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Educational Escape Rooms as a Tool for Horizontal Mathematization: Learning Process Evidence

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Abstract: The curricular perspective based on teaching processes which takes formal mathematical knowledge as a starting point has been severely criticized. This traditional perspective considers that the formal mathematical knowledge has to be taught prior to the application so, once taught, it can be used to solve problems. Along with this criticism, curricular alternative proposals that have focused attention on the learning process (rather than in the teaching one) have been developed. Recently, game-based learning has been developed as a problem-based learning methodology, able to achieve a deeper implication of the students. In line with this approach, the main scope of this paper is to provide evidence of the learning process in game-based learning environments. To do this, student teachers have designed an educational escape room that fits curricular learning outcomes. This manuscript reports on an educational escape room experience that was implemented in three different Primary Education Schools (total population of 117 students, while here we present a fragment of 5 participants). In order to evaluate the development of certain knowledge, a transcribed fragment is presented and analyzed. In the reported experience, evidence of learning processes and horizontal mathematization are reported in the frame of an educational escape room. This constitutes an evidence of learning processes in gamified environments.

Keywords: game-based learning; motivation; problem solving; mathematics instruction

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1. Introduction

The rise of escape rooms as a worldwide extended leisure activity is nowadays a reality. Such a success has been achieved in a brief time period, revealing its success as an innovative leisure activity [1]. In agreement with the available literature, an escape room (ER) can be defined as live-action team-based game where players discover clues, solve puzzles, and accomplish tasks in one or more rooms in order to fulfill a specific goal (usually escaping from the room) in a limited amount of time [2]. In addition to its leisure capability, ERs have gained research and educational interest due to potential applications for mobilizing abilities such as team building [3], leadership [4], creative thinking [5], and communication [6]. So, is not surprising that some educational institutions have started to integrate this resource in educational programs, using escape rooms with formative scopes. In this regard, some educators have gone a step forward in creating educational escape rooms which can be defined as "escape rooms whose resolution requires the mobilization of curricular knowledge".

Some authors have reported a successful use of educational escape rooms in a wide variety of topics such as in nursery [7,8], pharmacy [9], psychology [10], telecommunications [11], and STEM courses [12–14] or climate change education [15]. However, most of the authors do not provide evidence of a learning process during educational escape room (EER) experiences. Indeed, state-of-the-art educational escape rooms [16] highlight the lack of empirical evidence supporting the positive impact of educational escape rooms and game-based learning in general [17,18]. In this regard, EER-related literature lacks transcriptions of learning experiences, didactic analysis of the learning process, and analysis of the didactic suitability of the EER [16]. The lack of the weight of evidence in some game-based learning (GBL) published papers opens the discussion of the real performance, not only of GBL-EER approaches, but also of other GBL-serious games approaches [19]. So, the aim of this contribution is to provide evidence of a learning process in educational escape rooms by collecting data, transcribing an experience, and analyzing such an experience by using a validated model; thus supporting the validity of this approach as a learning tool.

2. Literature Review

This section presents a brief discussion connecting GBL as above mentioned; literature lacks evidence of learning processes in educational escape rooms [16]. In most of the available literature, cited in this manuscript, there is no analysis of the behavior, answers, and discussions of the students living the experience (at least, there are no discussions related to the curricular knowledge). Sometimes this information is deliberately omitted, so it is quite difficult—for the reader—to have a clear picture of what is really happening in the escape room, or even to verify that students have, in fact, learn something related to the curriculum. It might be because escape rooms are, indeed, a bad approach, or it may be because escape rooms are badly designed (becoming pure leisure games with no educational purposes or not fitting the curriculum).

2.1. Learning Through Gaming

Games, used as tools for educational processes, have some characteristics [20] that lead to a learning process centered on exploiting the features of this resource (mainly, freedom of action and being a leisure activity). On the other hand, this resource has a social and emotional impact due to its psychological and emotional factors (in terms of stress, joy, and motivation). Furthermore, the limited spatial and temporal extension of games allows players to instantly appreciate the value of their work being publicly recognized. On the other hand, applying games to education converts education into a universal activity, because games are a natural activity (we all know how to play). For this, we consider that team-play may awake relational aspects, favoring imagination and divergent thinking because of the socialization and group discussions linked to independent work (which may ease the exploration of a diversity of solutions by sharing ideas). Such elements are connected to the formative potential of games, conceived as a problem-based methodology. Indeed, stages in problem solving and gaming are equivalent [21], as detailed in Table 1 (where Polya phases [22] are connected with the comprehension of a problem/game [23]).

Table 1. Four Polya phases, connected to the comprehension of a problem/game.

Polya Phase	Comprehension of the Problem	Comprehension of the Game
Understanding the problem	What is the problem asking for? Identifying problem data	Which requirements do we have to fit? Identifying possible actions
Devising a plan	Comparing to similar problems Making guesswork	Comparing to similar games Making strategies
Carrying out the plan	Guesswork assessment Execution of the plan	Strategy assessment Gaming
Looking back	Strategy generalization: is it worth in any problem? Modeling the strategy for "certain types of problems"	Strategy generalization: is it worth it in any condition? Modeling the strategy for "certain types of games"

The use of specific game's dynamics to strength motivation and to stimulate individuals to achieve previously determined goals is known as "gamification". Even when "gamification" admits other definitions on the literature [24,25], all these definitions share a common aim: increasing the interest of a part of the population over a determined subject. Finally, gamification has been studied in the literature; to fulfil the goal of "transforming work into games", some specific properties have to be respected [26].

