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Amanda Mathieson and Edward Duca

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STEM escape rooms for public engagement

Amanda Mathieson* – *University College Dublin, Ireland*
Edward Duca – *University of Malta*

Abstract

Escape rooms are a relatively new cultural phenomenon, attracting a wide range of audiences to test their puzzle-solving skills. While this format has been trialled in an educational context, there has been little exploration of it as a tool for engagement. We ran a STEM-based escape room, open to the public, over five days at a science centre in Malta. This was an exploratory exercise to determine whether escape rooms could be successful in an informal science engagement context. Over seventy players attempted the game and completed our evaluation. Our results suggest that escape rooms can be used in engagement contexts as they provide a positive experience that encourages future interactions with science. They may also draw audiences not normally interested in science and help them engage with scientific content in a more accessible manner. Interestingly, players were able to persist in engaging with content they found difficult while still finding it enjoyable, which has implications for the science communication of complex topics. Finally, players perceived that they were able to learn science through the escape room, which may increase their self-efficacy.

Keywords: STEM, escape rooms, public engagement

Key messages

- Escape rooms are a format that can be effectively used to engage the public, including groups who might not normally be engaged through science alone.
- Escape rooms may encourage audiences to persist in engaging with difficult scientific concepts while still enjoying the process.
- Escape rooms may provide an experience that engenders confidence about one's ability to engage with science.

Introduction

Science education and public engagement with science and technology (PEST) can be treated as separate activities with differing goals, but there is much overlap in the challenges faced by both. One mutual challenge is how to arouse interest in science among those who are uninterested or disengaged. Educators continually turn to innovative methods to engage their students and, as such, several have begun to develop educational escape rooms for this purpose (Veldkamp et al., 2020).

Escape rooms are themed rooms in which players are locked inside for a specific amount of time, usually one hour. The players must solve several puzzles in order to find a key and escape from the room before the time limit. Variations now exist where the primary goal is to solve a mystery or unlock an item. Puzzles are highly varied, from

*Corresponding author – email: Amanda.mathieson@ucd.ie

logical to abstract, from physical to mental, from individual to team-based. They will often build from each other, and use props and technology. Each escape room normally comes with a narrative or scenario that puts the environment into context (Kolar, 2017). Interestingly, even for commercial escape rooms, STEM (science, technology, engineering and mathematics) themes are highly popular, with 'space' and 'science' continuing to rank in the top ten of preferred themes according to annual surveys run by The Codex website (Elumir, 2019).

Escape rooms are a relatively new form of entertainment: having appeared in 2010, there were 2,800 established businesses worldwide by 2015 (French and Marmor Shaw, 2015). More recently, educators have tested escape rooms as a pedagogical tool to teach mathematics (Glavaš and Staščik, 2017), physics (Vörös and Sárközi, 2017), diabetes management (Eukel et al., 2017), surgery (Kinio et al., 2019) and earthquake preparedness (Novak et al., 2019). Preliminary testing in educational environments has suggested that escape rooms cement new knowledge in a way that students find enjoyable and useful. There is an increase in intrinsic motivation, even in students who initially struggle with the concepts. Students can also develop teamwork, communication and leadership skills through in-game interactions. The findings from these reports analysing the use of escape rooms in an educational context have recently been collated into a systematic review (Veldkamp et al., 2020).

In contrast to science education, there are few case studies of escape rooms being used for informal PEST, and little or no research investigating their potential in this context (Wilkinson and Little, 2021). We posited that as educational and engagement practices overlap, the benefits of one may translate to the other. However, the primary goals of science education and PEST can also differ, highlighting the need to evaluate efficacy in both. For example, the PEST paradigm has moved practitioners away from appreciation and acceptance of science as being the primary goals of engagement, and from increasing science 'literacy' as a means to get there (Stilgoe et al., 2014). Instead, the importance of building the public's capacity to engage to amplify their voice in scientific matters is prioritized (Selin et al., 2017). Therefore, engagement professionals may aim to inspire 'positive associations' with science that develop citizens' confidence and willingness to interact in future. In an engagement scenario, perceived learning may be more valuable than actual learning, as this relates to self-efficacy and the likelihood of continued engagement. Consequently, a good measure of an engagement tool is its ability to engender these positive outcomes.

Through the Erasmus+ project STEAM, funding was provided to arrange innovative, creative science engagement events. We decided to test the use of a STEM escape room in our programme as an exploratory activity. We wanted to investigate whether the escape room would attract a broad audience, particularly those uninterested in science, and whether it would allow individuals to confidently engage with difficult scientific problem solving while remaining a positive experience overall.

