Engineering escape game for Science Gateway

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Abstract

As a part of the Summer Student Programme, I was tasked to make an engineering escape game for the new Science Gateway. This was meant to highlight the engineering work done here at CERN and give groups of four 15-year-old participants a look into how an engineer needs to think. This resulted in a portable escape game consisting of five puzzles. The puzzles still need to be refined to be presentable, but they give a good framework for the finished product.

1 Introduction

In October 2023, CERN will open a new center for science education and outreach; Science Gateway. One activity visitors will be able to do will be an escape game, where they will be introduced to some aspects of the work engineers at CERN does. In this activity, the participants need to solve puzzles which will give them an introduction to electronics, cryogenics, and precision work. Additionally, the participants will use skills typically associated with engineering, such as problem-solving and pattern recognition.

To further expand upon the concepts that they saw in the escape room, the CERN guide will do a light theoretical debrief of the concepts after all the groups are finished. This will then give them a better overview of what work goes into the experiments.

Escape games are often described as *"live-action team-based games in which players encounter* *challenges to complete a quest in a limited amount of time"* (Veldkamp et al., 2020). This escape game is portable, containing five puzzles in total. The puzzles have different difficulty levels and different ratios of puzzle-solving and pure problem-solving. It is important to vary this to allow all members of the teams to join in. The teams are going to consist of up to four people. The time limit for the escape room will be 25 minutes, with a short introduction before the timer starts and then a short debrief after the timer runs out, for a total of 30 minutes.

I would like to thank my supervisor, Dr. Julia Woithe, for the support and good discussions. For helping me in the brainstorming phase, I would like to thank Emanuele Freddi, Kamil Zielinski, Stephan Petit, and Thomas Schneider for their ideas and input. I would like to thank Dr. Torsten Koettig for helping me with designing the Peltier element puzzle. Lastly, I would like to thank the rest of the Teacher and Student Programme team for their support and friendliness throughout my stay at CERN.

2 Theory and method

Taraldsen et al. argue that using escape games facilitates active learning, creativity, problem-solving, self-regulation, fun, and social interaction. Further on, they argue that this kind of activity utilizes sociocultural learning theory (Taraldsen et al., 2022). Sociocultural learning theory is based on the social interaction of people, where one student uses other students' knowledge and help to learn. Through solving these puzzles, they work together using skills such as logic reasoning, mathematics, pattern recognition, and observation Veldkamp.

Nicholson (2015), and Veldkamp et al. (2020), categorizes puzzles in three ways:

1. Cognitive puzzles where the participants use thinking skills and logic.
2. Physical puzzles where the participants need to manipulate artifacts.
3. Metapuzzles that are connected to the narrative.

2.1 Layout of puzzles

There are several methods of designing how the participants go through the whole game. The game can be linear, where one puzzle gives a clue to the next, which gives a clue to the one after that. It can also have a more open design, where the participants are free to choose the order of the puzzles, which all give a clue to solve one final puzzle. The game designed in this instance has an open design.

2.2 Importance of storyline and immersion

For the participants to feel a connection to the problems presented in escape rooms and games, and for the escape games to be immersive, there needs to be a well-adapted storyline, that is being told throughout the whole escape room experience. For more immersion, one also needs to use tools, characters, and props to build a good storyline, which ties the whole game together (Nicholson, 2016, 2018).

2.3 Group organization

One of the requirements of the escape game is that several groups can do the game at the same time in the same room. Veldkamp et al. argues that although this might make the groups work harder because of competition between the groups, it might also be distracting and brake the immersion (Veldkamp et al., 2020).

When it comes to group size, there is a lot of research to be done regarding escape games. However, Ahmad et al. (2021) concluded that small group sizes for game-based learning will be optimal to make all the participants active. The group size for this engineering escape game has been set to a maximum of four participants.

2.4 Debriefing

In an exploratory learning environment, we often talk about *inquiry-based learning* (IBL), where the students or participants explore a given problem on their own. Angell et al. (2019, p. 200-204), says that a characteristic of IBL is that the students have to look for patterns and explanations when they meet situations before they have had any prior explanation. Further on, they describe the *5E model* for inquiry-based learning: Engage, Explore, Explain, Extend, and Evaluate. By this, we mean engaging the participants with open tasks, letting them explore by themselves, explain what they have done, extend their gained knowledge, and evaluate what they have learned. Angell et al. (2019, p. 204-208) argues that using IBL can be used to further the participants' engagement through the use of surprising observations full of contrast.

This escape game is based on the principles of IBL, where participants will not get much information about the puzzles before they engage with them. This is done to let the participants engage with and explore the puzzles by themselves. After the escape game is finished, a guide will do a debrief, where they explain the links between the puzzles and engineering at CERN.