In our context, the interest of applying educational gamification is related to its capability to mobilize specific competences and knowledges. However, most educational games are designed not to learn, but to apply previously acquired knowledge. In this regard, some studies [27] invite one to subtend the acquisition of the knowledge (more specifically, mathematic knowledge) taking a "situation-problem" as a starting point (so that a scenery and a context is specifically built for a problem-based approach). We decide to name the combination of these two approaches as "gamified environments", to focus on the importance of an immersive experience that stimulates the autonomous work.

2.2. Cooperative Learning in a Educational Escape Room

A conventional escape room consists in a live-action team-based game where players are jailed in a room where they will have to solve puzzles in order to unravel a story and to escape before the available time ends. Using mathematical puzzles (such as situations of calculus resolution, data acquisition, probability determination, and more) the players get access to a combination of numbers that enables them to open mechanisms—available in the room—which grant access to other puzzles. The last enigma (or the combined result of some enigmas), grants the final code to escape the room. Finally, there is a "game master" supervising the escape room experience, who can eventually communicate with the players.

In this contribution, the author's starting hypothesis considers that an escape room-based activity might be a powerful educational resource to create learning opportunities for primary-school students. By using an EER to tell a story, students are transformed into protagonists of an escapism tale and, to have success, they will have to mobilize curricular knowledge (conveniently fitted to the educational level of the students). In addition, this resource fosters collaboration, allowing the development of social skills (cooperation between players is essential to complete the adventure).

In this regard, cooperative games are presented as a common challenge to the players, who would like to "win the game". In this case, they should mobilize not only curricular knowledge but also communication skills [5]. The need for communication can be stimulated by using linked problems (for example, by using a code that may grant access to different, simultaneous puzzles) and by spreading clues all over the room. Communication is mandatory to track the obtained codes, the common tools, keys found, etc. The way in which students are grouped also has a direct impact on student success [28], and this is also true in EERs.

Literature has demonstrated that creating performance groups might be prejudicial (especially, for the case of low performance groups). Results obtained in international research reveals that heterogeneous grouping might improve the academic performance [29] and the self-esteem. According to this, in the transcribed experience available in this manuscript students have been grouped to ease peer to peer discussions; creating heterogeneous groups whose students show different social skills and academic performance.

2.3. Mathematization in EER

Mathematization is defined as the process of traducing "real problems" to a mathematic language. In this regard, two approaches can be considered: horizontal and vertical mathematization. Freudenthal [30] highlighted that "horizontal mathematization leads from the world of life to the world of symbols: In the world of life one lives, acts (and suffers); in the other one symbols are shaped, reshaped, and manipulated, mechanically, comprehendingly, reflectingly: this is vertical mathematization". So horizontal mathematization focuses on making a problem accessible to mathematical treatment, while vertical mathematization focuses on the mathematical processing (independently of how sophisticated this processing is).

In horizontal mathematization, the process of mathematization focuses mainly on ordering, schematizing, and building a model of the reality so that it becomes amenable to be dealt with by mathematical means. To achieve this goal, activities have to be designed establishing relationships between the natural language and the symbolic one, using appropriate tools and models, finding regularities and relations, recognizing isomorphism to similar problems, and identifying the relevant mathematics data. Once the real problem is traduced to a mathematical expression, the process can be continued to an argumentation and generalization stage. According to this, EERs should provide tools to collect data, as well as to establish relations and find regularities. The situation should emphasize the mathematization of the problem and the generalization of the conclusions.

In this regard, the way in that an EER conducts the narrative, connects the clues, and provides the tools can ease or make more difficult the research and, thus, the learning and the mathematization process. Literature highlights three main categories [16] depending on how the problems that composes the whole activity are connected among them:

- Linear escape rooms, whose problems are following a linear sequence and have to be resolved following a strict order.
- Non-linear escape rooms, offering a higher number of clues and puzzles that can be resolved in any sequence (so players can decide how, when and who is going to solve each problem).
- Distributed escape rooms, where players are "isolated" among them (each player is in a different room). Distributed escape rooms can also be linear or non-linear, but the fact of isolating each player makes them different enough to have their own category.

In our experience, a linear approach was used. This approach was considered because of the lack of experience of the players with EERs. The main advantage of linear escape rooms used in primary education is that each clue and key have a single use, thus simplifying the concatenation of quests and tasks.

3. Experimental Methodology

In January 2017 a group of 3 student teachers started to design educational escape rooms as final project of the "Primary Education Teacher" degree of the University of Cadiz, under the supervision of the author. As a consequence of the positive formative impact achieved (both, in student teachers and primary education students), Primary Education Schools (CEIPs) demands additional EERs experiences to be implemented. In the 2017–2018 academic year, three different CEIPs were interested on the implementation of EERs. To cover the demand as well as to impulse the formative potential that the design and implementation may have on student teachers, designing educational escape rooms was proposed as the final task of a two-year subject (Didactic of the Mathematics I and II, which have to be coursed during the second and third years of the four year degree). As a consequence, a complete EER was designed by a group of 68 student teachers during a two year formative process.