Escape Malta: Space Station

The premise for the escape room was that the Maltese Space Agency had lost contact with scientists on board a space station, who at their last communication were falling ill. The player was sent up to the space station to investigate the situation. The evidence that they had to analyse was the scientists' belongings. Each scientist had a different specialization, a narrative device used to allow the game to cover different STEM disciplines, including physics, chemistry, biology and mathematics.

The level of difficulty varied from puzzle to puzzle, and the scientific content ranged from secondary school to undergraduate level. For example, the most difficult puzzle required players to calculate the length of a gene from a plasmid diagram (a small, circular DNA strand) and analyse a Southern blot (a technique to measure DNA sequences) to conclude whether the gene was present in biological samples. Players were able to gather the information needed to solve puzzles through a mixture of searching for and unlocking objects, as well as reading protocol posters, Post-it Notes and log books.

An actor was present in each escape room for several reasons. They were able to set the scene through an initial dialogue, creating a more immersive environment. They could provide support for younger players, or when players seemed to be struggling. Therefore, Escape Malta could cater for different skill sets and knowledge levels. Actors were trained beforehand to ensure that they only guided players who were struggling, and did not provide answers. Players received points for each puzzle completed, as well as the ability to survive the game if they completed all of them. Based on these results, players were given personalized endings to give them ownership over their experience. It is also important to note that players were told that they were free to leave the room early, if desired.

The events were hosted at Esplora Science Centre, where two escape rooms were run over five days, and passing visitors could decide to play. The science centre was a logistical choice, as it was able to provide space and materials, as well as regular foot traffic. Visitors to Esplora include families, school groups and tourists. School groups often visit the centre on a mandatory basis.

Embedding public engagement theory in escape room design

While our project was exploratory, we wanted to apply theory in the design of our escape room to increase its chance of attracting and engaging players. Three theoretical lenses that detail the drivers of wilful participation were applied to our design: science capital, cognitive load, and self-determination theory.

Science capital is described as the knowledge, characteristics, behaviours and attitudes that a person possesses which can be used as leverage to engage in a scientific environment (Archer et al., 2015). This determines how comfortable an individual might be in said environment and, consequently, their willingness to participate. Recent science education research has suggested that to increase participation, rather than building an individual student's capital, educators should aim to change the environment around them. This is called 'broadening the field'. It requires a space to be created that values a student's existing capital (Godec et al., 2018).

Cognitive load is the mental effort needed to learn a new concept or complete a task (Sweller, 1998). There are several techniques which can be applied to decrease cognitive load, such as appealing to different senses, dosing information and providing cues as to what information is the most important (Mayer and Moreno, 2003). This may allow individuals to complete difficult tasks that they would otherwise abandon due to perceived effort.

Finally, we were interested in self-determination theory as defining the prerequisites for intrinsic motivation (that is, the willingness to participate through one's own volition) (Deci and Ryan, 2000). This theory posits that motivation is tied to innate psychological needs for autonomy, a sense of competence and interaction with others. Motivation can be increased even further if the task is also integrated into one's

Table 1: Theoretical drivers of participation and the means of embedding them in the Escape Malta escape room

Theoretical driver of participation	Means of embedding it in the escape room
Science capital	Puzzles were varied in nature, allowing different skills and knowledge (capital) to be applied. A game-based/live theatre focus provided a non-science environment where broader audiences could feel comfortable.
Cognitive load	Puzzles and other content were multisensory where possible. Information was dosed. Narrative content and a live actor provided cues as to which information was important where needed.
Self-determination theory – autonomy	Many puzzles were non-linear and could be taken up and abandoned as desired. Five possible story endings were available depending on the outcome of the game, giving players ownership.
Self-determination theory – competence	The puzzles and timed element of the game allowed players to test their skills. Teams were able to compete against each other via a scoreboard. Players could strive for the 'good ending' among a series of endings. Small 'wins', such as the discovery of items or codes that allow players to progress, provide recognition of competence.
Self-determination theory – social interaction	Players participated as teams. Players interacted with a live actor inside the room.

own values and interests. Evidence suggests that satisfaction of the above (or lack thereof) can influence a student's engagement with STEM (Niemiec and Ryan, 2009).

These concepts shaped our design of the escape room, and they were targeted as shown in Table 1.

Evaluation

The Escape Malta: Space Station events formed part of an Erasmus+ grant (STEAM) which funded science communication activities in Malta. As such, it was not part of an experimental study. The goal of the project was to give players an enjoyable experience that would allow them to overcome engagement barriers and confidently interact with undergraduate-level scientific content whatever their background. The exploratory study asked open-ended questions that would allow us to record some of the outcomes of the experience. We were interested to know whether it would be a positive experience that would increase motivation to participate in future PEST activities. We also wished to determine if we had attracted players who claimed to be not very interested in science. Unlike science education contexts, we were not interested in knowledge retention, but were more concerned with players' perception of having learned something. Perception of learning would suggest both that the content was new to a player, and that a player felt competent in engaging with it. A short exit survey was therefore administered, asking the following:

1. age and gender
2. prior interest in science and motivations for participation
3. general experiences of the event and solving the puzzles

4. perceptions of the game as a learning opportunity
5. interest in attending similar events.

