

Adaptability and Procedural Content Generation for Educational Escape Rooms

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Abstract: We present a literature review that aims to understand the role of the Educational Escape Room (EER) in improving the teaching, learning, and assessment processes through an EER design framework. The main subject is to identify the recent interventions in this field in the last five years. Our study focuses on understanding how it is possible to create an EER available to all students, namely visually challenged users. As a result of the implementation of new learning strategies that promote autonomous learning, a concern arose in adapting educational activities to each student's individual needs. To study the adaptability of each EER, we found the EER design framework essential to increase the student experience by promoting the consolidation of knowledge through narrative and level design. The results of our study show evidence of progress in students' performance while playing an EER, revealing that students' learning can be effective. Research on Procedural Content Generation (PCG) highlighted how important it is to implement adaptability in future studies of EERs. However, we found some limitations regarding the process of evaluating learning through the EERs, showing how important it is to study and implement learning analytics in future studies in this field.

Keywords: Learning; Educational Escape Room; Narrative; Level Design; Adaptability; Procedural Content Generation

1. Introduction

The use of educational games as learning tools allows teaching and reinforcement learning, developing non-cognitive skills like troubleshooting, teamwork, and communication (Mateos-Aparicio et al., 2020). This study defines the EERs activities as an effective and innovative learning experience in a high-pressure situation, besides having a positive impact on student engagement and learning (Dugnot-Menéndez et al., 2021).

The game's narrative is a crucial component of that initial impact, which motivates the player to play (Manzano-León et al., 2021). So, to engage all stakeholders, it is essential to adapt the narrative through good storytelling in which the World Design is well defined and developed. The EER design framework (Krekhov et al., 2021) should consider the MDA framework to outline the EER dynamic behaviour (Hunicke et al., 2004, Krekhov et al., 2021) and the Level Design to create lifelike and interactive experiences. Nonetheless, the EER framework must define the adaptability and the Procedural Content Generation objects and environments.

This paper is organised into four sections. Section 2 presents "from Escape Rooms to Educational Escape Rooms," and it is subdivided into two subsections: the first is about "Escape Rooms," and the second is about "Educational Escape Rooms." Section 3 summarises the "implementation of the new learning strategies through the EERs design." It has four subsections: the first considers the importance of the "Design framework," the second is about the "Narrative," the third is about "Level Design," the fourth is about "Adaptability concerns," and the fifth describes the "Procedural Content Generation." Section 4 presents a "Discussion" in which we summarise our findings, limitations, and the importance of this study. Section 5 closes this paper by presenting conclusions and perspectives on future work.

2. From Escape Rooms to Educational Escape Rooms

2.1 Escape Rooms

Escape Rooms (ERs) have been defined as Live-Action Games in which players must find objects with clues that address solving puzzles and finish the challenge(s). ERs take place in one or more rooms to improve and reach a specific goal (Veldkamp et al., 2020, Bakkum et al., 2021, Morrell and Ball, 2020, Karageorgiou et al., 2020, Jambhekar et al., 2020, Karageorgiou et al., 2019, Archontoula and Skoumpourdi, 2019).

The first real escape games appeared in Japan in 2007 and spread rapidly throughout Europe (Borrego et al., 2017, Moreno-Fernández et al., 2020, Krekhov et al., 2021). Recently, ERs have become a popular leisure activity because it offers a wonderful opportunity to spend time having fun, as well as to conduct a “teambuilding” activity by joining members of an organisation to troubleshoot, through the encouragement and the development of team spirit (Moreno-Fernández et al., 2020). So, there are many different or similar forms to refer to ERs: “escape game” (Borrego et al., 2017, Dietrich, 2018), “room escape” (Borrego et al., 2017, Sanchez et al., 2017), “breakout” (Leon et al., 2020, Nephew and Sunasee, 2021, Perumal-Pillay and Walters, 2021, Pozdniakov et al., 2021, Zouhri and Lee Running, 2021); “exit game” (Murto and Välimäki, 2011) or “unlock” game (Eukel et al., 2020).