By the end of the 2018–2019 academic year, the experience was implemented in three different CEIPs. The methodology involves a close communication to each CEIP, so that the experiences could be implemented well-fitting to the development of the conventional course. In this manuscript, a fragment of one of the experiences implemented is presented.

3.1. Design Criteria

In order to proceed with the design of an EER, design criteria were provided to the student teachers. In this regard, some educational escape rooms design guidelines are available in literature [31,32], lacking—in some cases—scientific references supporting such guidelines. Literature has plenty of "false" escape rooms [33,34]: players are accompanied by the teacher [13], or the escape room experience is reduced to "opening a box" [35] during a conventional lecture. Indeed, in these approaches, a player does not have to escape from any room. Educational escape rooms are yet in an emergent situation, so there is still some misinformation and confusion. This situation sets the point to establish specific criteria for defining "what an educational escape room is".

Going back to the basics, conventional escape rooms are designed to reach "flow state" [36,37]; a state where a sufficiently high effort is required in order to overcome the difficulty of the challenge (not so easy to be bored or relaxed, not so difficult to be anxious or worried). However, to the consideration of the author, some additional parameters have to be considered in order to create an EER. In this manuscript, the author considers that EERs should fit to a problem-based learning (PBL) approach, so PBL guidelines [38,39] have to be considered. The author assumes this approach because PBL characteristics such as activity-based learning, exemplary practice, interdisciplinary learning, and group-based learning are also present in EER. Taking this into consideration, the following design criteria are proposed:

- Dynamism: Linked problems and enigmas should be designed to be solved in a brief time. A good EER should be composed by many "little problems" rather than a single big problem.
- Performance: To achieve the previously described "flow state", the EER has to be fitted to the knowledge level of the student/players. Specific difficulties, detected during the conventional course, should be addressed during the game; creating a framework where peer-to-peer discussions help to overcome such difficulties. So, students should be grouped in a specific manner. This was discussed in Section 2.2.
- Communication: In the case of an educational escape room, obtaining the final code should not be the end of the activity; once finished with the escape experience, students/players have to be interviewed in order to discuss and to think about the problems solved (which should be connected to the story). This is due to the excitation of the players: the emotional dimension has to be reduced in order to avoid diluting the formative scope.
- Isolation: Isolation of the players is fundamental not only to promote autonomous work, but also to promote cooperative work. In the context of education, the game master becomes a "game teacher"; which may provide orientation, reformulate sentences, highlight clues, or even remind the players the position of a forgiven object. His role is to grant an optimum experience, both emotionally and formatively. Moreover, communication among players and the "game teacher" in real educational escape rooms is quite limited (normally, to audio–radio communication). In this regard, difficulty of the challenges and resources provided to the players plays a key role to deal with this limitation.
- Continuity: Educational escape rooms should be meaningfully connected to the concepts and knowledges that are being worked on the conventional course at the moment of the implementation. Furthermore, an EER might be useful to introduce new concepts, being later discussed in the conventional course. Finally, narrative, scenery, and storytelling are useful not only to create an immersive experience [40] but to fit to an integrated curriculum approach.
- Curriculum: Enigmas and problems of an EER should mobilize curricular concepts and, in the particular case of mathematics, they should fit to the standards and principles described by the NTCM (National Council of Teachers of Mathematics) [41] for each educational stage.
- Assessment: Finally, as in any educational experience, an EER constitutes an activity where the development of certain competences should be assessed.

Some of these criteria are coincident with traditional parameters used for designing and scheduling conventional [42] and PBL educational situations [38] (particularly curriculum, continuity, and assessment criteria). However, some criteria are specific of EER designing, because of its own peculiarities. In this regard the "isolation" criterion is an exclusive characteristic of EER, as well as "communication", "dynamism", and "performance" criteria.

3.2. Participants and Sampling

The design of the complete experience was carried out by student teachers during the second and third courses of the Faculty of Educational Sciences of the University of Cádiz (Spain), as a part of a project of the core subject "didactic of the mathematics" (this project is extended over two years of the academic formation). A total of 68 student teachers have designed the experience, with an average age of 21 years. As a part of the design procedure, student teachers (as well as the professor in charge) maintained discussions with the different CEIPs where the experience takes place, in order to schedule the implementation and to decide the curricular concepts of the EER.

Three different CEIPs were involved in this project and a total of 117 students have participated in 27 implementations of the EER. These 117 students belong to 6 different classroom groups, two by each CEIP. The participants in the study were students of the fourth course of primary education (9 years old). The inclusion criteria stipulated that participants would be video recorded as well as required to give a mandatory signature for a data protection agreement. Prior to the implementation, normalized diagnostic tests of the mathematic competence were carried out (covering basic mathematics knowledge).

Data collection was carried out by video and audio recording all groups; three different cameras were used to grant optimum visual access. The composition of the groups was established in 4–5 students. The different experiences had a maximum duration of 45 min (allowing to order/clean the room for the next group).

The implemented experiences took place at different timetables, depending on the needs of the CEIP (most of the experiences were implemented out of the conventional school timetable). Experiences performed in the same CEIP were carried out in the same week. Experiences performed with the same class-group were carried out on the same day. The same EER experience was implemented in the different CEIPs because of the similarity of the results obtained in the diagnostic test (no school-to-school adaptations were needed). Finally, the experiences were implemented in April and May 2019; the transcribed experience was recorded in May 2019.

