Looking for the Antidote for Contaminated Water: Learning Through an Escape Game

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Abstract. This article presents a Breakout played with students of the Master in Teaching of Compulsory Secondary Education and Higher Secondary School, at the University of Salamanca, as part of their training as future teachers. Both the difficulties and the advantages that this type of educational activities bring out are analyzed. Moreover, some possibilities of its possible utilization in the classroom, at different educational levels, are also discussed and presented.

Keywords: Escape Room · Breakout educative · Gamification · Competencies · Assessment

1 Looking for the Antidote for Contaminated Water

I am attending the master course with 14 fellows, in a "Physics and Chemistry Didactics" lesson. An unknown man arrives at the beginning of the class. He identifies himself as the person responsible for the Health Department of the Spanish Government. He asks for our help in solving a serious problem existing in the building of our Faculty: the water is absolutely contaminated. We have been selected to begin working as part of an interdisciplinary team of graduates in Chemistry, Chemical Engineering, Physics, and Energy Engineering.

On the classroom screen we see a video where the problem is set out: the polluted water of our building could be extended both to the University of Salamanca and to the rest of the city, endangering the life of the population. In addition it would tarnish the celebration of the VIIIth Centenary of our institution, it would project a negative image of our city. We have to find the chemical combination that could purify the water as soon as possible to avoid massive poisonings among the inhabitants of the city, students, and tourists who visit us.

The initial shock turned into an exciting experience. This was the introduction to a game. We have 60 min to solve some riddles and problems to find the antidote and to make the water drinkable.

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We divide ourselves into two groups and each one receives a bag containing a roadmap (with a brief outline of the game), a meter, paper, scissors, and pens.

We enter a classroom in which there are a box with six digital locks (Fig. 1) and different objects both within sight and hidden. Interest, intrigue, and curiosity in knowing the next stage was increasing. Game starts!

Fig. 1. Box with six digital locks: view of the locks (left) and the QR code to access them (right). The QR codes were on the back of the padlock.

This is what students found in our Breakout implementation. Students had no idea about the activity that us, as supervisors, were proposing and they were anxious and full of expectation.

2 Solving the Riddles and Problems

The main part of a Escape Room or Breakout is the riddle solving. Nicholson *et al.* [8] defined them as: "Escape rooms are live-action team-based games where players discover clues, solve puzzles, and accomplish tasks in one or more rooms in order to accomplish a specific goal (usually escaping from the room) in a limited amount of time".

In our case, players must search and classify all the material they find in the room (Fig. 2). There were posters with Quick Response codes (QR), paper bows, water glasses, straws, pieces of a white puzzle, lab coats, balloons with messages, an invisible ink pen with a small flashlight on the lid, an augmented reality (AR) marker, etc. In the classroom there are also a computer and a screen in which a timer is displayed.

The students must verify that the QR codes corresponding to each lock give them access to a *Google form* questionnaire with one question. When they answer it properly they will open the corresponding padlock. Figure 1 shows the box with the six digital locks [7]. These are numeric, with letters and directional locks and each theme riddle/padlock has a different colour.

The game was designed for students of the Master in Teaching of Compulsory Secondary Education and Higher Secondary School. Therefore, it includes tests

Fig. 2. The players look for and classify all the material they find in the room.

of Physics, Chemistry and Education. In addition, an effort has been made to work different multiple intelligences carefully choosing the tests.

2.1 Parabolic Motion

Students need to find some hidden information throughout the room. Some drinking straws containing small papers are at their disposal, and one of these papers has a web address. When they access the site they see a scene from the film "In July" [10], which is about a parabolic throwing problem. Solving this problem they find four digits, i.e., the key that opens a numerical padlock.

They identify the padlock and open it. So, to get the password of the orange numerical padlock, students need to solve a parabolic throwing problem.

2.2 Types of Plastics

The *Google form* that is accessed with the QR code of the green padlock asks for three numbers. On the one hand, students found a crossword puzzle inside balloons. On the other hand, there is a stuck poster on the wall which gives them, through an AR App, the necessary information about the plastics with which the pieces of *Lego* are made. This is the key to solve the crossword puzzle. In addition there were selected, in a different colour three letters, which, using its corresponding place number in the alphabet, will be the key to the green padlock.

