, ladders, and mazes... Oh my!

LADDER

-Solving the mazes requires team work!

-The twin with an opening can help their sibling tunnel through

-Navigate from one ladder to the next to level up

VISUAL

Rewards Cards (Levels 11-15)

Card: Ken

Type: Character

Level Earned: 14

KEN

Our connection is so strong that we walk and turn in step.

KEN

Name: Ken

Role: Adventurous security guard of the regional blood bank, Fran's mischievous younger twin brother

Hobbies: Unsynchronized swimming and tandem bicycling

Favorite games: Sawsee, seek-and-hide

Birthday: Jan 1, 1818

CHARACTER

Card: Dilution Refrigerator

Type: Computer Part

Level Earned: 15

DILUTION REFRIGERATOR

Keeps things really cold! Like 0.01 K above absolute zero!

DILUTION REFRIGERATOR

-Used to cool superconducting qubits down to super low temperatures

-Necessary in order for some types of quantum computers to operate

-Made from gold and copper and filled with liquid helium

-Kind of looks like a chandalier

COMPUTER PART

Level Summary

Levels	Left Twin (Fran) Moves	Right Twin (Ken) Moves
1-5	Up –Down-Left-Right	Up-Down-Left-Right
6-10	Up –Down-Left-Right	Down-Up-Right-Left
11-15	Up –Down-Left-Right	Left-Right-Down-Up