The implementations of the experiences were supervised and carried out by the author, with the support of three cooperating student teachers. The teachers in charge of the students also cooperated during the implementations.

3.3. Setting of the Implemented Experience

The experience transcribed below corresponds to a 5–7 min fragment of a whole 45 min experience and was designed to fit the curricula of Spanish students of the fourth course of primary education (9 years old). Timing is important, because the escape room experience must fit with the concepts being worked on conventional lectures at the moment of the implementation.

In this regard, concerning the student learning outcomes, student teachers (university) and on-service teachers (primary school) decided to work the curricular topic of "magnitudes and measurements"—particularly, those related with the third section of the educational law [43]: 3.2, 3.3, 3.4, 3.5, 3.6, 3.9, 3.13, and 3.14. This is because on-service teachers consider that "measuring" is a mathematic activity that is constantly appearing in our daily lives (indeed, measuring is a common activity for cultures of all over the world in any time and place [44]).

The educational escape room is composed of four main problems (and four introductory narrative problems, one per main problem), lineally connected among them. Each problem counts on its own tools, data, clues, and space of the room. Moreover, each problem was related with a specific moment of the narrative: "your mathematics teacher has been kidnapped!" The narrative involves a kidnaper which plans to ask for a rescue in order to pay bet bills. So, students on the EER will have two main missions: (i) rescue the kidnapped teacher and (ii) escaping the room on time (right before the kidnaper returns). The activities on the EER are narrativ ely connected among them:

- (A) Measurement—lengths: Entering the room and looking around, students should find the "diary" of the kidnaper. There, they will find many hippodrome bills. Reading the diary, they should note that the kidnaper is ruined because of addiction and bad prediction in betting games, they should also read a clue indicating some key objects on the room which have to be measured. The first problem involves length measurements over "on the room" objects which codes a locked box where the personal objects of the kidnapper are stored.

- (B) Measurement—weight: The second problem (transcribed below) involves the personal objects of the kidnapper, which have to be weighted in order to open the third activity.
- (C) Statistics—measurement of a probability: The next activity involves four horses over a marked track. There are also two DICES. The clue states that each horse will make a step on the track each time the sum of both DICES matches with the number written on the back of the horse. This is the problem that ruined the kidnaper, so the right bet is a key piece of the argument.
- (D) Magnitude—time: Once the activity is solved, players gain a code which grants access to the second room (gate (ii) on Figure 1). There, they can rescue the kidnapped teacher who will provide them with the last clue. Players will have to use superimposed transparent sheets to build a clock which will provide a code to escape the room (gate (i) on Figure 1).

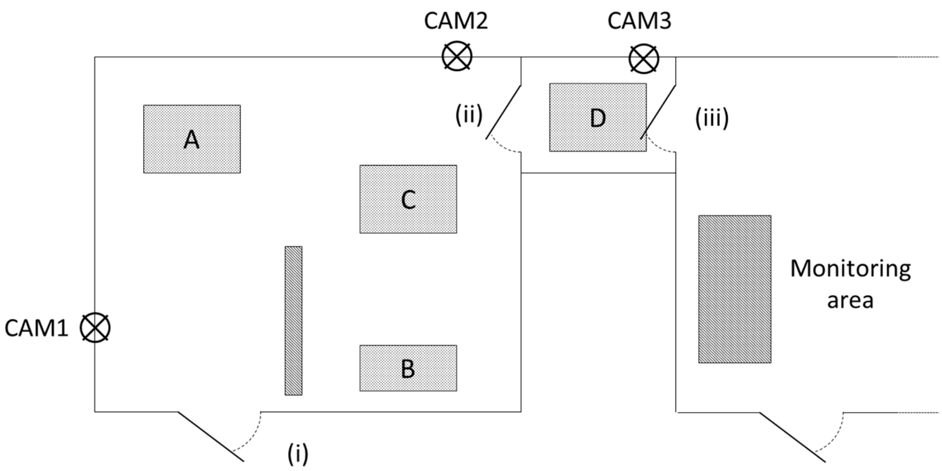


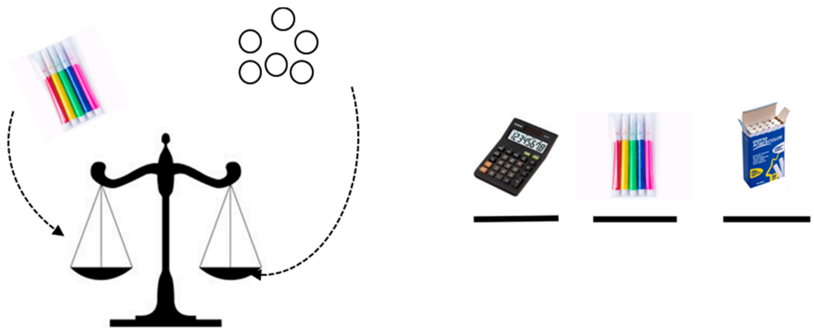
Figure 1. Schematic of the distribution used during the experience. A monitoring area is used to track, record, and communicate with the student players. The whole experience is composed of four problems (labelled as A-B-C-D). Students shall open (i) and (ii) gates in order to escape the room and rescue the kidnapped teacher, respectively. Each problem is narratively linked with the next one. Finally, three different cameras were used to grant a proper recording of the experience.

