Using Escape Room Puzzles to Motivate Students in a General Education Mathematics Course

Celes Woodruff

James Madison University

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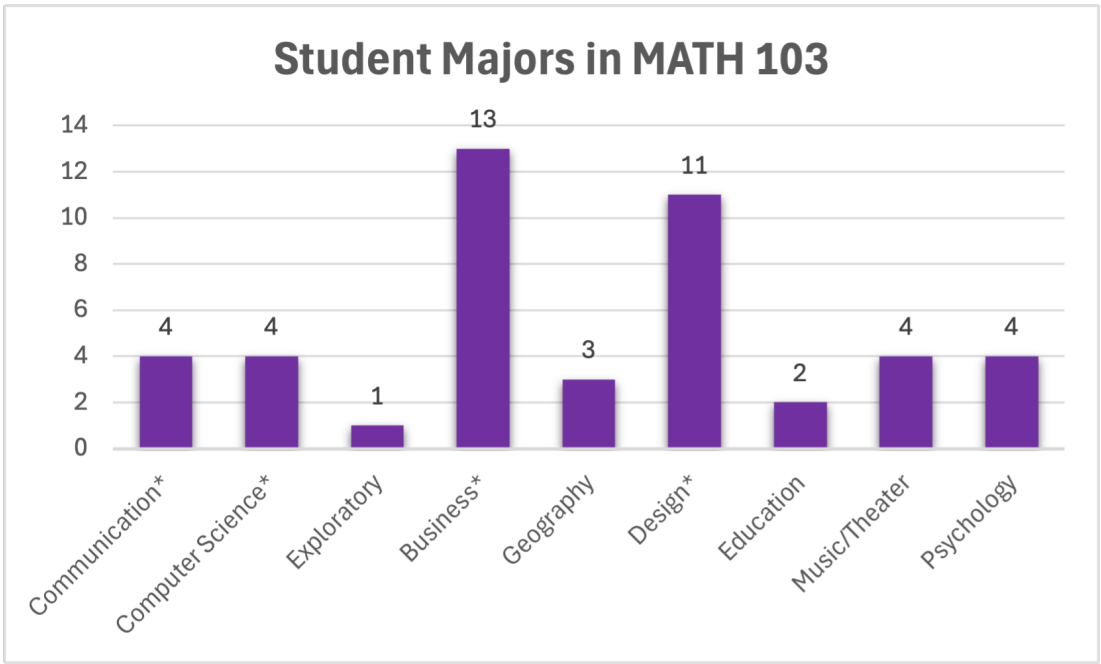
MATH 103: The Nature of Mathematics

Course Description: Topics such as geometry, computing, algebra, number theory, history of mathematics, logic, probability, statistics, modeling and problem solving intended to give students insight into what mathematics is, what it attempts to accomplish and how mathematicians think. May be used for general education credit.

3 credits

MATH 103 Audience

- Open to all students with no prerequisites
- One section with 46 students
- Pretty equally mixed across grade level
- 18 different majors



My Course Goals

My goals for this course were for my students to

1. To develop an appreciation of the usefulness of mathematics.
2. To view mathematics as a problem-solving tool.
3. To understand how math is useful in creating escape room puzzles.
4. To have fun!

What is an Escape Room?

According to Wikipedia, an escape room is "a game in which a team of players discover clues, solve puzzles, and accomplish tasks in one or more rooms in order to accomplish a specific goal in a limited amount of time."

Example Themes

- Escape from prison
- Escape the mad scientist's lab
- Diffuse a bomb
- Fix the broken oxygen scrubber before running out of air on Mars

What is an Escape Room?

Some specifics:

- You could work with your own team or a roomful of strangers.
- Teams are usually 4 to 10 players.
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- Time limits are usually 45 to 90 minutes.
- There are often employees who will give you hints if you need them.
- You're not really trapped!

Typical Gameplay Elements

There is such a wide range of escape room experiences that I can't make an exhaustive list of gameplay elements, but here are some that generally show up.

