Escape Room Design as a Game-Based Learning Process for STEAM Education

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Abstract: By combining elements of entertainment with creative writing, theater and technology, the increasingly popular live-action games escape rooms have the potential to improve the learning experience when used in academic settings. However, since educational escape rooms are still an emerging field, there is limited literature available about their use in STEAM education. The present paper addresses this issue by describing the methods followed by 39, 16 to 18-year-old, students and 10 teachers at a Vocational School of Greece to implement a STEAM-focused escape room activity using the Experiential Pyramid Model. The escape room was themed after the Spanish heist television series "La Casa de Papel" and incorporated creative writing, theatrical elements, and technology, such as Robotics, QR codes and Virtual Reality (VR), to promote communication, teamwork and peer learning. To make the experience more immersive, two team members had the roles of non-player characters (NPCs), and interacted with the players throughout the game, with a small script written during the design and evaluation phase. This collaborative activity was assessed via evaluation questionnaires, direct/participatory observation and interviews. The first results indicated that students were highly engaged and motivated especially at the design phase. They valued this pedagogical approach positively, since it facilitated the integration of contents of various subjects and enabled them to collaborate with their peers from different cohorts, thus promoting peer learning. This study aims to provide educators with an example of how they might develop and support non-traditional approaches to learning by immersing their students as active participants in the learning environment and allowing them to develop and apply knowledge, so to create a gameplay.

Keywords: escape room, theatre, technology, creative writing, education, STEAM

1. Introduction

STEAM projects, combine art and creativity with the knowledge of STEM (Science, Technology, Engineering and Mathematics) disciplines, bring the variety and diversity that are requisite for innovative product design and development (Oner et all., 2016). Research showed that when art is included in science areas, students pay more attention to STEM fields (Kang et al., 2013; Land, 2013) and cooperation with experts can affect their future decisions (Keefe & Laidlaw, 2013). STEAM education provides many opportunities for students to improve themselves in several areas, since they increase the appeal of subject areas and promote creativity (Sousa & Pilecki, 2013).

In order to establish a culture of creativity in schools, students should shift to active creators of knowledge (Rice, 2000). Educators have to foster both problem solving and problem seeking skills, while maintaining the interest of the students (Land, 2013). One way to do that is through escape games, because this type of activity is engaging, it stimulates critical thinking and problem-solving skills, it activates team spirit, and gives each participant the "flow" feeling and satisfaction (Nicholson, 2015). Play, according to Rowe (1992) is a fascinating, enjoyable and captivating activity that requires mental or physical engagement in the pursuit of anticipated awards (Grayson, 1999) and promotes creativity, imagination and spontaneous learning (Lieberman, 1977). Escape games are already used in education for a variety of subjects (Dietrich, 2018) and the Experience Pyramid Model is an explicit tool that can be used to design, analyse and understand services and products that are based on experience and observation (Riivits-Arkonsuo & Leppiman, 2013).

1.1 Vocational Education & Training (VET) & "A new beginning at EPAL"

Vocational schools try to follow technological changes, equip students with special skills and have access to the most up-to-date technologies. The economic climate of austerity has limited financial resources, so it's uneasy to respond to new and innovative challenges (Cedefop, 2018, a). "New beginning at EPAL", which was launched in October 2017, is designed to upgrade the role and image of VET in Greece and it includes actions that give priority to students' and society's needs and improve the school environment (Cedefop, 2018, b). According to

the Greek's Government Newspaper (Minedu, 2017) it supports designing action plans that link VET with local communities and establish collaboration with the greater educational and scientific society. These action plans can include STEAM, social, entertainment or cultural projects and teachers with active, participatory and experiential learning methods and in order to be implemented they are co-financed by Greece and Europe. The institution that is responsible for the whole project is Noesis (Science Center and Technology Museum of Thessaloniki).

One of the problems identified in Vocational Lyceum of Aiginio (a small town in the Prefecture of Pieria, Greece) is the lack of students' motivation, which strongly influences their study performance and their interests for school life, personal development and cooperation. The management team of EPAL Aiginiou discussed and agreed to support the idea of creating an Escape room at school. Such a live-action game for educational purposes seemed a perfect fit for students' needs. On the other hand, it would have a positive impact on the overall school reputation and image.