According to Krekhov et al. (2021), ER can be played by one or more players depending on each form or platform. Some rooms may include a game master and actors to add realism. Moreover, it can also be played in various ways depending on the place and device. The analogue ERs are presented in many forms and often use cards to display rooms, items, and text or combine various materials. Hybrid games combine analogue and digital elements by adding a digital camera or companion app, which usually provides hints, surprises, and multimedia content. Digital ERs often present rooms and puzzles in 2D or 3D graphics and use simple point-and-click or touch mechanics. However, others are predominantly text-based and work with text commands.

Virtual Reality Escape Rooms (VRER) provide human-computer interactions easier and the collaboration between the elements of the team more efficient – generating high immersion, like the student feel living their real-life (Li and Han, 2021).

2.2 Educational Escape Room

The use of educational games as learning tools allows teaching and reinforcement learning. Moreover, it develops non-cognitive skills like problem-solving, teamwork, and communication (Huang et al., 2020), beyond curiosity for students to discover scientific concepts, motivation and engagement comparable to the traditional educational games (Borrego et al., 2017, Nicholson, 2018, Gómez-Urquiza et al., 2019, Huang et al., 2020, Moreno-Fernández et al., 2020, Bilbao-Quintana et al., 2021, Dugnol-Menéndez et al., 2021, Macías-Guillén et al., 2021). Students may develop their learning path playfully and their own adaptive and responsive skills. As an alternative to traditional activities, students participate in a fictional story and attempt to achieve a fictional objective within a specific time by solving puzzles and challenges related to curriculum content within a limited duration with the help of their peers (Manzano-León et al., 2021). EERs are being used to improve and innovate teaching practices and positive feedback from students. According to Gaia Bistulfi (2021), the EERs develop team skills in Science, Technology, Engineering, and Mathematics (STEM). Still, we also found it in other fields, particularly in health sciences (Macías-Guillén et al., 2021). Jimenez et al. (2020) also pointed out that using EERs offers many advantages to students, including intellectual, social, emotional, and psychological benefits. For that reason, EERs have been used for various educational goals like (1) recruiting students; (2) for students to get to know institutions; (3) increasing students’ cooperation; (4) in a research environment; (5) observing students’ information search behaviour; (6) learning processes in student teams; (7) teamwork and leadership skills; (8) fostering design skills, domain-specific skills, and knowledge; (9) or even, to support the development of generic skills.

Most authors tend to describe the EER activity as “gamification” (Sanchez et al., 2017, Li et al., 2019, Pérez et al., 2019, Leon et al., 2020, Lopez-Belmonte et al., 2020, Bistulfi, 2021, Dugnol-Menéndez et al., 2021, Santos and Moura, 2021) although others as a “serious game” (Mystakidis et al., 2019, Brown et al., 2019). In both cases, students are meant to be motivated and engaged by the activity, and there has been extensive research on their differences (Mayer, 2016, Macías-Guillén et al., 2021). However, EER is also described as a playful learning activity. EER uses play and playfulness to facilitate learning through the “magic circle of playful learning” – students take managed risks safely and learn from failure – and the “lusory attitude” or “spirit of play” –

students face difficult or unfeasible situations in the "real world" (Whitton, 2018). EERs can also be used for problem-based learning (PBL) since their features are also included in the ER scenario with an "ill-structured" or "messy" problem within a "real-life scenario" and respective concepts. Students are encouraged to solve challenges they can find through open-ended tasks, endorsing their autonomy and collaboration with their peers (Pearcy et al., 2019, Krekhov et al., 2021).

