

OPINION

Breaking free: motivating mathematics through escape rooms

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Abstract

Escape rooms provide a unique and engaging way to promote mathematical thinking by embedding problems within a narrative-driven environment. This opinion piece highlights the effectiveness of escape rooms as a pedagogical tool, their ability to foster problem-solving skills, teamwork, and motivation among students. The study details the design principles used to create mathematical escape rooms, incorporating puzzles that require keen observation, logical reasoning and pattern recognition. Practical considerations, such as difficulty scaling and accessibility, are discussed, ensuring these activities cater to a diverse audience. By presenting mathematics in an immersive and interactive format, escape rooms encourage exploration and perseverance, ultimately improving students' confidence in tackling mathematical challenges.

Keywords: Escape rooms, Mathematical thinking, Problem-solving, Engagement.

1. Introduction

Being a mathematician, I have always enjoyed puzzles. I love unravelling a mystery and seeing a solution form before my eyes. Moreover, I enjoy playing board games with friends. While it is great to win, it is perhaps more interesting to observe the interactions between players and watch their strategies unfold. Through these two hobbies, I developed an interest in escape rooms.

For those unfamiliar, an escape room is an interactive game where a group of participants work together to solve puzzles, discover clues, and complete challenges to achieve a goal (such as escaping a room) within a set time limit. Critically, escape rooms are often themed, and no matter whether the scenario involves defusing a bomb, exploring ancient temples, or cracking alien codes, the joy of solving puzzles with friends against the clock is unparalleled.

This enthusiasm, coupled with my role as Head of Outreach in the School of Mathematics, inspired me to create a mathematical escape room. My goal was simple: to excite and motivate students about mathematics in a way that is both engaging and memorable. The goal of this article is equally straightforward: I want to convince you that creating a mathematical escape room is a beneficial addition to any outreach programme. It engages children and adults alike and leaves participants with a positive memory of mathematics.

Creating an escape room requires effort and money. By following my thoughts below and using all of my materials, hosted online for free at bit.ly/EscapeRoomMaterial, these challenges should be significantly reduced. Furthermore, an equipment list and solution structure are included in Appendices A and B, respectively.

2. Educational benefits

Of course, I am not the first person to use escape rooms for educational purposes. Their ability to combine narrative-driven challenges with teamwork and critical thinking has made them increasingly popular in classrooms. Studies have shown that these activities foster key skills such as collaboration, problem-solving, and resilience (Taraldsen, et al., 2022; Veldkamp, et al., 2020).

However, careful design is essential; aligning game mechanics with educational objectives is critical to achieving meaningful learning outcomes, rather than producing a set of trivialities.

When done well, the immersive nature of escape rooms keeps students focused. Unlike traditional classroom settings, where some students may feel disengaged, escape rooms encourage active participation. For example, in a classroom, if a technique is taught, students will grasp the concept at different speeds. Those who understand the work tend to push ahead, leaving others feeling that they can offer little to discussions that have not already been covered.

In an escape room, as long as it is focused on problem-solving and not dependent on prior knowledge, all participants are on the same footing. They do not know what tasks they are going to have to do, nor do they know what skills they will need. Moreover, their different lived experiences allow them to view problems in unique ways, which is crucial for team problem-solving. Thus, as clues appear, everyone is encouraged to contribute their thoughts because no one knows which answer will pan out best. This reduces learning anxiety and increases motivation (Fotaris & Mastoras, 2019).

However, implementing escape rooms in educational contexts presents challenges. Designing puzzles that strike the right balance between accessibility and complexity is a nuanced process. Additionally, ensuring that all participants can contribute, regardless of their prior knowledge, requires careful planning.

3. Design considerations

When developing the mathematical escape room, I carefully considered several factors to ensure its effectiveness and accessibility.

Firstly, the theme was inspired by Alan Turing. It made sense to set the game as though it were happening in Station X (Bletchley Park) during World War Two because, alongside the setting's intrinsic theme of spy craft, Turing's groundbreaking work on cracking the Enigma code is an incredible example of mathematics in action, showcasing its real-world impact and significance. Additionally, setting the escape room in an office made it completely transportable. As long as I have a desk and a chair, the "room" can be set up anywhere - from a theatre to a broom cupboard (see Figure 1).