On-service teachers cooperate with the experience, remaining in the "monitoring area" (see Figure 1) until the moment of going to the room where problem D is located: the place where the players will find the tied teacher ready to be rescued. The EER is composed of two rooms, the main room where three main problems are located, and an auxiliary second room (which also connects to the monitoring area). Students are recorded using three cameras (positioned as presented in Figure 1); the monitoring area is also used to establish audio communication with the students. As previously mentioned, the experience is composed of four main, consecutive problems on the topic of "magnitudinal knowledge": (A) lengths, (B) weights, (C) probability, and (D) time. The experience described below corresponds to the B problem and an approximate time of 15 min was estimated for solving each problem.

Prior to the access to the scene, students are organized by roles: one will get the "books of clues", another will get the "radio" to communicate with the game-master, etcetera; tools, normative, and other resources are also provided. The standard procedure is explained: when a problem is solved, a code is obtained; such a code will grant access to the next problem.

Concerning the B problem, students will find a chest containing a set of markers, a calculator, and a set of chalks and marbles. Players should use a conventional, non-electronic balance (available on the room) to weight the different objects by using the marbles, according to the narrative and the clue provided in de book of clues (clues provided for problem B can be consulted in Figure 2).

By using marbles and the balance—see clue available in Figure 2a, students should weigh each object. The weight, traduced as the quantity of marbles, will provide the code to the next problem once ordered as presented in Figure 2b.



(a) **(b)**

Figure 2. Clues provided to solve problem B (both images were available to the student/players). Figure (**a**) shows an example of how marbles shall be used to weight objects, while Figure (**b**) shows the sequence that will provide the code for the next problem.

4. Results: Transcription of the Experience

This section presents a transcription (5–7 min of the whole experience) of the educational escape room previously described. This experience was implemented in C.E.I.P. By the nature of this experiment, transcription becomes difficult (sometimes students talk simultaneously or whispering). The fragment transcribed corresponds to the problem B (see Figures 1 and 2), starting when players open the "B chest", finding the following clue: The kidnapper has lost some objects ... which he used to remember a secret code. You have to solve enigma B (players are referred to the book of clues, where Figure 2 is presented). The transcribed experience flows as follow:

1. Game Master: (student teacher, by using the speaker system) You've almost solved the whole room, you're closer to the end! What did you find in the new chest?
2. Student 1: A set of markers, a calculator, a set of chalks and many marbles
3. Student 2: (opening the clue book) Look, there is a draw!
4. GM: Really? What is drawn?
5. S2: That (signaling the balance)
6. GM: All right! What can you do with all this?
7. The group of students moves to the table with the balance, carrying all the objects of the chest and placing them in the balance using different configurations. The first configuration attempted was placing the clue book in a plate and the set of chalks in the other.
8. Student 3: No, no ... is not like that
9. Student 3 redistributes all the objects, looking for equilibrium in the balance: the set of chalks and the calculator in a plate, markers and marbles in the other plate.
10. S3: Now?
11. GM: Hello! What are you trying to do?
12. S3: This is not working!
13. GM: Why not?
14. S3: Because we don't know the number (referring to the code number they need to get access to the next problem).
15. GM: Try to check the clue book again; you are probably not distributing the objects properly.
16. Students check again the draws (Figure 2). After a brief discussion, they place all the objects (except the clue book) in one plate, and the marbles in the other plate.

17. S3: Still moved (referring to the non-equilibrium even using all the objects and marbles)
18. S1: We shall only use markers and marbles.
19. They place the markers in one plate and marbles in the other plate. They make various mistakes, trying with different amounts of marbles, showing impatience and discussing about the right position for equilibrium.
20. S3: No, is not like that
21. S1: Yes, is like that; but is not good if is still moving
22. After some minutes discussing and some fails (most connected over excitation and a lack of patience, waiting for the equilibrium of the scale), they manage to weigh the markers
23. S1: It is a set of markers and 5 marbles
24. S3: And now?
25. S2: (Consulting the clue book). Here we have three; we have to get three numbers (referring to Figure 2b).
26. Student 2 refers to the number of slots that are presented in the clue book. The weight (in quantity of marbles) will provide a number and the correct order will open the next chest.
27. GM: Nice! So you already have one of the three numbers!
28. S2: (Talking to the group) we still need two more numbers.
29. S3: Let's do the same with the calculator
30. Now the students weigh, one by one, the rest of objects, getting the equivalent number of marbles. They get the code by ordering the numbers, checking the clue book.
31. The group moves to the next chest-problem while S3 remains playing with the scale and trying different configurations (see Figure 3).
32. Student 3 remains playing and weighting different objects, including objects of other problems. Once different configurations and objects have been tested, he removes all the objects from both plates of the scale.
33. S4: Ey! look, look!
34. The whole group gets closer and asks "what happens?"
35. S3: (Talking to the whole group) Nothing and nothingness have the same weight!

Figure 3. Instant of the transcribed experience when S3 remains exploring and testing different combinations on the balance, even when the whole group considers that "the problem has been solved".