- A fun backstory, sometimes with a video
- Discovery of numeric and/or alphabetical codes
- Locks
- 2 or 3 items in the room that need to be used together
- Strange (or not so strange) symbols
- Moving objects in a certain way
- Interpreting maps
- Riddles

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- The puzzles are designed to require minimal prior knowledge
- It's a FUN application of math
- It's a great opportunity for students to be creative

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- Cons
  - Not enough detailed overage of each topic for my purposes
  - I still needed to code a lot of my own online homework problems

Topics

Cryptography (classical)

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- Substitution ciphers - Caesar, Atbash, Pidgeon, random key, keyword
- Transposition ciphers - columnar, keyword columnar, Rail Fence
- Affine

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Graph Theory

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Graph Theory

- Euler graphs
- Hamiltonian graphs
- Shortest path algorithms
- Spanning trees

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- Interactive polling using Poll Everywhere
- Group work - single problems with neighbor and worksheets in larger groups

Assessments

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- Participation (Attendance, Poll questions, Piazza) (5%)
- Biweekly online homework (15%)
- Biweekly quizzes (20%)
- Weekly reflections (25%)
- Projects (15%)
- Final presentation (20%)

Piazza

Updated 9 months ago by [redacted]

How do I know when i've reached my final vertex/vertice? Do I go through all 5 of them until I find the path with the lowest cost?

hw7

Edit 0 11 views

Students' Answer

Updated 8 months ago by [redacted]

I think it depends on the type of algorithm you're trying to solve. For RNNA you start with each vertex as the starting point choosing the lowest unvisited node for each route staring and ending a the same vertex, looking for the lowest cost hamiltonian cycle. (this being a yes to your question) But I think if it is a shorted edge algorithm you do the process once

Edit 0

Instructors' Answer

Updated 8 months ago by Celes Woodruff

Repeated nearest neighbor is used to create a Hamiltonian cycle, so you're done once you've formed that. Highlighting the edges as you go is helpful, so I highly recommend making a sketch that you mark up as you go.

Edit 0

0 Followup Discussions

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- Applications like making Zoom calls

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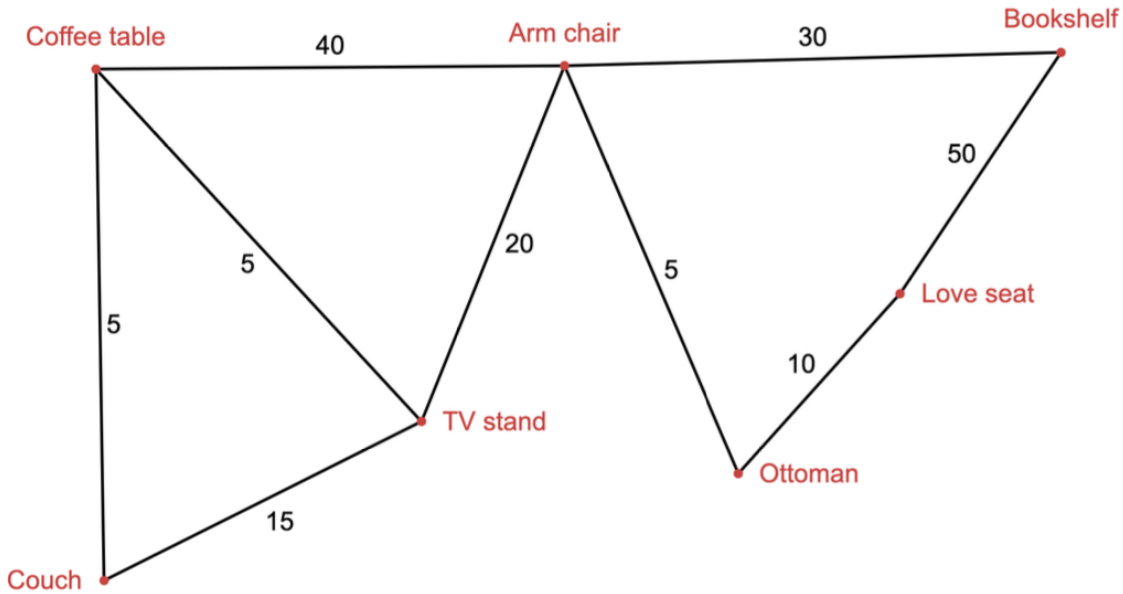
The kids next door created an awesome layout for the Floor is Lava and they need your help to find the ideal path to take to escape the room.