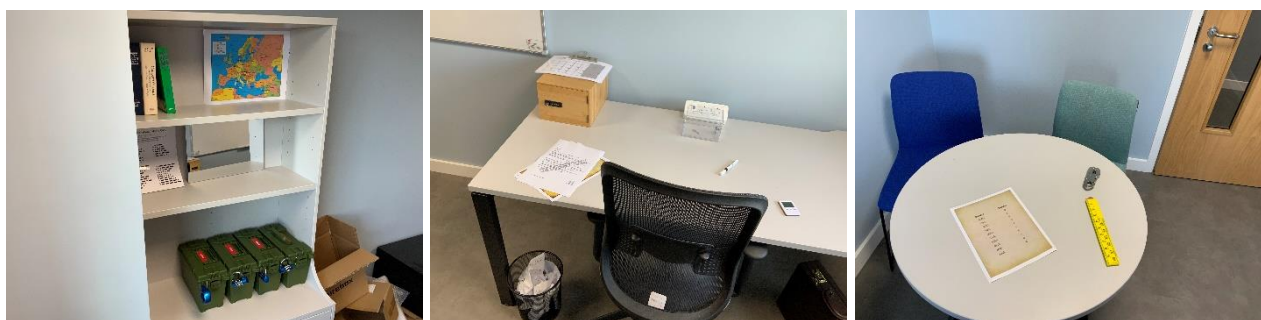


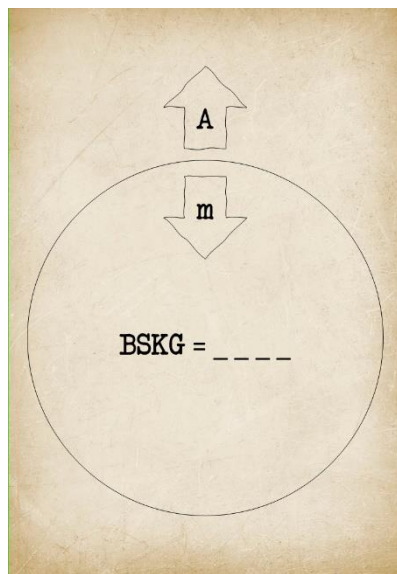
Figure 1. Basic setup of the escape room.

The activities, which include using Morse code and breaking ciphers, were designed to reflect a World War Two setting, enhancing the players' immersion in the game. Written materials were aged, and typewriter fonts were used to provide a sense of authenticity (see Figure 2). While these details

may seem minor, they contribute significantly to telling the story of the escape room and creating an engaging experience.

Accessibility was a top priority. To ensure inclusivity, apart from the initial “confidential letter”, which sets up the theme, I minimised text during the puzzles and relied heavily on iconography wherever possible (see Figure 2(a)). This approach reduced language barriers and made the puzzles more engaging and intuitive.

As mentioned, no prior mathematical knowledge was required, making the game accessible to participants with varying levels of expertise. For example, there are puzzles that depend on knowledge of Morse code and binary numbers (see Figure 2). To help the participants there are posters presented around the room that provide direct translations (e.g. from binary code to base 10 numbers, see Figure 1), thus, instead of testing their (potentially non-existent) knowledge of binary coding their powers of observations and pattern recognition are being tested.



(a)



(b)

Figure 2. Examples of aged props used in the escape room.

Transportability was another key consideration. The game was designed to be portable, with all equipment fitting into a large wheel-based case (See Figure 3). This flexibility allowed the escape room to be set up in diverse locations. Maintenance was streamlined by using modular components and off-the-shelf items, keeping costs manageable at around £400 per kit. The modular design also facilitated quick resetting between sessions, enabling multiple runs in a single day.

Technology is often a weak point in outreach scenarios. To keep technology requirements minimal, I opted for simple mechanical locks and physical props. This choice ensured reliability and reduced the risk of technical malfunctions. Moreover, the props could easily be fixed or replaced cheaply if needed.