Once the whole experience is finished, a picture of the student is taken (holding a banner with the total time used). It is at this moment when they are asked about the experience: degree of joy, main difficulties and concepts learned. Concerning the transcribed fragment and in the case of S3, he declares that "certain objects have more numbers than others in the balance" and that "the balance can be used to check if an object has more or less numbers than other one". Once requested and thinking about "which numbers do the balance measure?", S3 regains the association with the "weight" concept and no longer refers to the problem with expressions like "object that has more numbers".

While the whole EER experience is not reproduced here, some additional questions, regarding the degree of comprehension of the adventure and the sequence of clues followed, and the track of the argument was discussed. Students were asked about some narrative questions. Some questions were why was the teacher kidnaped? Why the kidnapper does needs money? What was the right bet not to be ruined? The answers to these questions are not analyzed here, because the author would like to focus on the use of EER as a tool for horizontal mathematization. However, it is clear that EER can be used to establish connections and to promote reasoning; establishing a frame to provide context beyond the mathematic knowledge.

5. Discussion: Analysis of the Transcribed Experience

Formative performance achieved on the transcribed experience has been evaluated by carrying out a didactic analysis of the experience. Didactic analysis is a common term used in didactic of the mathematics' research and it includes a set of concepts and methods widely used by research groups, highlighting conceptual and procedural aspects [45]. In this manuscript, a validated model created by Font [46] has been used (because of the agreement with the paradigm behind Font's model [47]). Additionally, a brief analysis of the didactic suitability of the formative process has been carried out using a validated model [48] which is in agreement with Font's model (sharing the same paradigm).

5.1. Didactic Suitability of the EER

In the particular case of a gamified environment—concreted as an EER—the importance of achieving the "flow state" has been already discussed in Section 2. In this regard, the curricular content as well as the tools, guides and supports have been fitted to the specific characteristics of the course and school (in order to preserve flow state). In this regard, the idea of "didactic suitability" presented in literature [48] fits well to our didactic engineering approach [47]. So, a "didactic suitability" check of the experience was carried out as follow:

- Epistemic suitability: it is the implementation of the institutional knowledge. To fulfil this requirement, knowledge and mathematical procedures mobilized on the EER shall be considered "good mathematics" (it is, useful in daily live). We consider that this item is fulfilled because of the agreement with the on-service teachers at the school. Indeed, the curricular topic (magnitudes and measurements) was specifically chosen for its direct application.
- Cognitive suitability: it is how the activities are distributed throughout the formative process. The transcribed experience is developed in the frame of a conventional course. The implementation of the EER was scheduled in agreement with the CEIP, so that the knowledge to be used in the room should be at a reasonable distance to what students already knew. That is why cognitive conflicts—induced by cognitive limitations right in the moment of the experience—were overcome through discussion and experimentation. On the other hand, EER was an opportunity to cover new questions; in this regard, problem C was proposed as a way to discuss the relationship of the statistics with the magnitudinal knowledge. Students were asked about "can you measure a probability?" or "is the probability a magnitude?"
- Interactional suitability: it is the grade in which the activity allows identifying and solving semiotic conflicts by negotiating meanings. In the transcribed experience, peer to peer discussion is evidenced to be useful to provide answers by negotiating mathematical terms like "equilibrium"—this word is not exactly used, but the players use other words to describe this concept, like "is still moved" (17).

- Media suitability: it is the grade of adequacy of the materials and tools provided. In the transcribed experience, the provided tools are shown to be enough for an appropriate development of the experience. However, weights of the measured objects may induce mistakes. For example, chalks might be broken, and, in that case, the equilibrium of the balance will not be perfect. Moreover, waiting for equilibrium slows down the game dynamic. We consider that the provided tools provide more advantages than disadvantages at this point.
- Emotional suitability: it is the grade of motivation and interest of the students during the formative process. We consider that the mentioned experience has a high degree of emotional suitability. Indeed, motivation arises during the process of solving the problem. On the other hand, students help each other, this is positive not only because of the common implication in a learning process, but also because of the moral values evidenced.
- Ecologic suitability: it is the grade of fitting of the experience to the educational project of the school. In this regard, we consider that ecologic suitability is quite appropriate because the topic, concepts, tools, and moment of the implementation were negotiated with the on-service teacher.

5.2. Didactic Analysis of the Transcribed Experience

For a proper analysis of the transcription, it has to be highlighted that the "game teacher" is, indeed, a student teacher (particularly, the student teacher which was "on-practices" with the student/players). The role of the game teacher, as well as the answers and interactions among the student teacher and the student/players will be discussed in future studies. On the other hand, Font's model [46] is here used to carry out the analysis, so the following aspects will be considered: (i) mathematical practice, (ii) mathematical objects and processes, (iii) interactions and conflicts, and (iv) mathematical norms.

5.2.1. Mathematical Practice

The first stage of analysis is "mathematical practice" and is related with the capability to understand the problem and the useful data. In the transcribed experience, some difficulties on "mathematical practice" are evidenced:

- Student 1: successfully reads and understands the statement of the problem, he solves the first section of the problem and proposes some ways to solve the conflicts.
- Student 2: looks like he is reading and understanding the problem, active participation in problem solving.
- Student 3: looks like he does not understand the statement of the problem until it is explained by his peers. He also realizes on contradictions among his expected result and the experimental results.
- Game Master/Student Teacher: collaborate to organize group's ideas, intervene to complete explanations and redirects the situation. However, it fails to clearly structure the objectives of the problem at first (11).