3 Results

The puzzles have been tested by a selection of the Summer Students at CERN 2023, and some of the employees at CERN. The data collection has been done through the questionnaire in appendix A. There were only 10 people who filled out the questionnaire, which is not enough to draw any well-informed conclusions. However, these answers together with observations can point to a tendency.

In general, there were only positive responses to the overall experience with the escape game. Depending on the group, the level of collaboration varied somewhat. Some said that several puzzles facilitated collaboration, and some said there was only one.

The participants said that the escape game highlighted different engineering areas practiced at CERN. They also commented that they would like more information about the CERN link.

A general observation was that the puzzles themselves were not too difficult. It was the introductory text and hints that dictated how difficult the participants would find the puzzles.

3.1 Puzzle 1: Faulty wiring

The first puzzle the participants encounter will be one where they need to find the error in a circuit. The idea here is to make them collaborate cross-group, where they need to find a resistor that is not connected to the rest of the circuit. When they have identified the resistor, they need to read out the value of the resistor, add that value with the values from the other groups, and that gives the code for a code lock. This would be categorized as a type 2 puzzle, as from section 2.

Figure 1: IR-camera picture of the *Faulty Wiring*-puzzle. The resistors that are used, and the LED, light up.

To solve this puzzle, they have to use an IR camera that will light up the resistors that are connected, and not light up the one that is not connected, as shown in fig. 1. The way the circuit looks without an IR camera is shown in fig. 2.

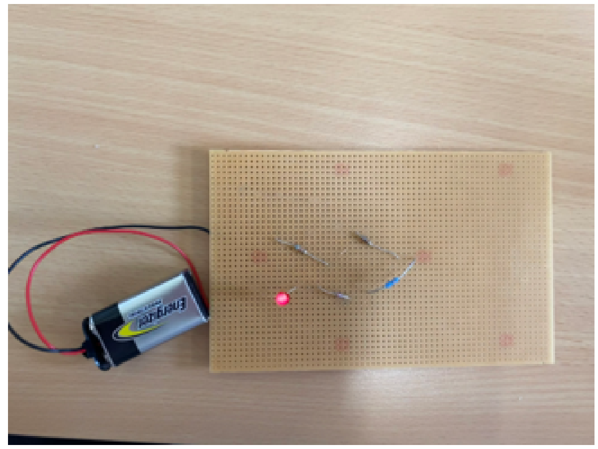

Figure 2: Regular picture of the *Faulty Wiring*-puzzle.

During testing, the test groups were able to see underneath the circuit board and see the connections in that way. In one group, one of the participants said *"Oh maybe they heat up"* while holding the IR camera, but soon discarded that idea.

The idea behind this puzzle is to have an introduction to troubleshooting. It is not always things that work, and things bets broken, both in parts that are being used, and parts in prototypes.

Out of the 10 people who answered the questionnaire in appendix A, there were 30% who answered that this was *"hard"*, and 60% who said that it was *"ok"*. The last 10% answered *"easy"*.

3.2 Puzzle 2: Cold canvas

To showcase some of the work of the cryogenics group in a way that the participants could do themselves, i.e. without the use of liquid nitrogen, this puzzle uses evaporation energy. By applying alcohol or water to dark fabric, the participants need to use an IR camera to see the code that has been written. When seen through an IR camera, the areas where the liquid was applied will be blue and the participants can read the code in that way, as shown in fig. 3.

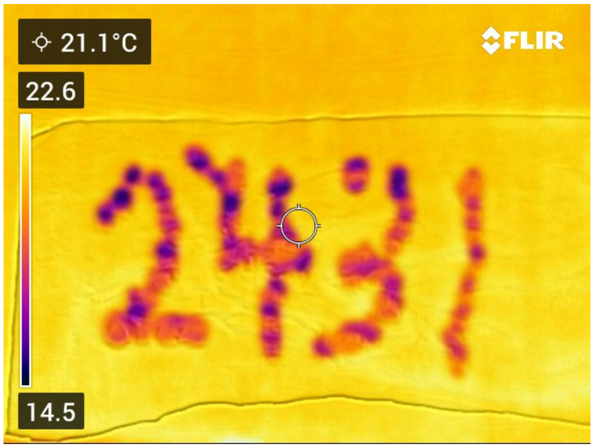

Figure 3: Picture from the IR-camera of the *Cold canvas*-puzzle.

In this puzzle, the idea is to bring in some thermodynamic concepts that might be relevant to the cryogenics group. In this case, it is evaporation energy, and how that looks in an IR camera. From section 2, this is a type 1 and 2 puzzle.

