A GAME-BASED LEARNING APPROACH TO TEACH MATHEMATICS TO UNACCOMPANIED MINORS IN PARIS

Bartzia, I.[1], De Smet, C.[2]

[1] *Institut Montpelliérain Alexander Grothendieck de l'Université de Montpellier (France)*
[2] *Laboratoire d'Innovation et Numérique pour l'Éducation de l'Université Côte d'Azur (France)*

NOTE: This is the preprint version of a conference paper, as published in the ICERI2019 Proceedings.
ISBN: 978-84-09-14755-7

Please cite as:
Bartzia, I.; De Smet, C. (2019). A Game-based learning approach to teach mathematics to unaccompanied minors in Paris. In: ICERI2019 Proceedings. ISBN: 978-84-09-14755-7

Abstract

Recent migration waves pose a challenge to the educational system and to the wider integration of migrant children. Most of these children suffer from language difficulties, the lack of parental support and educational opportunities, bureaucracy, social exclusion and psychological trauma.

In this paper, we study a game-based approach to teach mathematics to unaccompanied minors (in France), as gamification of the learning process may be used to increase motivation and implication of the learner in different contexts. More precisely, we present the conception and the realization of a serious game whose first objective is the discovery of different domains of mathematics by problem solving and the development of logical skills. The game is based on the escapED framework and has been specifically designed for unaccompanied migrant children; in the sense that it takes into account cultural, linguistic and technological barriers, and targets (as a secondary objective) to decrease their sense of isolation and exclusion by including different cultural and geographical elements. Furthermore, all physical senses were represented to increase the motivation and implication of the players.

This study describes two different iterations of a serious game; the second took place after evaluating the first one. During the first round of the game, the independence and interaction of the players proved to be complex to handle. The narrative was also weakly developed, and the players were not sufficiently involved. To address these problems during the second round, we adjusted the narrative, included the use of technology and redefined the interactions allowed. We conclude with general observations and recommendations concerning interaction and independence of unaccompanied minors, their perception of mathematical objects and the effect of an interdisciplinary approach. We believe that our work will be useful for future research towards a game-based approach to educate migrant children.

Keywords: serious game, game-based learning, unaccompanied minors, refugee

1 INTRODUCTION

Europe has been confronted with a considering number of immigrants trying to find a better life in the old continent. Various incidents around the world caused a flux of people applying for refugee status in one of the EU countries. The minors under study in this research mainly come from Africa (Sudan, Cameroun, Cote d'Ivoire, Mali, Guinée, Niger, Syria, Morocco, Algeria and more). Most of them are on the run from conflict zones, civil war or extreme poverty. In French these minors are called “Mineurs Isolés Etrangers” (MIE), which can be translated as “Unaccompanied Migrant Minors” (UMM), meaning they arrived in France without any family member [1]. Depending on the country where these immigrants apply for refugee status, the accommodation and integration procedures differ. However, most countries organize educational programs for both refugee and migrant minors [2].

The law [3] concerning minors arriving alone in France, forces the state to take care of any minor/child found alone on French soil. This means the French government needs to provide them with accommodation, food and education. Prior to this procedure, the minor needs to pass a legal identification process. More concretely, a judge will check their documents and determine whether they are minors or not. This procedure may take from two months up to a year or more. As a result, many minors become adults before the procedure ends. While waiting for the judge's decision, they are either provisionally placed in a shelter home or in some “wretched” hotels, others have to sleep on the streets, and some are hosted by solidarity citizens that provide them with accommodation through networks such as Paris d'Exil, Timmy (Team Mineurs Exilés) or other organizations.

In case the judge decides “in favour of the young migrant”, he/she will be placed in an institution or at foster care. As from that moment, they will start their education program taking basic school lessons, mostly inside their new institution or at a public school. They will mainly be trained for technical jobs such as electrician, cook or pastry maker. If the young migrant is not recognized as a minor by the judge, his/her future is unclear. Some of them will file an appeal and will launch a new procedure. If in the meanwhile the minor becomes an adult, some of them will ask asylum, some will be deported, while others will get lost in the system and become “sans-papiers” (or undocumented immigrants) working in the black market. In the worst case, they become drug addicts, prostitutes, criminals, or end

up in isolation, marginalized, or with mental disorders. Most of them suffer from a psychological trauma or depression and have health issues that were not treated, while others show signs of torture and fatigue [4-6].