According to Dietrich (2018), it is an opportunity for students to compete with and against their classmates, show off their skills, interact, and discover new things. So, the level design features are essential for EERs to engage students through VR design tools (Caldas and Keshavarzi, 2019), fitting the concept of game-learner-centred and problem-solving-oriented learning (Huang et al., 2020). EER designers are advised to use a thoughtful, methodical, iterative process to ensure quality, educational capacity, and a positive learning experience. To improve the educational simulations, they should be based on student needs, context-based, student-centered, and constructed based on measurable purposes (Eukel and Morrell, 2021).

3. Implementation of new learning strategies through the EERs design

3.1 EER Design Framework

The EER design framework presents important design considerations to the creation process. Krekhov et al. (2021) pointed out that developers should consider in the first place the target audience and setting's theme. Second, developers should provide mini-games defined by challenges, starting from prior works and known classifications, leading to the basic version of anatomic mini-games taxonomy. So, from this point, it's suggested to refine, improve, and validate the EER. It is also highly recommended to start from the analogue and then proceed with the digital versions. It is meant to have an overview of the state of the art, analysis, and classification of analogue and digital EERs. This framework can be applied to simplify and streamline the design and decision-making process for the researchers and practitioners involved in it.

ERs have different game mechanics and input modes but share a similar conceptual structure with a series of connected puzzles at their core. By consolidating the evidence from related work, Krekhov et al. (2021) identified the main design aspects of ERs: target group/team and composition; theme/narrative; modalities/platform; puzzle organisation and design; and clue system and resilience. On the one hand, the first three features provide the framing for creating the room concept and puzzles. On the other hand, the last three describe more specific aspects of the puzzle design and composition. Clarke et al. (2017) presented a study of a theoretical design framework for EERs ("escapED"), which defines six steps of the process (Figure 1).

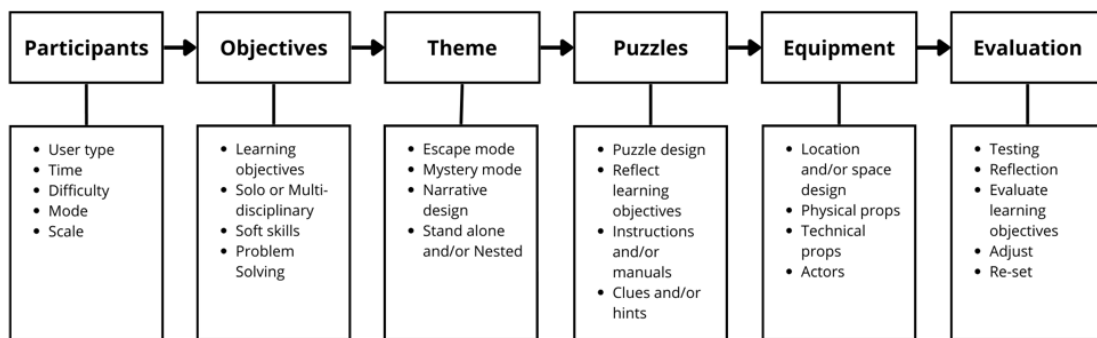


Figure 1: escapED Framework (Clarke et al., 2017)

Synder Escape Room FrameWork (SERF) extends the escapED framework (2020) because Synder (2018) suggested that other design concepts and heuristics should be added due to the fact that each phase has an impact on the others, and this should be considered when designing an EER (Figure 2).

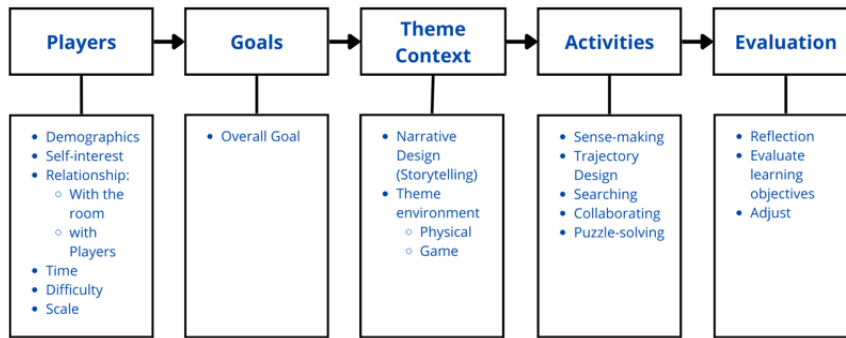


Figure 2: SERF Framework (Snyder, 2018)