Paper surveys were handed out after players had left the escape room and read their personalized ending. They were completed anonymously, although if players were 10 years old or younger, they were aided by a trained volunteer. A nine-item questionnaire was used, as the escape room was a short intervention. The survey was pilot tested with other members of the team to test duration and clarity. It took approximately five minutes to complete. The evaluation process complied with General Data Protection Regulation and Erasmus+ ethical requirements. No data were gathered that could identify individuals, and players could play the escape room without completing the questionnaire. Closed-ended questions were analysed quantitively as percentages. Open-ended questions were analysed through a conceptual content analysis method. Phrases were coded, and the frequency of these codes appearing across players' responses was recorded.

Results

A total of 76 players completed the escape room over the five days. Players ranged in age from 8 years to 69 years, with an average age of 22; more than half were female (~55 per cent). They participated as individuals, couples, peer groups and families. No player group chose to leave the room early. Players were asked what had drawn them to try the escape room, and to tick all elements that applied. While 80 per cent of players were drawn due to the game element, only 44 per cent were attracted due to its science theme. Therefore, over a third (36 per cent) of our audience engaged with us due to the escape room format alone. We further asked them to tell us their perceived level of interest in science: 14.6 per cent stated they were not interested, while approximately half of the players were only somewhat interested in science. Despite this, all expressed some interest in going to a similar event. This high participation rate may suggest that the escape room format helps broaden the field in a way that allows those with less science capital to engage. Responses are shown in Table 2.

We were interested to know if players felt that they had learned some science through the escape room. Three-quarters of our players (75.7 per cent) believed that they had learned some science, while most of the remainder (16.2 per cent) stated that they were not sure. A higher proportion of players felt that this was a good way to learn science (85.5 per cent), and they were asked to explain their answer; 48 responses were given, and the content analysis of this is detailed in Table 3. Each comment was

Table 2: Percentage of respondents filling each category of interest, and number of respondents answering the question (n)

Category	n	Percentage
Female players	76	55.3
Attracted by game format but not by science content	75	36.0
Not interested in science	75	14.6
Somewhat interested in science	75	49.3
Felt they had learned some science	74	75.7
Felt it was a good way to learn science*	76	85.5
Would likely go to similar events	76	94.7
Would maybe go to a similar event	76	5.3

Note: *Further explanation was asked for this question

Table 3: Explanations of responses to the question, 'Is this a good way to learn science?'; gender and age of commenter is provided next to each sample comment (gender/age), n=48

Theme and sample comment	Comments (number)
Because it was fun	11
e.g. 'Cause it's fun and when it's fun you're learning.' (F/11)	
Because it was hands-on	10
e.g. 'An interactive way of learning will help you to remember.' (F/14)	
Because you seek information to complete the game	10
e.g. 'In order to complete the challenges science had to be used.' (F/20)	
Because it motivates you to learn	7
e.g. 'Got us wanting to be more knowledgeable.' (M/39)	
Because scientific concepts were included	5
e.g. 'Since it focused on biology and chemistry I learned more about the subject.' (F/18)	

categorized under a specific theme, and the number of comments in each theme was counted, with examples given.

One person did not think it was a good way to learn science; they commented that it was difficult for them to learn in a group, suggesting that this method might not be suitable for all learners.

Players were also asked about their experience solving the puzzles, and their answers varied (see Table 4). The descriptor that appeared most frequently was 'fun', followed by 'challenging', 'good' and 'difficult'. One interesting theme was that players found the puzzles difficult, yet they still enjoyed them and/or persisted until they overcame them. It may be that the escape room format can reduce perceived cognitive load, or that intrinsic motivation is high enough to overcome perceived difficulty. Additionally, the different approaches to problem solving may allow those with non-scientific capital to leverage it in order to complete tasks. These results need a more in-depth study to confirm.