2.3 Refraction Index

In this case, the proposal is to solve an experimental test. Among the material found in the room there are an apparently white puzzle, an invisible ink pen with light on its lid (Fig. 3, left), a glass, a bottle of water and a stick. When the puzzle is illuminated with ultraviolet light, a formula can be observed (Fig. 3, right). This formula allows them to determine the refractive index of a liquid inside

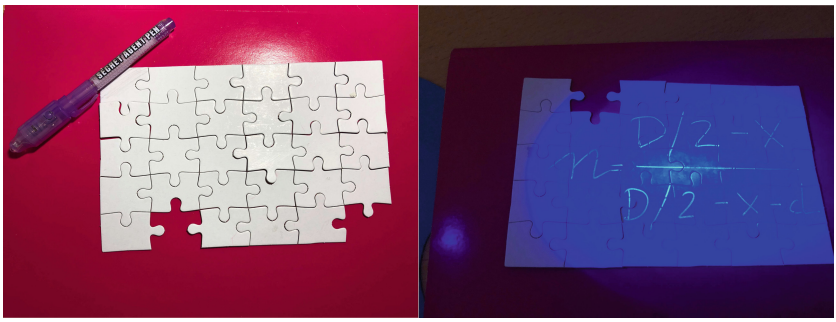

Fig. 3. An apparently white puzzle and an invisible ink pen with light on its lid (left). When the puzzle is illuminated with ultraviolet light, a formula can be observed (right).

a glass, experimentally, after taking the corresponding measurements. When they find the refractive index of the water, comparing it with a key-code which associates number intervals with the names of different colours, they will find out the name of the colour that opens the correct padlock.

2.4 Musical Ladder with Glasses

The students found tall glasses in the classroom, a bottle of water and a spoon to perform this musical challenge (Fig. 4). In the paper made bow ties they found different *Twitter* accounts from authors working on Breakout issues. One of these tweets contains the instructions to carry out the experience. They had to tune a musical scale with a different volume of water in each glass, to record a video with the musical scale and upload it to a *Twitter* account. Then they got the key to the purple padlock.

Fig. 4. The students found in the classroom tall glasses, water, and a spoon to perform this musical challenge. They had to achieve a tuned musical scale with a different volume of water in each glass.

2.5 Metacognition Staircase

To open the blue lock, students should know the meaning of the *metacognition scale*. The players, when scanning a hidden QR code, could see a video that explains what the *metacognition scale* consists on. On the other hand, they have to find some incomplete words, as in the *hangman game* [1]. With the video information they should be able to complete the sentences of the *metacognition scale*. Once resolved, they should select the letters marked with red colour. It is completed in ascending order from top to bottom. This is the key with the correct combination of letters for the blue padlock.

2.6 Secondary Education Law

In this test the padlock's key is some information that should be known about the education law currently in force in Compulsory Secondary Education. To answer the questions, the players found the clues in an interactive image made with the web tool "Genially" [2].

2.7 Opening the Sixth Padlock

With all the tests passed and, therefore, with the locks open, the students were able to get the only real key that opens the box. The box contains the chemical compound that managed to turn poisoned turbid water into crystalline. Amazing! The big problem of the contaminated water in our building has been solved.

This is how the game ends. However, the analysis of the reasons that support the realization of this type of experiences in the classroom, with students of all age, begins here.

3 Innovation Through Breakout

A *Breakout* is an immersive game derived from the popular Escape Rooms that are being played as leisure spaces in cities around the world. Can it really contribute somehow to the teaching-learning process?

Innovation in the classroom is done for different reasons. First of all we are playing with the objective of learning. This is what is now known as *Gamification* or *Game-based learning (GBL)* [9]. It is also contextualized in a narrative, which is the motivation to solve the tests and the common thread of all the activity. As Tang *et al.* [11] says "Games-based learning takes advantage of gaming technologies to create a fun, motivating, and interactive virtual learning environment that promotes situated experiential learning".

It is also a *learning based on challenges* because students must overcome a great challenge and small challenges in an estimated time. Undoubtedly, it is a process of mobile learning or *M-learning* as technologies such as QR codes, augmented reality, searches in different databases through the Internet, *Google forms*, applications like *Genially*, etc. are usually used. If the Breakout has been