In this context, several organizations in France such as Paris d'Exil, Timmy and Singa France haven't only been organizing accommodation networks, but also provided language courses, legal advice and food distribution to replace the missing state care. In this context, the first author of this paper started in February 2017 as a voluntary teacher for Paris d'Exil, organizing mathematics and science courses for the UMM. These courses took place at the Louise Michel municipal youth library (situated in the Réunion - Père-Lachaise neighbourhood in the 20th arrondissement) of Paris and were taught on a weekly base on Wednesday. The teachers were all volunteers, some of them didn't have a mathematical background. On average, between 10 and 25 minors were following the course. They had a basic to advanced understanding of mathematics and a moderate to advanced level of French.

The course aimed to let the UMM benefit in several ways. A first objective was to familiarise the minors with scientific reasoning and terminology, and to teach them the fundamentals of mathematics. In view of their different skill and knowledge levels, this ranged from practising basic operations to studying advanced subjects such as probabilities or calculus. A second objective was to keep them off the street by providing them with a meaningful activity. Considering that many UMM suffer from post-traumatic syndrome disorders [4], offering them a learning experience (even for a few hours), may reduce significantly their anxiety and frustration. In addition, during the course they were required to work in teams, forcing them to communicate with each other, which also may reduce their sentiment of isolation. A third objective was to prepare them for their future educational and social integration. As many UMM come from different cultural backgrounds, they aren't necessarily familiar with the existing school regulations or know how to conform themselves to social behaviour in France. Finally, the course aimed to encourage them to be more confident and independent when addressing mathematical problems.

Organizing the course has been difficult for several reasons. The first problem was the organisers' zero budget. Notebooks and pens were supplied by several libraries, institutions and other individuals located in the neighbourhood. Second, as mentioned above, the students had different levels in mathematics and French language. They showed very little self-confidence and independence, therefore they needed continuous encouragement to diminish their feelings of frustration and failure. Given the many constraints, the organisers had to be very creative to accomplish their objectives. They relied on concrete and abstract problem-solving exercises and used interdisciplinary gamification (riddles, puzzles, experiments, Makey Makey) to motivate the minors, in order to increase their implication while decreasing their frustration.

The purpose of the present study was to study a game-based learning approach to teach mathematics to UMM. However, scientific educational research on how to teach to this specific group of learners is lacking and the target group has been understudied within recent research.

2 METHODOLOGY

There are many definitions of serious games, but we will follow the definition by Alvarez and Djaouti [7], who describe a serious game as "an artifact, digital or otherwise, for which the original intention is to combine with consistency, both serious aspects such as non-exhaustive and non-exclusive, teaching, learning, communication, or the information, with playful elements from the game. Such an association is made by embedding the utilitarian functions within the story, graphics and audio elements of the game, which no longer only focuses on pure entertainment". The advantage of this definition is that it doesn't limit serious games to a digital format only.

To create our games, we used the inclusive and human centered escapeED program [8], as developed within the GameChangers Project of Coventry University's Disruptive Media Learning Lab. The escapED program is based on the traditional escape room games, and consequently adapted for education and the development of soft skills such as communication and teamwork. The framework provides not only a methodology for creating educational escape rooms, but also for learning games aiming behavioral change. Six main areas were identified to create a game: Participants, Objectives, Theme, Puzzles, Equipment and Evaluation.

In this research, an action research methodology was used to investigate and improve the teaching and learning process of an UMM course. Sanchez [9] concluded earlier, that action research is a valid and frequently used research method when researching games. He cited Mills [10] to explain how all

actions by all actors involved in a study, can possibly influence the research they are conducting: “action research is any systematic inquiry conducted by teachers, researchers, principals, school counselors, or other stakeholders in the teaching/learning environment to gather information about how their particular schools operate, how they teach, and how well their students learn” [10, p. 21]. All action research has in common that it is conducted by an internal expert, with the goal to make improvements in the educational setting under study [11]. As mentioned above, the first author of this paper started teaching to UMM in February 2017 and conducted all phases of the current study.

Wouters, van der Spek and Oostendorp [12] proposed a taxonomy consisting of four categories of learning outcomes: motor skills, affective, communicative and cognitive learning outcomes. The latter can be broken down into 2 sub categories: knowledge and skills. This taxonomy of learning outcomes was confirmed in a literature review by Connolly et al. [13] on the potential positive impacts of games. Most learning games were found to achieve knowledge acquisition in both the classroom and in informal learning environments. In addition, an important role was noticed for enjoyment and motivation through game-based learning. In the results section, we will mainly focus on the progress made by the minors in acquiring knowledge and skills development.