(a) **[25 pts]** Perform **Dijkstra's Algorithm** on the graph to find the **shortest path** from the **Love seat** to the **Coffee table**. (Make sure to include all of the markings and numbers that we have used in class.)



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1. **Reflection 1** - Tell me about your previous math experiences and what you think about the escape room theme for our class.

2. **Reflection 2** - Describe an escape room experience that you've had. Was it virtual or in-person? What was the theme? How much time did you have to escape? Who did you play with?

Example Cryptography Reflection

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1. Which of the substitution ciphers would you use and why?
2. Does your intended audience play a role in which one you chose? Explain.
3. Beyond the math, also talk about how it would fit into the room. Talking points can include placement of the material in the room, how the player would tie the encrypted message with the key, hints at decryption etc.

Example Cryptography Reflection

Sample student response:

I would use Pidgeon cipher because it wouldn't be too hard for escape rooms participants to crack. I think that for this one the audience could be taken back to the time of the cavemen, and the room is set as a cave. All along the walls are different symbols but at one part of the wall is a sequence of symbols with a lock right under it. And after solving for a previous step, the play receives a map of what letter align with the symbols, allowing the participants to unlock the lock.

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Explain how you could use a Hamiltonian cycle task in an escape room.

1. Which way would you have the players try to find the Hamiltonian cycle? (Brute force, NNA, RNNA, or Sorted Edge)
2. Does your intended audience play a role in which one you chose? Explain.
3. Beyond the math, also talk about how it would fit into the room. Talking points can include placement of the material in the room, graphical vs text representation of the puzzle, hints at solving it etc.

Example Graph Theory Reflection

Sample student response (edited for brevity):

1. I would probably go with Sorted Edge
2. Yes. Brute force is a longer and more tedious process which wouldn't be super fun in a timed environment. For NNA or RNNA this type of puzzle could be confusing to players, since the results can vary. Sorted Edge puzzles can be more visually and logically easier to understand.
3. This could be part of a "delivery route" plot. Where players need to help a courier find the most efficient path to deliver items to all outposts once, then return to base. For hints/clues a journal from a previous traveler could say, "Always start with the shortest path," or "Never loop before you've seen every town." Along with clues around the room highlighting distances/road tolls for each connection.

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Unlike the reflections, they were required to create an idea for an escape room that would involve 3 or 4 puzzles from that topic.

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- Create a backstory to go along with the room
- Give the objective for that room

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I gave them a list of requirements for each puzzle to help them make sure they were thinking about all of the game aspects.

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- Placement in the room and puzzle medium
- Hints that could be given by the game guide

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This forced the students to really examine what made the problems difficult and find creative ways to get around that.

Final Presentation

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It was phrased as a salespitch.

Final Presentation

You work for an escape room company, however, your company does not create physical rooms or even virtual rooms. Instead, your company creates escape room scenarios and sells them to other companies who will create the physical versions.

Dr. Woodruff is the owner of a local escape room. She is looking for new escape room ideas with unique and creative themes and puzzles. Having a background in mathematics, it is important to her that the puzzles are mathematically sound so that her patrons can get a taste for how mathematics can be fun.

Your mission is to pitch your escape room concept to Dr. Woodruff. All the other sales teams will also be present and are hoping to wow her to get the deal for themselves.

JMU JAMES MADISON UNIVERSITY

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All of the same puzzle description requirements from the first two projects were the same, with the exception that the solution could be shortcutted a bit.

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- Visuals must look professional (i.e. no hand-drawn graphs)
- Bring one tangible object to the presentation to represent something found in the room
- Audience participation in the form of poll questions
  - Theme of the room
  - Names of puzzles in the room

Company Names

- B.E.N.S Escape Rooms
- Breakout Tech
- Brewmasters Escape
- Can't Get Out Escape Rooms
- Code Crackers Escape Rooms
- Crypto Escapes
- Escape the Past
- Escape the Universe
- Escape University
- Escapology
- Meddling Kids
- RAJ Escape Experiences
- The Elite Escapists

Escape Room Themes

Most of the chosen themes were classical escape rooms themes and some were from shows they had seen.

- Cursed castle
- Dragons
- Heist
- Lab Rats
- Pirates
- Prison escape
- Scooby Doo
- Tomb raid
- Treasure hunt
- Virtual reality
- Where's Waldo
- Zoo

Escape Tangibles

The tangible objects were varied. Some were used in the room and some were just related to the theme.