Out of the 10 people who answered the questionnaire in appendix A, there were 10% who answered that this was *"ok"*, and 60% who said that it was *"easy"*. The last 30% answered *"very easy"*.

3.3 Puzzle 3: Measuring bolts

This is to show the participants how important it is to be precise with measurements. Here they need to use a caliper to find the four bolts with the same diameter. There are ten bolts in total, and all of them are marked with a number, as shown in fig. 4.

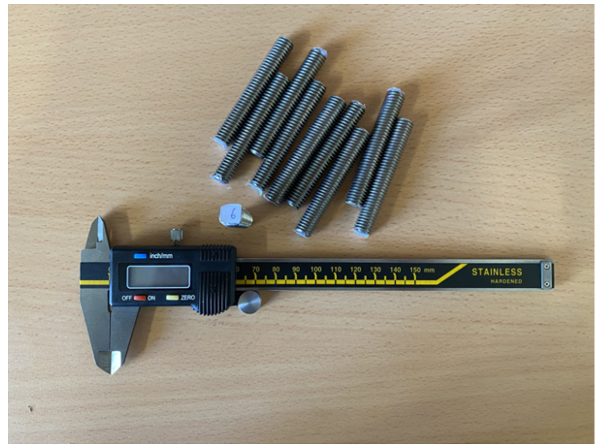

Figure 4: Bolts and calipers from *Measuring bolts*-puzzle. The bolts are indistinguishable by eye, and have numbers on top of them.

After they have found the four bolts, they need to arrange the numbers in the correct order. They are given a clue saying that it is a year that is important to CERN: 1954, the year CERN was established. This puzzle fall in category 1 and 2, shown in section 2.

Out of the 10 people who answered the questionnaire in **??**, there were 80% who answered that this was *"hard"*, and 10% who said that it was *"ok"*. The last 10% answered *"easy"*.

3.4 Puzzle 4: Magnet maze

The inside of the magnet maze is shown in fig. 5. This maze contains a small key that opens a padlock. On top of the maze is a lid that the participants cannot see through, so they have to feel their way through the maze using a magnet. When they reach the end they will be able to take the key out and open the padlock.

Figure 5: The inside of the *Magnet maze*-puzzle.

This puzzle is included to have something anyone can do, with some time. It showcases how CERN uses magnets to guide particles through for example the LHC. This is a type 2 puzzle, as stated in section 2.

Out of the 10 people who answered the questionnaire in appendix A, there were 10% who answered that this was *"hard"*, and 70% who said that it was *"ok"*. 10% answered *"easy"*, and 10% answered *"very easy"*.

3.5 Puzzle 5: Logic gates

This puzzle is meant to showcase the work that is done with microelectronics, for example in the pixel detectors. To distinguish it a little from the faulty wiring puzzle in terms of theme, the puzzle was designed using logic gates, which are a central part of microelectronics. The solution is shown in fig. 6. In the puzzle that is given out, the logic gates themselves are missing, and the participants would need to match the right logic gate to the right spot to get a four-digit code.

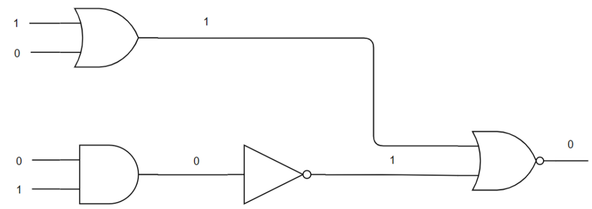

Figure 6: Solution of the *Logic gates*-puzzle. The logic gates are *and, or, nor* and *not*.

As discussed in section 2, this is a purely logical puzzle, therefore a category 1 puzzle.

Out of the 10 people who answered the questionnaire in appendix A, there were 10% who answered that this was *"hard"*, and 50% who said that it was *"ok"*. 10% answered *"easy"* and 10% answered *"very easy"*.

4 Discussion

Buchner et al. (2022), argues that a pre-instructional approach is better to lessen the cognitive load. This escape game is meant to give them an introduction to what engineering areas you can work in at CERN, and how an engineer thinks. The participants are supposed to discover the puzzles and theme by themselves, based on the principles of IBL.

However, one observation that was consistent throughout the groups, was that it would be a good idea to instruct the participants on how to use the IR camera and caliper. This ensures that they know what they can do with them, and that they notice them and start thinking of what they can be used to do. This would have to be done before the time starts.

It is hard to say what the participants put into the word "collaboration". In the answers, most of the groups said they collaborated well. However, from observations, the groups seemed to divide the tasks among themselves and do them by themselves or in smaller groups.

5 Future work

A suggestion for future work with this escape game is to look into how this can be implemented for age groups other than 15 years. There are different ways to do that. In the *logic gates*-puzzle, one could make the circuit simpler and simpler by reducing the number of gates, or they need to put in the outputs instead of the gates themselves.