Finally, safety was paramount; a Games Master is always present, and participants are never actually locked in. Moreover, the Games Master plays an important role in managing the engagement of the game's players. For example, they can encourage ideas from those who seem

disengaged and guide them to follow a separate path to solving puzzles. Equally, they can support a stymied team, by encouraging thoughts from the team, without explicitly providing a solution.

To provide a suitable climax and a “ticking-clock” element to the proceedings, I use a transparent post-box (see Figure 4). The start of the escape room is signified by the clock being started and the clock being posted into the post-box. The elapsed time can then be viewed throughout the challenge. The room ends once the last key is found, which opens the post-box, and the team stops the clock. These clear start and end points provide structure and an immutable “final score” of the team's performance.



Figure 3. The entire set of escape room props fits into one wheel-based case.

Unfortunately, capacity is a fundamental limitation of escape rooms. The room's capacity is limited to 1–8 participants per session, with each session lasting approximately an hour. While this limitation is partially mitigated by having four kits available, enabling up to 32 participants to play simultaneously, scaling up further would require additional resources such as multiple trained Games Masters and more funding to purchase more equipment.



Figure 4. The transparent post-box and timer, used to start and end the escape room.

Another potential solution for scaling up the reach of the escape room is to develop a digital version of the puzzles. Creating such an online platform would require additional funding to support app development and programming expertise. While a digital format would undoubtedly increase accessibility and reach, it risks losing key elements of the experience, such as the hands-on, tactile interaction and the collaborative, in-person teamwork that are central to the room's educational and engagement value.

4. Puzzle design principles

Designing the puzzles required careful thought to balance challenge and accessibility. Each puzzle was crafted to be engaging yet solvable, avoiding unnecessary complexity. To accommodate diverse skill sets, the puzzles varied in type, including logical deductions, spatial reasoning, and pattern recognition. Critically, no knowledge is assumed, thus, although there are questions that involve European geography and binary numbers, there are maps and posters that are hung around the room, which can be used to interpret the questions into solutions. This allows all students to be on the same footing initially, because all the answers are "visible", it simply comes down to who can put the building blocks together in a logical way.

When designing puzzles, my golden rule was, "do not try to be clever". The enjoyment of a puzzle lies in its solving. What feels like a logical leap for one person can be baffling for another. Equally, none of the clues are purposefully misleading or red herrings. The goal is not to fool participants or make them feel inadequate. Instead, every suggestion, even incorrect ones, should be encouraged by the Games Master, with the hopes of building the correct answer. Intentionally leading participants down the wrong logical path benefits no one.

One key principle was ensuring that each puzzle had a clear purpose and outcome. Keys and codes were used only once and had obvious applications, reducing the likelihood of confusion. Moreover, although several combination padlocks are used, they each require a different number of numbers, or letters, ensuring that each padlock clearly links to a given solution.

Most challenges were designed as single-step puzzles, following the structure "Problem → Solution → Problem". However, towards the end of the escape room, multiple-component problems were introduced, requiring input from several previous solutions. These multi-component problems were carefully scaffolded to ensure that participants knew which solutions corresponded to which questions. Moreover, these intermediate successes kept participants motivated, providing them with a sense of progress while building anticipation for the final payoff.

To ensure that no one person could monopolise solving the problems, the escape room was designed with two initial routes that could be used to progress the challenges. By splitting into subteams, no participant should be left without something to do, or a meaningful way to contribute.

5. Evaluation

The escape room has been tested with over a hundred adults, undergraduates, graduates, and secondary school children. Feedback from all groups has been overwhelmingly positive, highlighting its ability to engage and challenge participants across a wide range of ages and backgrounds.

Comments from Cathays High School students include:

- “It was really hard, but I think it showed us how to be smart and patient”,
- “I thought it was fun and quite tricky as well”,
- “It was very entertaining!”.

A teacher from Mary Immaculate High School also said, “the escape rooms activity was fantastic and my group thoroughly enjoyed [it]”.

Graduate students also reported strong engagement:

- “It was really collaborative, it felt like we were all involved the whole way through. The puzzles were fun to solve as well, it was an engaging way to deliver maths”,
- “The puzzles in the room were well thought out and encouraged our group to collaborate together well. Overall, it was a very enjoyable experience that had been put together with good care and attention to detail.”