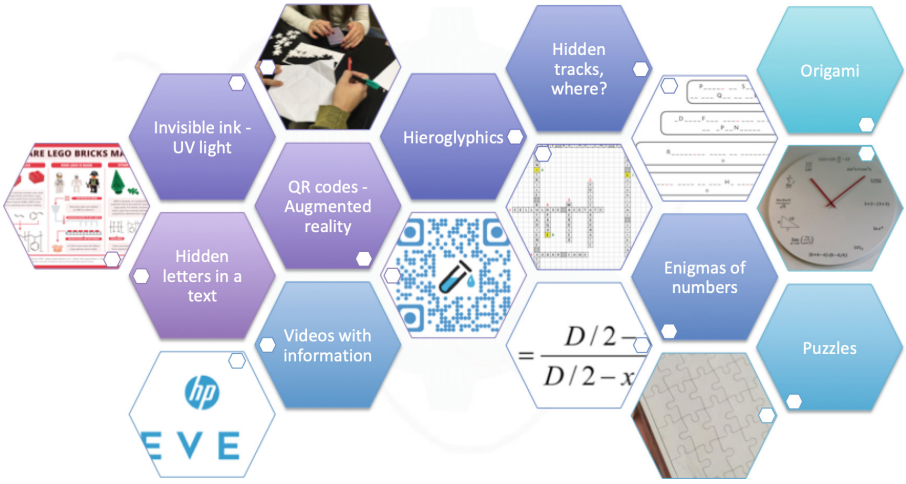

Fig. 5. Different type of tools used in the game. QR codes, augmented reality (AR) markers, puzzles, an invisible ink pen with a small UV flashlight on the lid, origami, hieroglyfics, etc.

properly prepared, *multiple intelligences* are also worked on, since the tests are of a diverse nature (Fig. 5), such as word games, riddles, maps, encrypted codes, hieroglyphics, puzzles, songs, experiments, origamis, etc.

This activity is designed so that the whole group of people involved collaborate, each one with their own skills, i.e., the most powerful Gardner intelligences [5]. It is played in teams made of 5 to 10 students, in which it is necessary to cooperate, to dialogue, to assume a role, and to reach a personal consensus to overcome the challenge. This is a fundamental aspect to take into account: the *collaborative work*.

With the use of a Breakout, different tests, challenges or problems are introduced in relationship to the *curricular content* of a subject.

There are many situations that allow themselves to introduce this tool in our teaching-learning methodology: initial motivation of a didactic unit, review of acquired learning, assessment of student learning, ask students to design tests for an activity of this type. For sure you, as a reader, also have some proposals.

The Escape Room experiences and Breakout in Education are growing, not only in Primary and Secondary Education, but also in Higher Education, as several studies show. In a recent study Clarke *et al.* [4] presents a framework for creating educational Escape Rooms for Higher/Further Education. The paper presents a pilot study that was used to assess the feasibility and acceptance of University teaching staff of embedding interactive GBL into a higher education environment. They concluded that there is a high level of interest from higher education staff on how to develop these experiences for their own teaching practice.

Vörös *et al.* [12] have developed an educational escape game for high-school students about physics of fluids. They concluded that gamification of educational process has multiple benefits: it is engaging (involves students towards active learning), stimulates curiosity, gives the "flow" experience, and gives real learning tasks. Even students with poor grades in physics had good results in the final quiz.

Hermanns *et al.* [6] presented a study to describe the use of a toolbox gaming strategy based on an Escape Room concept to help nursing students learn about cardiovascular medications in a pharmacology course. They ask for future studies to be conducted to quantify the students' academic success, i.e., test grades, self-confidence, and perceived competence after engaging in a non-traditional learning activity such as the toolbox puzzle exercise.

We think that Breakout is a really interesting activity to do with future high-school teachers, because it brings together all the aspects mentioned above. As noted by Castañeda Quintero and Adell Segura [3], an effective strategy for teacher professional development should incorporate exposure to innovations in teaching and technology, training to test new strategies and facilitate reflection and discussion aimed at a common purpose.

4 Discussion

Carrying out the evaluation with the group of students involved in the experience, the following reflection was achieved: it is an activity with numerous advantages but undoubtedly it also presents a series of difficulties, both are listed in Table 1.

Table 1. Breakout strengths and difficulties.

	For teachers	For students
Difficulties	Initial motivation	
	Calculate times adequately	Difficulty of the tests themselves
	Properly organize tests and clues	Teamwork
	Calculate the difficulty well	Working under pressure
	Excessive work	Frustration tolerance
	Teacher as manager of coaching	
Strengths		Learn playing
	Motivated/Motivator	Creativity
	Competencies-Based assessment	Multiple intelligences
	Multiple possibilities	Teamwork
	Learning	Student-centered learning

Among the difficulties that a teacher should take into account is, in the first place, the need of carrying out a good initial motivation of the activity to

get all the students involved. In addition, it must be taken into account that the adequate preparation of an activity of this type takes a lot of time and dedication before the game is set up (compared this with the time used to solve it). It is necessary to organize tests and clues very well, thinking about all the phases of the process to be solved. Always putting yourself in player's shoes. It is also important to calculate the appropriate times for the resolution of each particular test and the Breakout in general. The teacher, as game master, will have a role of "coaching and scaffolding": he guides the students by providing the instructions to carry out the activity, and is aware of possible difficulties or doubts that may arise. If there is any difficulty arising in the group, the teacher will take care of giving clues or advices so that the activity can follow its course, without getting to solve it in any case.