Table 4: Responses to the question, 'What was your experience of solving the puzzles?'; gender and age of commenter is provided next to each sample comment (gender/age), n=75

Theme and sample comment	Comments (number)
Generic positive comment	25
e.g. 'It was very fun.' (M/10); 'It was interesting, something new.' (F/13)	
Found it difficult, but still enjoyed it	11
e.g. 'Connecting clues was fun even if we got stuck in some.' (M/12)	
Found it difficult, but overcame the challenge	11
e.g. 'The puzzles were not that easy but we solved them all.' (F/14)	
Found it difficult	8
e.g. 'It was a bit hard for me.' (F/16)	
Enjoyed the teamwork element	4
e.g. 'Very nice way to spend time with your friends.' (F/18)	
Found it a good way to learn	3
e.g. 'Really fun and cool way to learn.' (F/13)	

Limitations

There are several limitations to this case study. As this is an evaluation of a specific event, any results may be specific to this context and difficult to extrapolate to other cultures and locations. The sample size was small and included many players who already had an active interest in science. As the event was hosted at a science centre, it can be presumed that many would already be happy to engage with a science-based activity, although there were those that may have attended with school as a compulsory visit, or who may simply have been accompanying friends and family. Finally, due to the short nature of the event, the survey needed to be concise, and more detailed demographics such as education level and socio-economic background were not collected. Also, the project was exploratory, and while we recorded organic outcomes, we did not specifically analyse the features that were embedded in the design of the room to drive participation. Therefore, we did not assess the impact of science capital, cognitive load and self-determination theory on the level of engagement, although this will be explored in future research. Additionally, for the indications provided by this case study to be verified, the escape room format should be tested as part of a larger experimental study, with a carefully selected sample adequate size and a detailed analysis.

Discussion

Escape rooms have been trialled as tools for science education and have been shown to have several educational benefits, but they have not been evaluated as a format for informal engagement. This case study suggests that they retain many of their benefits in an engagement context and that they can be used successfully as an engagement tool by targeting PEST-specific aims. Escape rooms may also be used to attract new audiences, as there is a commercial appetite for them. A third of players participated in our activity based on the escape room format alone, and there were two player groups who came specifically for the game, despite having to pay an entrance fee to Esplora Science Centre. This may be of interest to institutions who are looking for ways to widen their audience through their public engagement programme. Escape rooms are non-age specific, and they can be applied to any context, provided that the scenario and puzzles make sense. The narrative also creates an opportunity for cultural as well as scientific learning. This makes the format incredibly adaptable to a wide variety of engagement aims. However, escape rooms still need to be tested in a number of other contexts before being validated as a general engagement tool. More particularly, the educational background and socio-economic status of players should be noted to determine if escape rooms can reach audiences traditionally underserved by science engagement.

Escape Malta also highlighted an interesting area for exploration, namely, how those not very interested in science and of varying ages may still engage with undergraduate-level concepts, and perceive the activities as difficult, yet persist in completing them. While the escape room was designed with the theoretical concepts of science capital, self-determination theory and cognitive load in mind, our evaluation does not assess which factors were influencing participants' motivation. We recommend a more rigorous investigation, with methods in place to assess players' perceived cognitive load, sense of autonomy, self-efficacy and experience related to teamwork. Ideally, play-throughs would also be observed to record when other forms of cultural capital were being leveraged by players to succeed.

Ultimately, the escape room was frequently described as a 'fun' activity that provided players with value in the form of entertainment, as well as being a bonding opportunity. Players walked away delighted, having had a good interaction with STEM concepts, even if they were not very interested in science initially. Players also thought that they had learned some science, and they were eager to discuss their experience with staff or other players who had also completed it. This makes it a promising tool, not only to engage audiences and build positive associations with science, but also to prompt informal discussions about science outside the activity and to encourage future engagement.

Conclusion

STEM escape rooms can be used to provide positive experiences for informal interactions with science, and some of the benefits of this format already identified in an educational context can translate to the engagement context. Escape rooms may also be used to target PEST-specific aims, such as increasing capacity to engage with science. This has many implications for practitioners, organizations and institutions wishing to work with public groups. The game provides a non-intimidating environment where players can leverage many forms of capital to interact with science. This might allow escape rooms to reach broader audiences, or to increase or diversify footfall to science centres. Players are able to engage with difficult scientific concepts without losing motivation, and they can still enjoy the experience, leaving with a more positive association with science. The success of this activity in Malta, combined with the popularity of escape rooms around the world, suggests that they have international relevance. However, this was an exploratory case study. More research is needed to validate escape rooms as an engagement format. Similarly, evidence-based research needs to be conducted to understand what features of an escape room might allow for greater engagement, and how they contribute to this.

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Notes on the contributors

Amanda Mathieson is the Public Engagement, Education and Communications Manager at BiOrbic Research Centre, situated in University College Dublin, Ireland. She also coordinates the STEAM Summer School in science communication, training researchers to communicate science through the arts. Her work focuses on using innovative means such as play to engage broader groups with STEM.

Edward Duca is a science and innovation communication lecturer at the Centre for Entrepreneurship and Business Incubation at the University of Malta. He is also the

Editor-in-Chief of the research magazine *Think*, which has received over four million online views. His research interests include recommendations for improving science communication in Malta, evaluation of the impact of science communication activities on audiences, and the evaluation of the impact of large-scale festivals.

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