5.2.2. Mathematical Objects and Processes

The second stage of the didactic analysis is known as "mathematical objects and processes"; this stage is related to the mathematic knowledge, language, arguments, propositions, and procedures. In the transcribed fragment, some mistakes are identified:

- Student 1: deals with the initial error, participates in the analysis of the process (16), and correctly interprets the coding of the problem (18) represented in Figure 2. During the measurement process (18), he builds an argument and indicates the correct procedure to carry out the measurement (21).
- Student 2: once observed the resolution of the first problem, and he identifies a common strategy to solve the next problems. He relates the remaining digits of the code (25) with the quantification (28) of the rest of the elements of the problem, stating the problem to be solved.
- Student 3: after the initial error, he participates in the analysis of the process (16) and draws conclusions (17). During the measurement process (19), he questions the validity of the resolution

(20). Subsequently, he proposes a resolution strategy following a procedure similar to that followed to obtain the first digit (29), thus, identifying a pattern for solving the problem. Once the problem is over, he continues working on it, showing productive disposition (31) and exploring new possibilities by modifying the problem (32). Exploration with different objects allows him to conclude that "objects are heavy"—even "nothing" is heavy—showing a process of generalization (35), which is communicated (33) to his peers. This process of generalization and idealization is hampered by the cognitive limitations of the student at the time of learning (see interview after transcription). However, an approach to the idealization of the measurement process is evidenced.

In the case of transcribed experience, the mobilized mathematical objects are those related to quantification (that is, to the concept of quantity). Such a quantification arises when defining a unit of measurement (the weight of the marbles) to assign a quantity to the "magnitude: weight" of the object to be measured. Therefore, the mobilization of mathematical concepts (called objects in the Font model) related to quantity, magnitude, equivalence, and unit of measurement are evidenced. In the same way, in the described experience, the notion of equivalence between quantities stands out (22), being established through the use of the balance, in connection with the concepts of equality and equation "calculator = x · marbles". On the other hand, an estimation process is observed at the time of placing the objects on both arms of the balance, thus optimizing the resolution process by trial and error. Finally, other processes such as analysis, argumentation, systematic resolution, and generalization are observed, which are also manifested during the experience.

5.2.3. Interactions and Conflicts

The escape room is a strongly interactive environment in which student players are continually interpreting and regulating their group performance. In this regard, students could autonomously use measurement tools, thus allowing them to think and discuss about the problem. In the transcribed experience, the balance has allowed us to verify estimations, establish equalities, and corroborate hypotheses, familiarizing students with the scientific method through the process.

On the other hand, as a consequence of the great diversity of didactic interactions, we have focused on semiotic conflicts [49]. In the analyzed episode, students 3 and 1 discuss the correct application of a strategy (20, 21), right when student 3 questions the procedure used. In such a moment, student 1 gives a "phenomenological" argument of the resolution (providing a response so that an understanding of the "equilibrium phenomenon" can be intuited). This supposes an intention of student 1 to overcome the contradiction of his partner. Student 3 seems to overcome his contradiction throughout the experience, since there is a practical disparity that reflects the overcoming of a semiotic conflict. Student 2, meanwhile, acts as a spokesperson of a valid way to solve the problem.

5.2.4. Mathematical Norms

A social dimension emerges from the transcribed experience. In fact, the escape room is a micro-society where the dissemination and construction of mathematical knowledge takes place through social interaction between students (and, eventually, the game director). Consequently, mathematical learning is conditioned by didactic and mathematical meta-knowledge. In this regard, assuming an "epistemic norm" as the configuration of objects which regulate mathematical practice in an institutional framework, we can conclude that this group of students has advanced in the understanding of the phenomenon treated by implicitly answering questions such as: what is the problem? When is it solved? Which procedure should be followed to solve it?

Finally, this educational experience has an emotional aspect that becomes evident in student 3. In this case, student 3 experiences an autonomous learning process by physically experiencing and "discovering" the weight measurement procedure using a balance throughout the experience. Based on the Csikszentmihalyi model and with respect to student 3, it can be assumed that the level of the proposed challenge was "high" for this student. This student has rapidly evolved from a state of apathy (12) to one of anxiety (20), reaching a "state of flow" at the end of the transcribed experience;

thus tuning the level of difficulty of the proposed task with his level of knowledge (which has been promoted during the experience). In fact, student 3 continues autonomously working once the problem is assumed to be solved and the rest of the classmates proceed to work on the following problem (31–35).

The need for sharing a significant learning moment (34) of student 3 evidences a motivational process based on solving a problem (it is, intrinsic motivation). In addition, student 3 manages to generalize (35) elements that are outside the body of the problem, demonstrating a capacity for analysis beyond solving the problem. We can conclude that this need to share the experience, revealing for student 3, and the triggered reactions allow us to consider this process as "close to ideality" from the emotional point of view.