So, Seebauer et al. (2020) developed the EduER framework combining all the escapeEd (black) basic procedures with all the essential factors of the SERF framework (blue). This combination resulted in six phases (Figure 3). The study design and usability conducted with the EduER framework presented that it is obvious to determine findings without questionnaires, e.g., timeframe, because some participants didn't realise when the task was finished and could continue to do the next one.

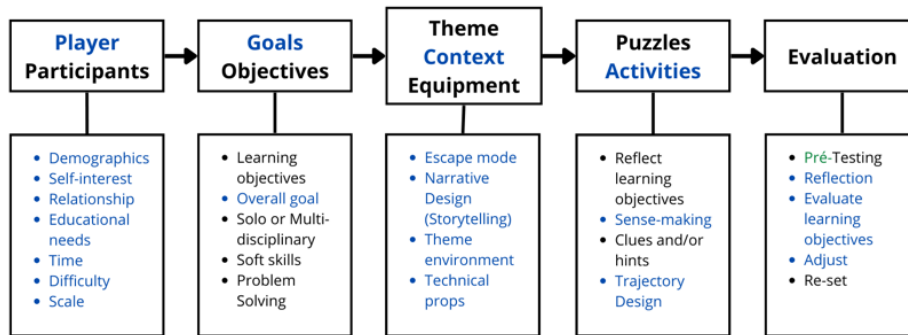


Figure 3: EduER Framework (Seebauer et al., 2020).

Moreover, Jimenez et al. (2020) considered EER design to outline: the specific context to place the action, revealing the general information like the game rules to the participants, considering the game director or game master, participants, puzzles, and the sequence of the game (linear path, open path or multilinear).

3.2 Narrative

According to Itenge et al. (2021), narrative development is part of a co-design project whose goal is to co-create a game that causes emotions that result in an immersive experience for the participants. ERRs learning environment commonly involves a mystery (Veldkamp et al., 2020), with adventure, real-world team-based, and problem-solving (Avargil et al., 2021). So, to potentiate the feeling of fun, it is essential to use some game methodologies throughout the game narrative. It is possible to choose two different kinds of narratives. First, the emergent in which the player is free to do what she/he pretends, and the quality depends on the choices made by the player; or the second, in which a story is well defined and the player doesn't have any option to change the game path (Champagnat et al., 2009). As Zagal et al. (2005) and Champagnat et al. (2009) pointed out, a game framework should describe the game elements based on the interface, rules, objectives, and entities.

3.3 Level Design

It is fundamental to consider the relationship between rewards and difficulty when designing a game. According to Li et al. (2021), game designers must know how to match the level design (LD) to this relationship fundamental in their game's mechanics. LD pretends to find the equilibrium with the game elements and sequencing them to promote engagement and satisfaction, besides forming a coherent experience in which the player can be defeated or pass a game element. Dormans (2011) pointed out that using rewrite systems to formalise LD principles enables level designers to increase their efficiency in designing levels and reduce the possibility of mistakes. Level designers can use model transformations as part of an adaptive framework where missions are generated before space or vice versa. Generally, action-adventure games benefit from utilising mission and space grammar to generate various quality levels (Dormans, 2010). So, developing spaces for missions allow multiple paths to converge on the same goal. A framework that will enable a level designer the possibility of

generating game mechanics during the level generation process allows simultaneously the chance to create game levels that better integrate the unique elements that define the gameplay of a game.

3.4 Adaptability concerns

The user-centred design focuses on using the system, applying some characteristics defined by the International Organization for Standardization. These characteristics include an iterative design process, users' participation in the design, evaluation of the user experience, multidisciplinary perspectives and skills, and understanding of end-users, tasks, and environments (Doroudian et al., 2018).