The Lead Author of this paper was appointed as the coordinator of the action plan. She fulfilled documents concerning a time-schedule and a budget. After sending them to Noesis (Thessaloniki Science Center and Technology Museum), the project was approved and co-financed with the amount requested from EPAL by Greece and the European Union.

2. Aims

Research reveals that escape rooms give a further boost to many valuable skills of the students and this results in the increment of their use for educational purposes (Lopez-Pernas et al., 2019). Williams (2018) observed the use of active listening skills, effective conflict management and efficient interdependent methods between students in his projects. Batzogiannis et al. (2018) indicate that students' engagement with co-creation of an escape room helped them discover and realize what they learn in STEM informal classes and enhanced their motivation towards STEM. Although several studies show that there is a successful use of the escape room as an educational tool in STEM courses, research reveals the huge gap in the literature about its use in an interdisciplinary approach that includes arts too (STEAM).

The basic aim of the study is to sheds light on the tools used for the co-creation of an alternative escape room in the Vocational School of Aiginio in Greece. It examines students' creativity in a STEAM project that entails the design of an escape room including the transformation of computer class using theatre, creative writing and theatre elements.

Its contribution is to show that it is possible to create an escape room based on the Experience Pyramid Model using theater, creative writing and technology elements in secondary education. It will present the puzzles, a survey about the reasons why members of the designing group didn't participate in the implementation part, comments from debriefing and observations that will help educators, scientists and anyone else interested in conducting such a project.

3. Related work

Some of the research that has been carried out till now and that involves escape rooms in education are:

- The educational escape room of Polytechnic University of Madrid that was conducted in December 2018 and 124 students participated, in order to solve computer-based and physical puzzles in two hours. Hints were given to them if they answered quiz questions correctly. The course staff organized it to increase the low pass rate. The results provide evidence that appropriate use of escape rooms can impact positively on student's engagement and learning in programming courses, that students prefer this method over traditional computer lab sessions and that an escape room that allows large number groups to participate at the same time can be a reality (Lopez-Pernas et al., 2019).

- Marinou (2018) implemented "THESEUS'S TOUR TO CRETE" for elementary school children, as an educational tool. In 5 rooms playfully and interactively students understood and consolidated History lessons, using at the same time knowledge they have gained from the Robotics Seminar STEM4KIDS to solve puzzles, spells and drive their robotic vehicle. She used VR to let them travel in the past, LEGOS to construct their robot and Programming in Scratch. She concludes that the use of the escape room in an experiential and playful way helped students exploit the knowledge gained during the robotics seminar, broadened their

skills and fostered motivation for learning and further deepening in the field of robotics and STEM. Marinou's project was based on Experience Pyramid Model.

- Fotiou Sotiris (2018), a Computer Science teacher in Vocational School of Corfu, implemented with his adult students a Tech Escape Room based on the principles of gamification. This project resulted in a unique collaboration of his students with teachers, inventors, scientists and researchers from other countries, the improvement of creation spirit and the gain of valuable knowledge and experience through fun. The room has a unique international character and it was designed using quiz, algorithms, programming problems, mathematics, literary poems, and physics, chemistry and electromagnetism experiments. Fotiou provided his material with the riddles to many schools in Greece and abroad in order to create the same successful educational game.

- "The Gate School Escape Room" was designed and implemented in a secondary educational center in Valladolid. It offers clear evidence that educational escape rooms, can support and enhance teaching and learning processes and improve students' academic, personal, and social attainments (Macias & Rocio, 2017). The innovative educational tool known as eduesc@peroom (Lookingatlearning, n.d.) was used, providing a toolkit with examples of different escape rooms developed, considering their strongest points.

- Kuriakidou (2019) teaches French and English lessons in a small Greek High School and started using escape room games as learning environments 3 years ago. Last year she joined forces with Fotara E., a French language teacher, and this year they cooperated with 5 European schools via e-twinning project, where 10 students of each school created the same scenario game in order their classmates to learn French in 30 minutes and manage to escape. She declares the great success of the project and that she will continue to implement it by expanding her cooperation with other schools.