To make it easier, one could also make the *magnet maze*-puzzle easier, for example, remove the sheet so the youngest participants could see what they do.

One final suggestion would be to remove the *faulty circuit*-puzzle for younger participants. This puzzle also utilizes colors, which could be difficult for participants with color blindness.

5.1 Puzzle: Peltier element

An alternative that could replace the *cold canvas*-puzzle, is one using Peltier elements, as shown in fig. 7. Peltier elements are used for cooling down equipment and could be used as a way to show a code. With a small voltage ($\approx 3V$) applied to it, one could, for example, fix four of these elements to a plate with an array of numbers, and make a four-digit code from that. This could then be placed somewhere in the room, so the participants would have to search for it.

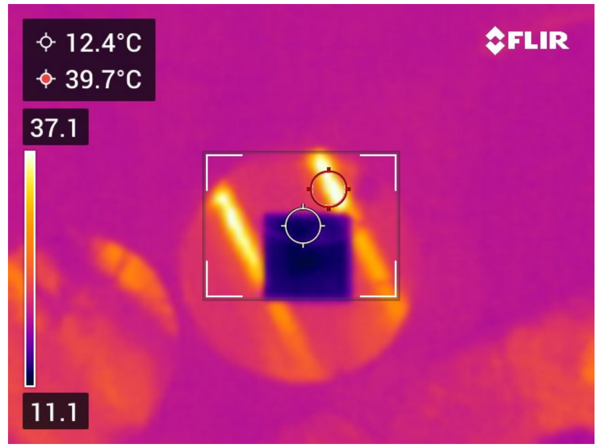

Figure 7: IR-image of a peltier element on top of a heat sink. The peltier element is shown in blue, and the heat sink is shown in orange.

6 Conclusion

In total, these five puzzles and how they are laid out show promise. Built out from sociocultural learning theory, and on design theories from Nicholson (2015), and Veldkamp et al. (2020), the puzzles make an open, portable escape game with varied categories in terms of what skills the participants need to use. It is made with groups of four 15-year-old students in mind.

There has been made a presentation to be used by the guides as briefing and debriefing. There has also been made a help sheet for how to set it up. More work is needed to make the escape game presentable for Science Gateway, but it gives a good framework for further work.

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A Appendix A:

Engineering Escape Game

This is a survey to measure the impact of the different puzzles in the first itteration of the engineering escape game for Science Gateway.

The escape game is meant to highlight different engineering aspects at CERN, and emphasize cooperation. The target audience are families, and mostly students around 15 years old.

* Obligatorisk

1. From a scale from 1 to 5, 5 being very good. How was the overall experience with the escape game? *

- ◯ 1 - Very bad
- ◯ 2 - bad
- ◯ 3 - Ok
- ◯ 4 - good
- ◯ 5 - Very good

2. From a scale from 1 to 5, 5 being very good. How would you rate your groups collaboration? *

- 1 - Very bad
- 2 - bad
- 3 - Ok
- 4 - good
- 5 - Very good

3. Do you think the escape game facilitated cooperation? In what way? *

4. From a scale from 1 to 5, 5 being very easy. How would you rate the puzzle with faulty wiring? *

- 1 - Very hard
- 2 - hard
- 3 - Ok
- 4 - easy
- 5 - Very easy

5. From a scale from 1 to 5, 5 being very easy. How would you rate the puzzle cooling fabric? *

- 1 - Very hard
- 2 - hard
- 3 - Ok
- 4 - easy
- 5 - Very easy

6. From a scale from 1 to 5, 5 being very easy. How would you rate the puzzle with correct bolts? *

- 1 - Very hard
- 2 - hard
- 3 - Ok
- 4 - easy
- 5 - Very easy

7. From a scale from 1 to 5, 5 being very easy. How would you rate the puzzle logic gates? *

- ◯ 1 - Very hard
- ◯ 2 - hard
- ◯ 3 - Ok
- ◯ 4 - easy
- ◯ 5 - Very easy

8. From a scale from 1 to 5, 5 being very easy. How would you rate the magnet maze? *

- ◯ 1 - Very hard
- ◯ 2 - hard
- ◯ 3 - Ok
- ◯ 4 - easy
- ◯ 5 - Very easy

9. Were you able to finish in time? *

- ◯ Yes
- ◯ Just in time
- ◯ Just not in time
- ◯ No

10. Imagine you did not know how engineers work, or what they do at CERN. Do you think this escape game highlighted the different areas of engineering av CERN, and layed a fundation for further explanation after the game was finished? *

11. Do you have any comments for the puzzles and/or the overall experience?