- Beer stein
- Stuffed llama
- Tablet for entering the key
- Paper with an encryption code
- Map

Example Presentations

There were a wide range of presentations with a wide range of following directions. Here are some example slides from 2 groups in particular.

EDDIE'S Escape

B.E.N.S Escape Rooms

SCENARIO

Eddie has been wrongfully imprisoned for a crime he did not commit. He needs to escape the prison and leave the country soon after to ensure he does not get captured again. He has heard through the grapevine that a past inmate hid a key in the room, and he's been planning his escape. Will you help him with his jailbreak?

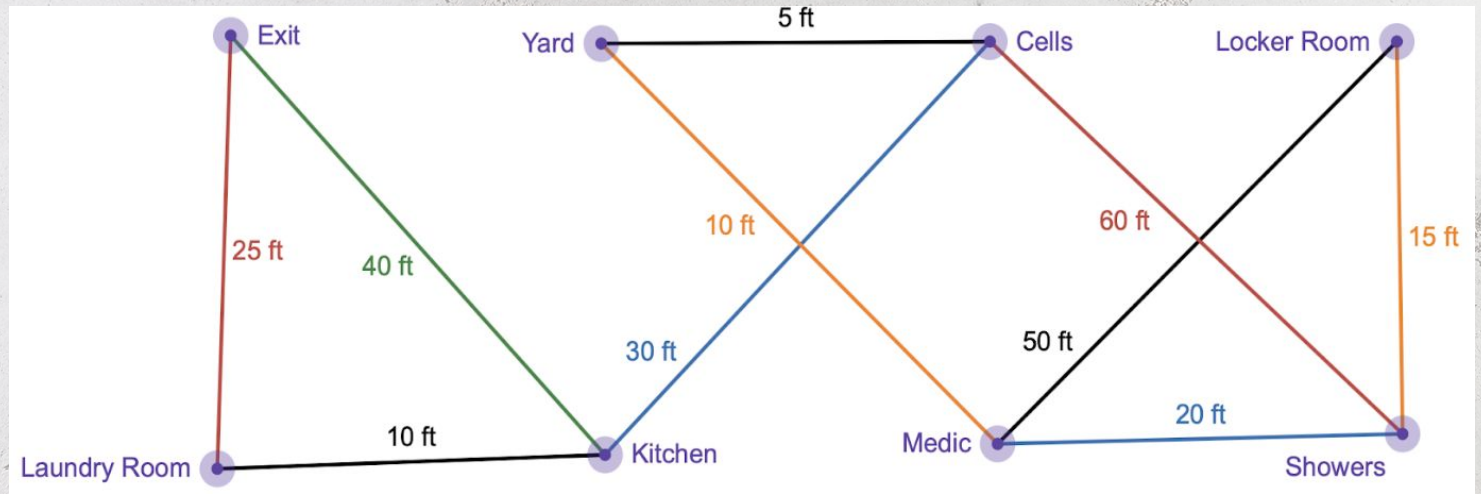
Great! He is out of the cell, now what?

He has to move quickly to avoid being caught. Eddie bribed a guard a couple years back for blueprints of the prison with the distance of each hallway to each room displayed. He knows that wandering around the prison will just make it more likely that he gets caught, he must leave here the quickest way possible. *Can you help him find the quickest possible path to the exit and get out of jail?*