- MathEscape is an Escape room game with tasks connected to mathematical content of a certain teaching unit. It was conducted for 24 second grade students of Croatian Grammar school program and 4th year students of Department of Mathematics majoring in Education of mathematics and Computer science participated in the study. Survey results showed that MathEscape was amusing, fun and enjoyable to be involved in and could be the method to make interesting any mathematical content revision lesson. Finally, it can help boost positive attitude towards mathematics (Glavas & Stascik, 2017).

- Mills & King (2019) created an escape room in order to help new academics in higher education enhance their learning about pedagogic theories. Game master communicated with the players through Skype and puzzles were both digital (some used Augmented Reality (AR)) and analog. The game ran for three different groups. None of them completed their mission successfully and some players were disappointed. The writers concluded that escape room isn't suitable for teaching higher level concepts, since its implementation is time consuming and it can run simultaneously only for small numbers of individuals. Finally they recommend that escape elements should be integrated into broader learning experiences or as small-scale learning activities within a workshop/class.

- CrashEd is an interactive learning experience using characteristics of an escape room, since it includes a "crime scene", participants that work together (applying STEM-based skills and knowledge) in order to solve a crime and a ticking clock. A timely animation is placed at the end of the educational experience to enhance the learning. CrashEd has proven especially effective as a way to enhance the learning cycle, empower and motivate pupils identified as detached from education and engage talented STEM students (Bassford et al., 2016).

- Scott Nicholson – Professor of Game Design and Development at Wilfrid Laurier University in Brantford, Ontario and the director of the Brantford Game Network game lab (BGNlab) – has written research papers on escape rooms, meaningful gamification, games in libraries, online education, and data mining. In his latest article "Creating engaging escape rooms for the classroom" (Nicholson, 2018) he explains the key design concept behind creating an engaging escape game and the importance of using such type of live-action games in school.

4. The project

The action plan took place at Vocational School of Aiginio (EPAL Aiginiou) that consists of 29 teachers and 120 students. Pupils from 5 specialties and 4 sectors of the school where selected to use their knowledge, their fantasy and their abilities in order to design an escape room using the Experience Pyramid Model. They should also be prepared and positive to cooperate with the 21 students of A' Class as tutors in order to show them how a knowledge gained from each field can be used enriched and linked to personal experiences, so to create a

project that can potentially be a future professional goal. Also 10 teachers from all the specialties discussed about the subject and decided to help this project to be implemented.

A meaningful experience is a positive and unforgettable emotional experience which can lead to a personal change (Tarssanen & Kylanen, 2009). Students that took part in the project during their lessons (Robotics, Information Technology and Programming, Food Technology, Electronics and Electrical Engineering and Marketing and other) should always had in mind which part of knowledge and learning could be used for the tutoring of A' Class students and the puzzles of the game.

In order to create an engaging experience, escape room design principles (Nicholson, 2015; Wiemker, Elumir & Clare, 2015) and Experience Pyramid Model (Heikkinen & Shumeyko, 2016) were taken into consideration. Technology, theater and creative writing elements were used with privilege or newly acquired knowledge simultaneously with key elements for designing and production of games and multimedia applications (Iuppa & Borst, 2012; Papakonstantinou, 2004). Table 1 summarizes the parts of the whole process that took place. The paper describes with detail only implementation and a post-evaluation, since other stages have been already presented in other papers or are still running.

Table 1: Summary of the parts of the procedure

Number	Part
1	The idea – Brainstorming – Working groups
2	Market research
3	Timetable – Budget
4	Pre-evaluation (online survey about students' opinions)
5	Space study and room selection – room design
6	Visit to escape room – Riddle recording
7	Theme selection – Artifacts from scenes of the serial
8	Scenario – New riddle recording
9	Theatrical games – Painting – Cooking – Experiments
10	Robotics – Programming – 360º Video capture, editing
11	Equipment – Decoration –Electrical installation
16	Storyboard – Riddle connection
17	Roles and Game master – Script
18	Implementation – Integration of riddles in escape room
19	Testing – Post-Evaluations
20	Marketing

4.1 Implementation

Based on the storyboard made at the design phase, students tried to link the riddles in a logical sequence, connect them with earlier course materials and achieve graded difficulty to them. The final ones that were integrated into the escape room are the following:

- Players should take off their masks and taste the cupcakes. Inside they will find four letters which create the word DALI. Posters of Dali Salvador and his paintings are used as decoration.