From the student's point of view there are several clear difficulties. Of course, one of them is the intrinsic difficulty of the game's tests. But another fundamental challenge is the need to work as a team, coordinating the tasks of all the components. Otherwise, it is difficult for them to overcome the challenges, as they demand different skills, knowledge, and competencies. A third difficulty is the fact that they must solve the tests in a limited time, that means, working under pressure. It is a game and, it is not always winning. Some of the students do not have a good tolerance to frustration, they do not really accept to loose. In fact, this actually happened because none of the teams solved the six tests by themselves, they needed the teachers' help.

We think that these difficulties can become a wealth, if they are calmly analyzed. Reflection can contribute to improve in future occasions.

The strengths presented by carrying out this type of activity are greater than the difficulties. From the point of view of the teacher it is an activity that achieves a very high motivation of students to solve a problem properly. A competencies-based assessment is actually carried out, since students should be able to perform activities in a different way of the normal protocols used to solve problems. The possibilities that are open are multiple, both to include the contents of any topic and the type of tests that can be designed. But, without a doubt, the main advantage is that not only students learn, but also who prepares a Breakout learns both during the process and in conducting the test.

One of the Breakout main values for the student is the possibility of learning while playing. In addition to discover the power of teamwork, as they see how the skills of each individual are necessary for getting the outcome of the proposed challenge. At the same time, multiple intelligences are valued as something real, not just in a theoretical way. It also encourages creativity that is characterized by the ability to perceive the world in new ways, to find hidden patterns, to establish connections between apparently unrelated phenomena, and to generate solutions. Finally, it can be said that it is a learning process focused on the student. As previously mentioned, the teacher plays a supporting role to give clues only if the game does not progress.

5 Evaluation

This experience has been carried out with students of the Master in Teaching of Compulsory Secondary Education and Higher Secondary School, at the University of Salamanca. The studies of these students are: Degree in Chemical Engineering, Degree in Physics, Degree in Energy Engineering. Only 40% of the people who made up the group had played an Escape Room before, therefore it turned out to be a new experience for 60% of the students. Most of them were not familiar with the usual techniques of searching and solve the riddles and problems. Students with previous experience in Escape Rooms have more facility to look for clues.

This has been a first pilot experience on escape games and their application in teaching. We plan to carry out this activity with graduates who are being trained to be future teachers because their opinion is important once the experience has taken place. As young people, but at the same time mature, they are familiar with the innovative trends in education, and open to experimenting with new teaching-learning proposals and therefore their viewpoint are very important.

Some of the opinions of the participants in the game are gathered here, after making the evaluation:

"We did a Breakout in class. I loved it. I find it a great idea. I saw a lot of possibilities. I am motivated, I'm sure I'll make one. The balance between master classes and games is perfect to consolidate learning."

"And it is not that everything went well, neither of the two groups were able to solve the complete enigma, but we did not erase the smile from the face or the desire to get it."

"I thought it was a good experience especially to motivate and encourage teamwork, while providing different views of the subjects and work the multiple intelligences of each person."

"Probably one of the best lessons of my life."

"The experience from my point of view has been spectacular, because I have had a good time, I have learned many things, especially experimenting."

"Give thanks to those who made it possible. Motivated teachers create motivated students, and if the students are future teachers ..."

"When we repeat?"

Reading the comments of the students it is clear that it has been a really positive experience. Despite the fact that they were not able, on their own, to solve all the puzzles, it is an experience to be repeated.

6 Conclusion

A Breakout has been carried out with students of the Master in Teaching of Compulsory Secondary Education and Higher Secondary School, at the University of Salamanca. The motivation to start playing was that they had to solve the problem of non-potable water in the Faculty. Six riddles/problems with contents of Physics, Chemistry and Education have been proposed. The final prize was to discover the chemical compound that will allow to purify the water.

The evaluation of the activity, together with the group of players, future teachers of Secondary Education, allowed us to reflect on the difficulties and advantages of this type of activity.

The Breakout activity is conceived as a good practice of innovative teaching, which includes important elements for the teaching-learning process: motivation, work with multiple intelligences, evaluation by competencies, teamwork, promotion of creativity and the students-centered learning.

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