5.3. Fitting to the Design Criteria

Design criteria were provided to the student teachers in order to establish common ideas and guidelines about what an EER is and how shall it work. The main aims of the design criteria were to provide technical recommendations for the implementation of an ER in the frame of a primary education school. Design criteria, proposed by the author, were useful to state objectives, strategies, activities, and learning outcomes as well as to manage the expected results and to organize discussions during university lectures related to the project. The impact of the design criteria in the formative success of student teachers deserves its own research. However, a discussion about the utility of such criteria on the performance of the experience is needed.

A dynamism criterion is achieved by scheduling enough time for each activity, leaving time for discussions, making mistakes, and problem solving. On the other hand, problems and activities had a clear goal (obtaining a code), which makes the problem-solving process much more straight-forward. On the other hand, players are not showing apathy or boring throughout the experience, while there is a moment of worry in which most of the students abandon the activity in the transcribed experience.

During the experience, the performance criterion is shown to be well implemented because students show optimum emotional behavior. In this regard, one student shows a clear control of the situation while others show some anxiety/excitation. This is in good agreement with the Csikszentmihalyi's theory for optimum experiences [36] and it is also shown that the EER creates a framework where peer-to-peer discussions help to overcome difficulties.

On the other hand, the communication criterion is shown to be useful to accommodate ideas and promote reasoning. Particularly, it is shown that the final interview is useful for S3, who regains the association with the "weight" concept and no longer refers to the problem with expressions like "object that has more numbers".

Isolation criterion makes the complete activity an "escape room experience". Cooperative and autonomous work are promoted so that no interference of the teacher could steal the "eureka" moment. In the opinion of the author, this is the key criteria to consider the experience as a true escape room experience, not a substitutional one. Challenges, clues, and resources provided play a key role through the experience and the group of students self-regulate their emotional and formative outcomes.

Concerning the continuity criteria, this manuscript reports on a fragment of the whole experience for a single group, while the total amount of groups rises up to 27; moreover, the complete EER experience covers total of five activities. For this, continuity criteria cannot be appropriately discussed. However, it is clear that an immersive experience was created and that the narrative may provide opportunities to link activities. New discussions were introduced in the ER, such as "can we measure the probability?" or "is the probability a magnitude?" However, these questions are limited to problem C, which is not shown in this manuscript.

Finally, curriculum criteria were considered through the design process so that concepts mobilized on the EER were at a reasonable distance of previous knowledge (note that ER was implemented in order to fit conventional flux of the academic year). Indeed, students had to compare, describe, identify, and characterize magnitudinal properties, which implies the mobilization of mathematical sub-competences [50,51] such as: strategic skills, productive disposition, adaptive reasoning, procedural fluency, and conceptual comprehension.

6. Conclusions

This manuscript presents a transcribed fragment of an educational escape room experience, designed by student teachers. The analysis of the presented transcription has been carried out according to a validated model [46]. From this analysis, it has been deduced that—in this particular experience, but also in other experiences that are part of the same research project—the escape game used as teaching/learning resource in mathematics motivates students to solve problems. In addition, the analysis of the didactic suitability of the fragment presented shows the involvement of all the participants in finding the solution to each enigma, thus supporting and validating the design of the room proposed by the teachers in training.

On the other hand, indicators of epistemic, cognitive, interactional, mediational, emotional, and ecological suitability [48] are fulfilled. This didactic suitability is a consequence of the approach taken: the escape room is designed so that the students assume the responsibility of solving the problems through exploration, formulation, and validation. In this experience, the topics and knowledge to be discussed—presented in Section 3.3—have been clearly presented with a clear a concise narrative (the connections between tasks and enigmas are clear). In addition, the escape room facilitates including concepts in conventional math lectures by treating the knowledge already taught and serving as a bridge to build new knowledge, promoting dialogue between students, so that everyone is involved in solving problems.

Horizontal mathematization is achieved once the real problem was traduced to a mathematical expression (in this fragment: weight = x · marbles). Once this expression was achieved, the process continued to an argumentation and generalization stage. This could be achieved because of the use of tools, group discussions, and other resources which were used in the EER to establish relations and find regularities. The situation created during and after the EER experience, emphasizes on the mathematization of the problem and the generalization of the conclusions.

The presented EER was designed by following the design criteria presented in this manuscript. Design guidelines for EER are, to our knowledge, not present in scientifically meaningful literature. In this regard, it has to be noted that the "isolation" criterion allowed the participants to express their perceptions and experiences spontaneously and reflect on them, generating an exchange of ideas. So, the design guidelines here presented could be valuable for designing future EER experiences.

Therefore, based on this positive experience (and others that are part of this project), we believe that this tool can be useful to identify semiotic conflicts, analyze didactic trajectories and interactions, build a positive relationship with the mathematical discipline, and identify knowledge and competencies. Particularly, EER used as an alternative evaluation method can be a promising way for future research. Finally, we consider that the complete sequence (design, implementation, and analysis) of this type of experience presents a high level of complexity that, with the appropriate adaptations, can become a training activity for student teachers. The impact of designing, implementing, and analyzing EERs in the formation of student teachers is also an open discussion which deserves its own research.

In this regard, we believe that the present study can contribute to perceive educational escape rooms as an innovative and useful didactic resource for both teachers in training and Primary Education students. The potential of this tool as an instrument for teacher training will be analyzed in future studies.

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