Given that teaching to unaccompanied migrant minors is an understudied domain and the exploratory nature of this study, we only formulated a central research question [14]. Our research question was: Will playing a serious game with UMM enhance their knowledge and skills?

3 RESULTS

In this section we present the game creation process as modelled by the escapED framework and the two iterations of the game played. We explicitly detail the six areas of the escapED program. The vulnerability of the migrant children was considered during the creation of the game.

1.1 First iteration (July 2018)

The first iteration of the game took place in July 2018 at the Louise Michel library.

1.1.1 Participants

The first session was played by three UMM participants between 15 and 18 years old. The game was conceptualized as a one-off experience and the play time of the game was set to 60 minutes. Players had the option to play the game either on an individual base or they could choose for a collaborative strategy, which shortened the time needed to resolve the puzzles. The level of mathematics chosen for this group envisioned pupils in the first three years of secondary education.

1.1.2 Objectives

The main learning objective of this game was to develop the minors' mathematical knowledge and to raise their skills. Our first goal was to demonstrate the use of mathematics by various cases of problem solving, to discover different subdomains of mathematics (geometry, calculus, logic, combinatorics), to experiment with mathematical reasoning, notions and counting techniques and to familiarize them with mathematical terminology and vocabulary. A second goal was to decrease the sentiment of isolation of the players and to increase their confidence levels in mathematical problem solving but also in communication. To realize this, we designed the game in a way that players weren’t forced but rather strongly encouraged to collaborate, as we tried to motivate them to communicate with each other. On the other hand, we included several cultural elements from around the world into the game’s narrative, to awake their curiosity and to show them that cultural diversity is an asset and shouldn’t be regarded as something negative. This goal was added based on our earlier observations, where UMM developed feelings of shame for their status as migrants: we observed that some of them were trying to hide their migrant status, while others were strongly holding on to their cultural habits and values (religion, language, food) and had difficulties to integrate into their hosting country. As a result, our first narrative was conceptualized as a journey through four different countries, holding the implicit message that the world is full of different shapes, colors, sounds, tastes, smells etc., and a place where diversity should be considered something worth exploring and not something to avoid.

1.1.3 Theme

When designing the narrative, we took into consideration the possible traumatic experiences and the fragile psychological condition of the UMM. Stress factors such as confined spaces and references to violence, war, death and religion were avoided. The detailed narrative was as follows:

Mamadou's grandmother is diagnosed with a rare disease and is slowly losing her sight. The doctor says that only her Indian friend can prepare the medication she needs. As a result, Mamadou decides to go to India to find the doctor and bring the medication back to his grandmother. The Indian doctor also happens to be a Bollywood star, preparing for her new film. She asks Mamadou to help her solve the first puzzle before she will help him with the medication. When they are done, the doctor realizes she has left the medication at the place where she shot her last film: Egypt. This brings Mamadou to Egypt, where he meets an Egyptian pastry maker and needs to solve the second puzzle. Next, to complete the medicine recipe, he will have to travel to Mexico, where he will meet a puma veterinarian. But first he will need to solve the next two puzzles to discover the name of the last medicine's ingredient. His last destination is France, where he can only escape a shark threat by solving the last puzzle.

1.1.4 Puzzles

We chose puzzles adapted to our learning objectives, with the desired language levels, and achievable with the foreseen equipment. We proposed the following puzzles:

- Puzzle 1: "If a Bollywood star has 3 pairs of sunglasses, 4 scarfs and 6 bindis, how many possible outfits can she wear?" This corresponds to the mathematical problem: "Given three sets A, B, C of respective cardinals 3, 4 and 6, what is the cardinal of the set AxBxC?" This puzzle is a classic combinatorics problem, introducing the multiplication principle. Moreover, it contextualizes the notion of the cartesian product of sets (set of all ordered pairs, triplets etc.). The reasoning strategy to solve the problem requires the use of trees and/or tables.
- Puzzle 2: "If you want to build a pyramid made of dates (sweet fruit), and the base of the pyramid is a square of side 12, how many dates will you need? This puzzle is a counting problem closely related to the geometrical problem: "Given a square pyramid with base of side 12 and height 12, what is the volume of the pyramid?" In the geometrical problem, the triangular faces of the pyramid are smooth surfaces, while in the case of the pyramid puzzle, they aren't. Nevertheless, the puzzle requires breaking down the geometrical form of the pyramid into square areas and therefore demonstrates the relation between volume and elementary volume units. It also allows for an exploration of geometrical forms and shapes. Based on earlier observations, the UMM have more difficulty with geometry than with algebra, which may be related to the fact that geometry requires precise language definitions while algebra demands more symbol manipulation. This particular puzzle allows for experimentation with areas and volumes and for the development of analytical skills.
- Puzzle 3: "If you have 5 different letters, how many different anagrams can you make?" This problem is formally stated: "What is the number of permutations of five different objects?" This is a classic combinatorics problem introducing the notion of permutation. It also introduces the notion of order and the difference between sets (order does not matter) and lists (order matters); The set {a,b,c} is the same as the set {b,a,c} while the list (a,b,c) is not the same as the list (b,a,c). As in puzzle 1, the reasoning strategy for answering this problem involves the use of trees and/or tables.
- Puzzle 4 invites the players to find three missing numbers, based on the partial information provided. This puzzle is a simple cryptographic riddle (it resembles to the mastermind game) and stated: "Find the three number code to open the lock, given the information about a number of triplets; for example in the triplet (0,7,9) all the numbers are incorrect, in the triplet (6,7,5) one number is correct, but not on the right place etc." This puzzle requires deductive reasoning and synthesis of the partial information given. It also introduces (naively) the idea of cryptographic attacks which is exploiting partial information to find a missing number (key or message).
- Puzzle 5 invites the players to draw a geometric design following a number of indications. If the drawing is correct, the image of a shark appears. The drawing was inspired by l*e dessin mystere* [15]. It involves the use of a ruler and a compass, as well as the understanding of

geometrical notions, figures and terminology such as rectangle, square, segment, intersection, middle. To solve this puzzle, rigor and preciseness are required.

The first 3 puzzles are based on counting problems. There are different reasoning strategies of solving them, by using trees, tables or by counting all possible results using an elementary arithmetic strategy. Puzzle 4 can be solved by logical reasoning (interpreting the partial information given), or by trying all possible results (which is time consuming). These puzzles seem to be easy, as the numbers aren't too high, but the complexity quickly raises, forcing the players to find a problem-solving strategy. For puzzle 5, there exists only one way to solve it (by following the indications rigorously).

During the first iteration of the game, two teachers explained orally the puzzle assignments and the players had the right to ask for help four times during the game. This has been reconsidered for the second iteration, as the presence of the teachers reduced the independence of the players.

1.1.5 Equipment

The game was set in a room at the Louise Michel library. As mentioned above, the project was realised with a zero-budget, leading to a low-cost decoration of the room. We provided decoration objects referring to the four countries and to the senses of taste, sight, touch, smell, and sound. These objects were either of cultural interest or they corresponded to the puzzle. For example, for Egypt we made a paper pyramid and provided a box of sand, dates and post cards. We also played traditional Egyptian music. In addition, two teachers participated as actors: their role was to observe the players and give clues if the players were encountering problems.

1.1.6 Evaluation

Although we didn't use pre-tests or scored the players' knowledge and skills before the first iteration, we reflected with them after the session to assess their experience. Formal evaluation is almost impossible when teaching to these minors, mainly because of the language barriers [16]. A video-based evaluation wasn't feasible as well, given the complicated legal situation of the minors. As a result, the puzzles were discussed at the end of the session to evaluate their knowledge and skills. By observation, we also evaluated the motivation and participation of the players, the impact of the narrative and the interaction with the players. Those observations helped us to adjust the game for the second iteration.

Our first observation was that the players collaborated to find the problem-solving strategies. They found all the solutions, but some puzzles were only solved by one player, while the others clearly hadn't understood the solution. In that sense, our learning objectives were partially achieved. The players responded very positively to the different culture-related elements and the subsequent conversation proved that they were impressed and curious about it.