Finally, the escape room was used as part of a Cardiff University Summer School focused on supporting students with autism spectrum conditions. Amongst all the activities that were done during the week, two participants said their favourite part of the Summer School was the escape room, with one specifying that they liked it because it “was a group effort”. This feedback demonstrates the room’s versatility and its capacity to create an inclusive environment regardless of learning needs.

A video showcasing the engagement that can be generated from running four rooms simultaneously can be viewed on Instagram at bit.ly/CardiffEscapeRoom.

Notably, these responses highlight more than just enjoyment; they point to the deeper educational impact of the escape room format. Teachers and students alike reported enhanced motivation, a willingness to persist through difficult problems, and a heightened sense of collaborative learning. Importantly, the structure of the escape room dissolves traditional hierarchies of expertise. Rather than privileging those with prior mathematical training, it invites all participants to contribute through observation, logic, and reasoning. In doing so, the activity reframes difficult mathematics as a collective challenge rather than an individual obstacle, promoting a more inclusive and resilient problem-solving mindset.

Initial observations led to minor adjustments after some early test sessions. The adjustments included replacing Bluetooth speakers with push-button sound effects and swapping fragile 3D-printed props for easily replaceable paper versions. These changes have improved both reliability and cost-effectiveness. Importantly, these refinements demonstrate that escape rooms are adaptable and can evolve with feedback.

6. Conclusion

Creating this escape room has been an immensely rewarding journey, blending my passion for puzzles with my commitment to inspiring future mathematicians. It has demonstrated that mathematics is not just a subject confined to the pages of a textbook but is alive, dynamic, and filled with creativity and teamwork. Through this project, I have observed participants from all backgrounds engage, collaborate, and discover the joy of problem-solving in ways they may never have experienced before.

If this has sparked your curiosity, I encourage you to consider creating your own escape room. It is a powerful way to connect with students, showcase the creative side of mathematics, and inspire a lifelong love for learning. If you would like tips, ideas, or more information, I would love to help. Feel free to contact me at woolleyt1@cardiff.ac.uk. All the resources, including puzzle designs, setup guides, and templates, are freely available online at bit.ly/EscapeRoomMaterial.

Together, let us work to inspire the next generation of problem-solvers and mathematicians.

7. References

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Appendix A: Equipment list

Below is a list of equipment required to run the escape room. Wherever the object can be made, or printed you will find templates in the online files, bit.ly/EscapeRoomMaterial. Moreover, many objects that I have suggested should be bought can usually be found for free, e.g. wastepaper bin. Finally, it is suggested that white board markers be provided and any paper materials are laminated to preserve them, since they often get written on.

Item	Make (M) or Buy (B)	Comment
3 Enigma wheels	M	Initially, 3D printed but can be made from paper.
3-digit book safe	B	
4-digit lock	B	
5-digit lock	B	
5-letter lock	B	
Item	Make or Buy	Comment

3 pages of acetate	B	
Binary code poster	M	
Briefcase	B	
Caesar wheel	B	Initially, 3D printed but can be made from paper.
Cryptex	B	
Directional lock	B	
Doodles	M	These are added to fill the bin, so it is not obviously an empty prop.
Key safe	B	
Lock and key box	B	
Map of Europe	M	
Mirror	B	
Morse code poster	M	
Opening letter	M	
Other general books	B	These are to place around the book safe, for obfuscation.
Pig pen cipher grid	M	Initially, 3D printed but can be made from paper.
Ribbon	B	For wrapping around the wooden rod.
Sound button	B	Plays Morse code when pressed. The Morse code sound file is given in the online resources.
Thin timer	B	
Transparent post box	B	
Wastepaper bin	B	
Wipeable calendar	M	
Wooden rod	B	

Appendix B: Solution structure

If you are interested in planning your own escape room I found it most useful to plan the “shape”, or structure of the room first on paper. Namely, the challenges (coded blue) and solutions (coded black) are mapped by arrows to highlight how each puzzle relies on the rest.