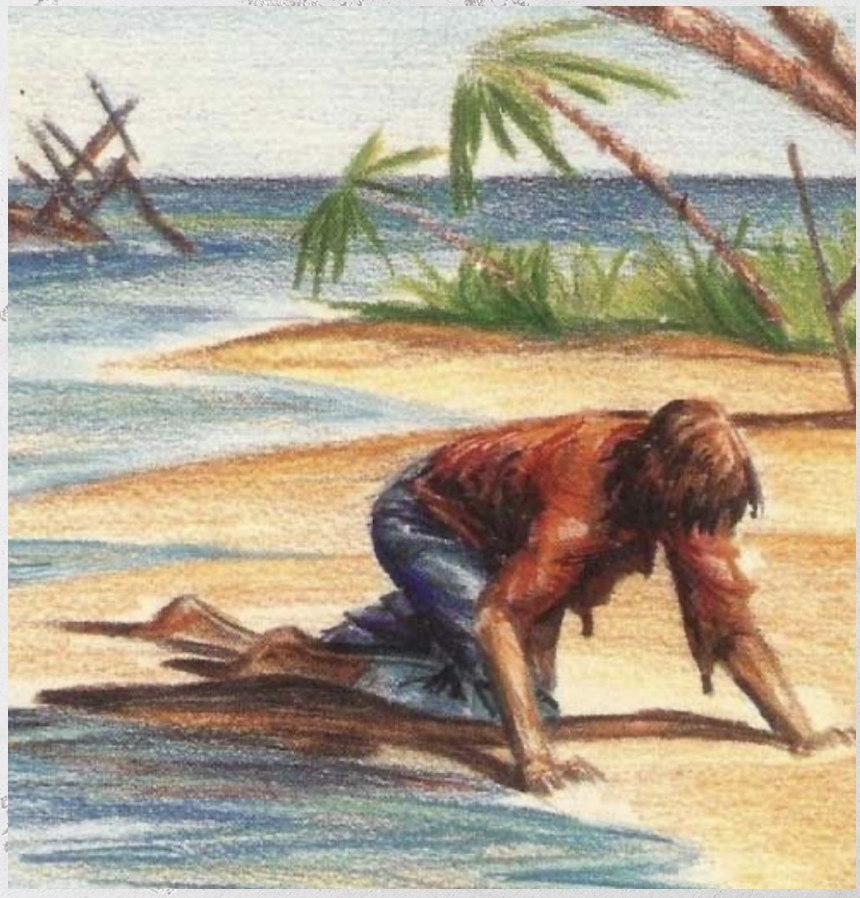
Puzzle 2-Light at the End of the Tunnel

Graph Type: Shortest path

Eddie must find the quickest route from the Locker rooms to the Exit. With this problem it is best to start at the end point and work your way back to find the quickest route. We also recommend following a 6 step plan to complete the puzzle, that we luckily hinted to our "Eddie".



Puzzle 3- Hidden in plain sight

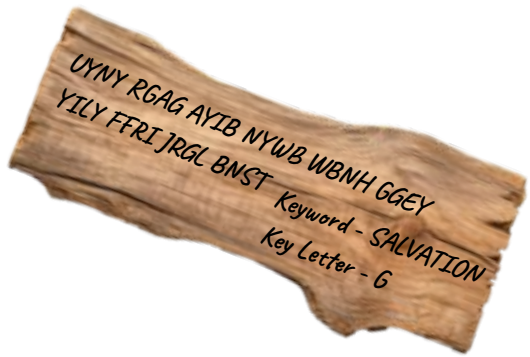


Cipher Type: Keyword Cipher-Substitution Cipher

After washing up on shore he found a message carved into a large piece of driftwood on the beach, alongside it is the key letter and word carved into the log. The encoded message contains the location of the bunker on the island that contains life-saving materials and a radio to reach any nearby boats. Will you help Eddie solve it?

UYNY RGAG AYIB NYWB WBNH GGEY YILY FFRI JRGL BNST

- **Keyword - SALVATION**
- **Key Letter - G**



DEMO:

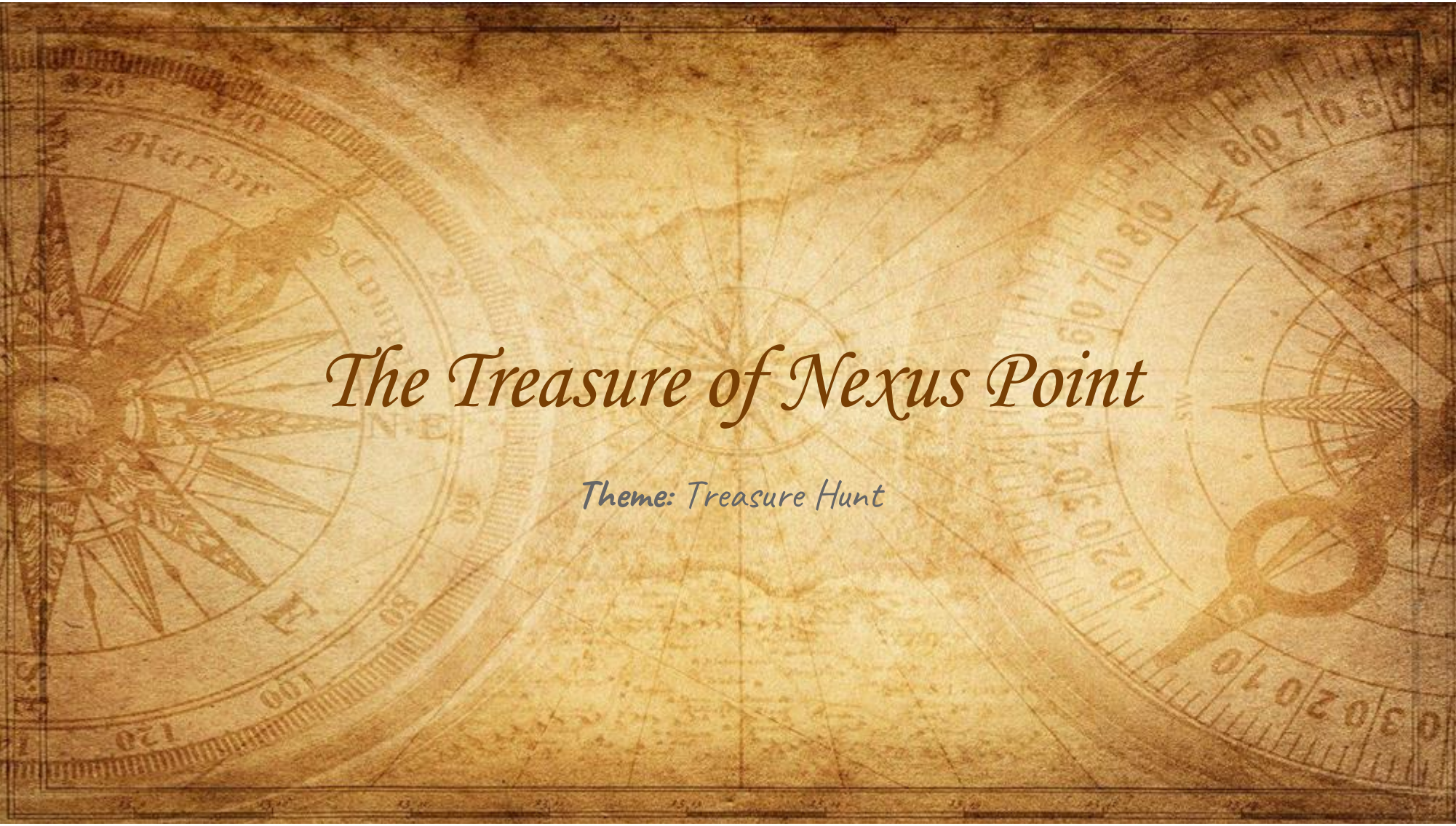
Keyword Cipher

Keyword: SALVATION
Key Letter: G

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
R U W X Y Z S A L V T I O N B C D E F G H J K M P O

Decoded Message:

BENEATH THE LONE COCONUT TREE LIES SALVATION


The Treasure of Nexus Point
Theme: Treasure Hunt

About the Escape Room

As a pirate, you spend your years travelling the seas and plundering them for all their worth. You always make sure there's never a gold coin left unturned.

That is why, when you hear of a mythical treasure hidden on a barely charted island, that to this day has been unclaimed, there's no question in your mind that you will be the first pirate to find the **Lost Treasure of Nexus Point**.

But there's a reason this treasure has never been found... Your journey will not be easy.

Puzzle 1 - Map

Players are given a nautical map with 5 islands on it, each containing 4 landmarks and a set of coordinates. They are also given a key detailing the icon associated with each landmark.

Puzzle 1 - Clues

In addition to the map, players are given the following clues:

A hint that the puzzle uses an Atbash cipher

IN THE END, THE BEGINNING.
IN THE BEGINNING, THE END.

ZYXWVUTSRQPONMLKJIHGFEDCBA

A story containing the main goal: locate the **lost treasure** on one of these islands

THOUGH THE ISLANDS OF NEXUS POINT HAVE MOSTLY BEEN PLUNDERED, THERE EXISTS A HIDDEN TREASURE THAT HAS YET TO BE CLAIMED.