In the EER design process, it is crucial to know the target group – the audience (Clarke et al., 2017) – to create an experience personalised to their needs. This kind of setting's adaptability could include an appealing theme, an appropriate difficulty level, and a mix of challenges that fit their skills. Mainly, if a design is meant for people with special needs, a need assessment is crucial, and it is recommended that the target group be involved in the design process (Menzies, 2019).

The common adaptability flaw in game development is to design immersive games without triggering lights or colours. Epileptic seizures related to video games started to be noticed in January 1993 with the *Super Mario World* game. In this sense, understanding how some games are more provocative with visual stimuli than others is essential to preventing and designing a safe EER. Two tools to help developers to choose EERs' colours are ColorADD (2022) and Adobe Color (2022). So, the proximity settings, patterns, background colours, and contrasts proved crucial to understanding how each parameter affects these users (Kasteleijn-Nolst Trenité et al., 2002).

3.5 Procedural Content Generation

Procedural Content Generation (PCG) refers to creating game content (semi-)automatically through algorithms, providing the possibility to generate personalised games that the player can adapt according to his preferences and optimise the gaming experience. So, these features allow a wide range of content production and elements such as terrain, maps, layers, stories, dialogues, quests, character rules, dynamics, or weapons (Korn and Lee, 2017).

There is a constant challenge for PCG algorithms to implement the quality/diversity paradigm to find the set of diverse and high-quality solutions in a single run (Gravina, 2019). The EER designer must consider the rules and environment of the game. According to Murray (2017), PCG designers, besides settling the narrative possibilities, in the education field, should provide a layout that gives the player the freedom to explore and improvise, indulging in a spontaneous strategy to reach what students believe that it is some sort of reward. In our study, we found that Houdini (SideFX, 2022) and Unity (Unity, 2022) allow to develop ERs more immersive. So, EER developers should consider these tools to build games with graphics more realistic.

4. Discussion

EER designers should consider some specifications in the EER design framework, narrative, LD, adaptability, and PCG. However, they also should have concerns depending on students' differences, like regional or cultural, in how they prefer certain theme types or challenges, as Krekhov et al. (2021) pointed out.

In future studies, researchers may find some issues in implementing PCG in an EER with adaptability concerns, depending on the students' needs. However, EER should use the PCG methods for specific parts that can be organised based on a taxonomy of six layers (bits, space, systems, scenarios, design, and derived content) ordered by the complexity. Each layer uses techniques and methods from the layer before (Hendriks et al., 2013). However, the progress of EERs built on PCG depends on a multidisciplinary team from the field outside computational intelligence (Togelius et al., 2011).

We found some gaps related to the use EERs by visually challenged people, such as photosensitivity, colour blindness, and epilepsy. During this study, we also perceive the EERs assessment processes aren't being deeply studied. A deeper understanding of these topics can be gained by conducting further research.

5. Conclusions

Students are accustomed to technology and expect the school to provide innovative learning materials and methods. By promoting autonomous learning, new learning strategies enable the development of learners'

autonomy, especially for learners with disabilities. To study the adaptability concerns, we found that the EER design framework is essential to increase the student experience by promoting the consolidation of knowledge through great narrative and a high-level design. There is not yet a specific EER framework that has to be followed step by step by all developers, which gives more freedom of creation and design to adapt the EER to the educational needs and, if needed, special needs of its stakeholders. We verified that students have more significant gains when playing an EER than using traditional learning methods. Adaptability is becoming more evident in game development, potentiating the flow and immersion in the game, allowing an improvement in participants' experience. To develop an EER for the scholar community, with inclusion and adaptability concerns, designers should consider the different participants' needs because health issues shouldn't compromise their education. PCG increases the students' motivation, so it should be considered in future EER applications. Overall, the results of our study present evidence of progress in students' performance while playing an adaptable EER than traditional learning approaches.

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