- DALI is the code that unlocks the unique, open computer that is on a table. A QR code appears on the screen with the message "Use a mobile to decrypt the QR code"

- There are 4 mobiles on the wall into a white case with pockets. One of them is smart phone and it needs to use a pattern to unlock.

- In a bin next to the door, there is a perforated card in A4 size. It has 4 holes. Behind the projection screen, on a whiteboard, 4 groups with several numbers are written in four lines. Players must use the card to reveal the unique digits that open a lock (on a drawer) and find a light blue len.

- Lights lower and players have to find arrows and coordinates of the motif for the mobile on the wall with the lens.

- When they open the mobile, they must scan the QR code on the screen, and a photo with 5 author names, photos and dates will be displayed. Photographs and biographies of 10 authors are on 2 notice boards. Highlighted digits from the date of birth or death of the author point to a page in the author's book.

- In the library, the authors' books on specific pages have words encircled. In one book players also find an envelope and in another one a paper with the following text: "Write a short story or a poem with the words you'll find, put it in the envelope and drop it under the door, to show that you're alive."
- Before placing the document in the envelope, the actor asks participants to play using improvisation their text or to sing the lyrics of the written poem in order to help them.
- Help is a riddle about chair. Players must find under a chair a key that unlocks a drawer with VR headset.
- The robber-actor puts the cell phone into the headset, a player wears it and, while watching a 360° video, he seeks for a 4-digit password that opens a small safe on the wall.
- From the safe box players get a magnet for a lock that opens a drawer with an Edison robot and user instructions about it.
- Players must place the robot on a second table and press play. The robot turns 3 times on the right or on the left side and plays musical motifs using different notes. The combination of the notes and the turns gives the code to open the final drawer with a master lock pad.
- Inside there is a 25-piece puzzle which presents the logo of a book safe box, in the bookcase. Under the puzzle is the 3digit code that unlocks the book where the exit key is in.

Before players enter escape room, game master gave instructions to them in another classroom. Debriefing took place in the same room, while photos and video were taken the whole time. During the game there was physical or social engagement with the actors (a student and the coordinator of the action plan). All of the riddles needed team communication and co-operation.

4.2 Post-Evaluation

This phase presents data collection through an online survey about the reasons that made students from the design group abort the implementation phase. It included a list of statements to which students should answer using the 1-5 Likert scale (1= strongly disagree and 5=strongly agree). At the end there was a space for other reasons, but no one fulfilled it. Table 2 presents the questions and the results of this survey, in which 12 students (all male) took part, 9 from C' Class and 3 from A' Class. For each question the Mean (M) and Standard Deviation (SD) are included.

Table 2: Results of online survey about students' abortion

Number	Statement	M	SD
1	I thought project wouldn't be implemented due to a delay in starting implementation.	2.83	1.14
2	I thought implementation would be a waste of time.	1.58	0.64
3	I preferred afternoon meetings.	2.50	0.95
4	Finally, I was not interested in escape rooms.	1.67	1.18
5	I was not willing to deal with / I was bumping.	1.91	0.86
6	I stopped because my friends stopped coming too.	2.17	1.14
7	I could not cooperate with the rest of the students.	1.17	0.37
8	This process was very difficult to me.	1.92	1.26
9	I was already tired from the designing phase.	2.00	1.08
10	There was no good cooperation with the teachers.	1.00	0.00
11	There was no good cooperation with the project coordinator.	1.00	0.00
12	I did not have enough free time for this project because of my examinations.	2.92	1.32
13	They did not listen to my ideas.	1.58	1.11
14	I felt uneasy/embarrassed/ashamed.	1.50	1.12
15	I never felt a member of the team.	1.17	0.37
16	I shouldn't have involved with the escape room and the action plan from the beginning.	1.17	0.37
17	It was enough for me to participate in design of the game.	1.83	0.99
18	I believe that my classmates couldn't teach me anything more.	1.67	0.94
19	I do not think that teachers could teach me anything more.	1.50	0.96
20	I had to work (outside school).	2.75	1.36
21	I had to use bus/taxi and this had a cost for me.	2.33	1.24
22	I had to leave from town.	2.00	1.53
23	My parents didn't let me participate anymore, since lessons had finished.	1.00	0.00
24	My friends didn't let me participate.	1.00	0.00
25	I wanted to play in the game, so I didn't want to know the puzzles.	2.58	1.44