IT WON'T BE EASY TO FIND, AND MANY PIRATES HAVE ALREADY TRIED AND FAILED. BUT IF YOU ARE CUNNING ENOUGH, YOU MAY LAY CLAIM TO THE **LOST TREASURE OF NEXUS POINT**.

Clues to help decide which island has the treasure

THE ISLAND YOU SEEK HAS:

- QFMTOVHSIRMV
- ML IVVU
- ZMXRVMGGVNKOV
- ML HPFOOILXP

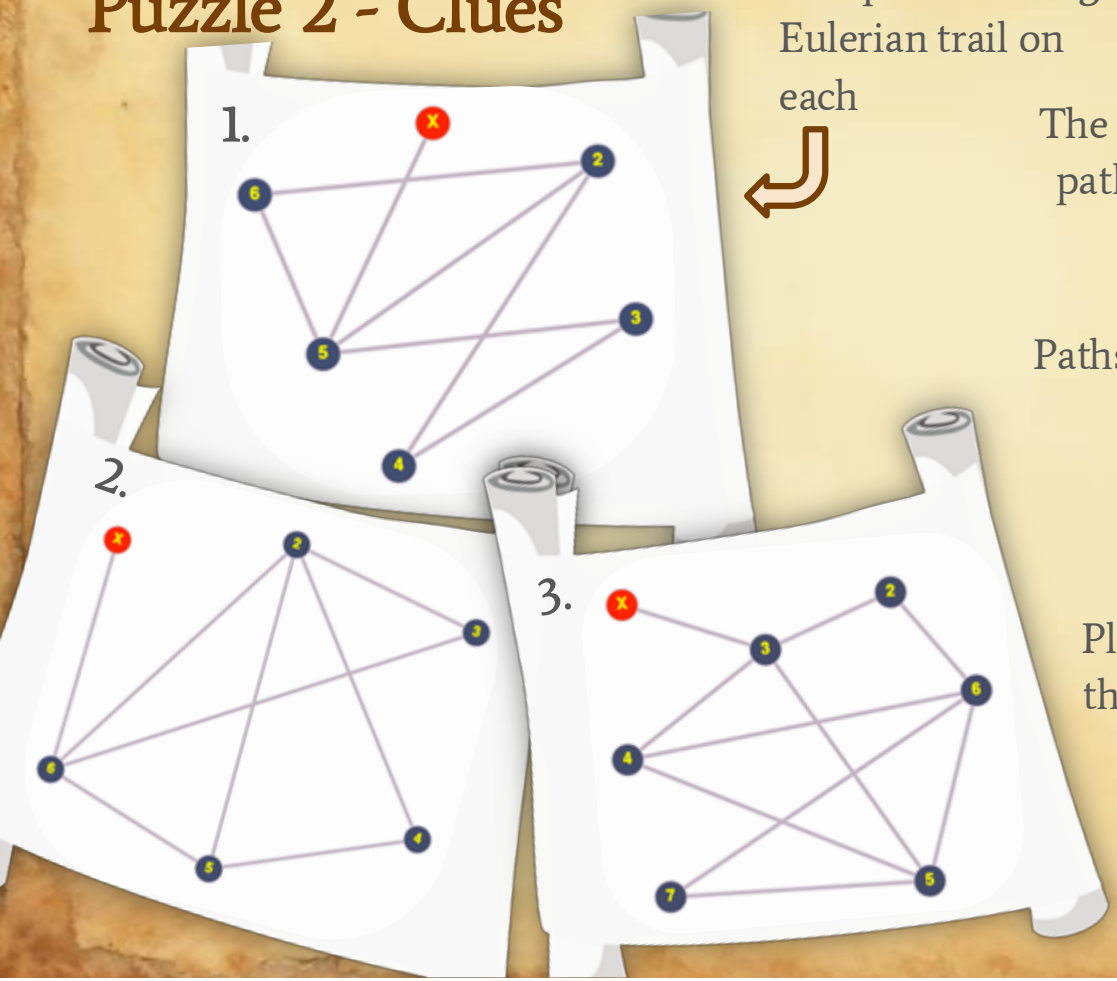
Puzzle 1 - Solving the Puzzle

Once deciphered, the clues are as follows:

Players will find that **Island 4** fits these requirements.

- Skull Rock
- Jungle Shrine
- Lost Lagoon
- Dead Man's Dock
- Whistling Cliffs
- Crimson Reef
- Ancient Temple
- Crown's Peak

Puzzle 2 - Clues



3 maps containing a Eulerian trail on each

The goal is to find a path to the red "X" node

Paths must use each edge once.

Players must find the starting point for each trail

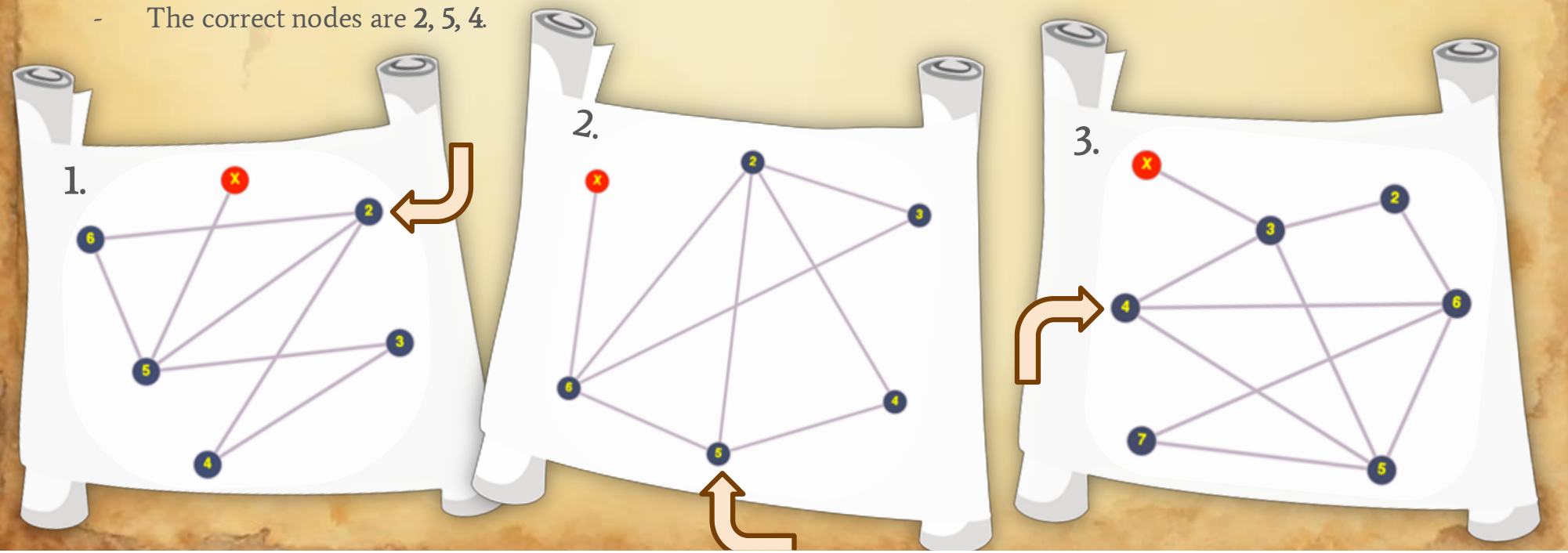
At the bottom of this temple lies bountiful treasure. The chamber of each floor marked with an X contains a staircase to the floor below. The chamber in which you start each floor will be unknown to you.

But this temple is afflicted by a powerful curse. To unlock each staircase, you must travel through **each and every passageway**, and end in the chamber marked with an X. However, **you may never travel through the same passageway twice**.

If you want to claim the treasure of this island, you must determine **where to start on each floor** to make it to this temple's depths.

Puzzle 2 - Final Solution

- Some players will know to look for the nodes with odd degrees. Those who don't may find this a fun challenge.
- When the correct node is chosen, any valid path will end on the node marked **X**.
- The correct nodes are **2, 5, 4**.



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- Explore other topics.
- Give students more in-class examples of breaking down difficult problems to a general public level

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- Write down the tangible objects!

Thank You!

JAMES MADISON UNIVERSITY