In general, it seems that there is no specific and clear reason for students to drop out the action plan after the designing phase. There was a good climate of cooperation among students and between students and teachers and, nearly all, agreed that they were glad for their involving in the project. Parents and friends didn't influence them negatively and pupils believed that they could get even more useful information and knowledge.

The implementation phase started at the end of May, when students stopped attending school because of their examinations. The survey showed that 4 students of C' Class (44.4%) agreed with statement 12 and 3 of them (33.3%) neither agreed nor disagreed with that. So probably time of implementation wasn't appropriate for a big percentage of population.

Regarding students of A' Class, 1 of them absolutely agreed that the team didn't listen to his ideas, didn't expect to gain any more knowledge and believed that it was enough for him to participate in design of the game. 2 of them agreed that they felt uneasy in the team, though they all (3) integrated into the group.

A percentage of 25% (3 of 12 students) agreed that employment stopped them from participating and 33.3% (4 students) neither agreed nor disagreed with that. Also, 34% (4) left from town during the period of the implementation. Finally, 25% of the pupils stated that they would like to play the escape room game, which meant that they shouldn't know about the final riddles and another 25% neither agreed nor disagreed with that.

Another data collection is still online, and its results will show whether the action plan accomplished its aims and gave players an immersive and engaging experience according to the criteria of Experience Pyramid Model. The writers believe that its results will confirm the success of the room, because the post-experience communication with each team that played the game and the comments players wrote down after their participation were positive, full of enthusiasm and wishes for a new escape room topic in the coming year.

5. Conclusions

The lead author of this paper not only was the coordinator of the action plan, but also was the main participant of the project. She teaches robotics and programming and Information Technology (IT). Her observations during the lessons about the students' opinion, motivation and attitude concerning the game are the following:

- Students had real fun when they first used VR Headsets. It was a strong motivation for tutoring others, did extensive research and used their imagination.
- Learners during tutoring expressed prior interest in mobile programming and used their smart phone as QR reader, for 360o video capturing and editing with enthusiasm.
- Students found Edison robot programming very easy, really enjoyed those lessons and had many ideas about their use in the escape room.

In regard to creative writing, the expected collaboration with pupils of the literature class was not achieved because the course took place for one hour every week. However, students found phrases frequently used in escape rooms and actors finally, used those that originated from players' movements and dialogues, hints of the game and their own imagination and improvisation.

Although the design phase showed learners' full engagement to the project at the implementation phase, many of them resigned from it, mostly because of their examinations and their need to work. The online survey proved that time is an important factor, that influences both students' and teachers' participation.

A unique escape room was conducted in a Vocational School combining so many different elements of STEM and Art. During debriefing the comments were positive and encouraging:

- all of the players had a positive opinion about the game,
- some of them said it was professional with 3.5 level of difficulty,
- some of them suggested new themes for the next year,
- players congratulated the team because they created something original to the town,
- a new student of the EPAL asked to be member of a team that will create again an escape room in next year, while a student of another school asked the coordinator to cooperate with teachers from her school to implement a same project.

- Some players that didn't manage to escape asked to play the game again.

It's worth mentioning that inquiry has shown that in Greece there isn't any similar educational escape room. For future work an interview of a student that participated to every phase of the action plan and an online survey for players' opinion will be conducted to make sure that the criteria of Experience Pyramid Model were met. Also, the framework of this action plan will be used from other institutions, so to create their own escape room as learning environment. A proposal from the principal of an elementary school in the town is already made. Further investigation is certainly needed in the way an escape room is used as learning environment with STEAM elements, when created with time planning and specific team members.

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