More explicitly:

1. Puzzle 1: They used trees to solve the puzzle and all of them understood the multiplication principle. The manipulation of the objects related to the puzzle facilitated the concrete understanding of the problem.
2. Puzzle 2: They succeeded in breaking down the problem to pieces, the manipulation of the objects being very important for this part. We consider this interdisciplinary approach very helpful since the UMM perception of geometrical objects is not clear (as explained previously).
3. Puzzle 3: They had difficulty understanding the problem and finding a reasoning strategy. One of them succeeded in the end, using trees, but the rest didn't understand the technique. We believe that this was partially due to the fact that there was no manipulation of objects involved, they had to solve the problem using pen and paper only. In addition, this problem is more difficult than the previous ones.
4. Puzzle 4: They all understood the notion of an ordered list. Provide them with an actual lock, proved to be very helpful to the concrete understanding of the problem. They had difficulty combining the partial information. When they succeeded, they showed moderate understanding of the reasoning technique. This may have been due to language difficulties (the indications were provided as text and they had to logically combine them). Moreover, as it was the fourth puzzle to solve, they started presenting signs of fatigue.
5. Puzzle 5: They all mastered (after a while) the use of ruler and compass. In the beginning, they had difficulty following the instructions, but they managed it with help. They all

understood the geometrical notions and the terminology used. As the 5th puzzle required more time, they were allowed to finish it after the game session.

Second, we noticed that interacting with the UMM during the game setting was complicated. On the one hand, UMM don't easily trust people they don't know, and they feel easily exposed. On the other hand, they lack independence and self-confidence, and repeatedly request for interaction and guidance. As a result, two of the teachers (whom they already knew) participated as actors to observe, help and reassure them. Unfortunately, the players couldn't dissociate the actors from their role as teachers and they kept seeking for approval when they tried a problem-solving strategy. Moreover, the players had no reasons to test their answers independently, as they had to ask the actors for every puzzle, if their answer was correct or not.

Third, it was impossible to represent our narrative realistically. We also missed an occasion in the story to justify a time limit. As a result, the game lacked an element of suspense, and reduced the players' implication and motivation.

Finally, regarding their behavior, we observed that when they were provided with paper and pencil their first reaction was to start writing down and to propose inconsistent answers; for example at puzzle 2 (volume of a square pyramid with base of side 12) one proposed directly 120 or 144 (12x10 or 12x12). Their second reaction was to reconstruct the problem using actual dates (some were provided) which helped the concrete understanding. Their first reaction may be interpreted in two ways; either it reflects a stereotypical idea of mathematics: "solving a mathematical problem consists of performing some kind of arithmetic operation and proposing an answer in the end" (in our example, they intuitively understood that the answer would be larger than 12, so they chose multiplication directly); or they didn't know the answer and started experimenting with previous knowledge: "as they saw triangles and a square in the pyramid, they calculated the surface of a triangle or a square". We also observed that when a puzzle involved the manipulation of an object, they had the tendency to collaborate, while when the puzzle involved only paper and pencil, they started working on an individual base.

To adjust the game for the second iteration, we took all these observations into account.

1.2 Second iteration (June 2019)

The second session of the game took place in June 2019 at the Louise Michel library.

1.2.1 Participants and Objectives

The participants, learning objectives and playtime were kept the same as during the first iteration. The second iteration was played by four UMM participants.

1.2.2 Theme

After the evaluation of the first iteration, we changed the narrative as follows:

A dangerous epidemic is spreading quickly around the world. An agent of the French government has been assigned with the mission to transport a suitcase containing a vaccine to Berlin. He is ready to travel by train from Paris to Berlin but stops to buy some coffee at the train station before getting on the train. When he opens the suitcase after their departure, he realizes suitcases must have been switched, leaving him with a suitcase that's not his! He has exactly one hour (the time for the train to arrive) to search the content of the suitcase and to find the owner's telephone number, in order to contact him/her and ask him/her to bring the suitcase to the agent's destination. The owner of the suitcase is a cook, who kept three souvenir boxes coming from three different countries (India, Egypt, Mexico) in his suitcase, next to a traveller's notebook containing cooking recipes and the puzzles.

We chose this narrative because it justifies a precise time limit and allowed us to re-use parts of the first iteration equipment. Moreover, it was easy to represent the scenario in the room given our minimal budget.

1.2.3 Puzzles

Puzzles 1 and 2 are the same, but we used a slightly different statement to match the new theme. For example, the sunglasses, scarfs and bindis became Indian appetizers, main dishes and desserts, while the questions remained the same. Puzzle 4 was included as a helping clue (the role of the helping clues is explained in the following paragraph). Puzzle 3 and 5 were replaced by puzzle 6:

- Puzzle 6: A female quetzal bird has three feathers on its tail while a male quetzal bird has only two feathers on its tail. If we count 15 bird heads and 37 feathers, how many are males and how many are females? This puzzle corresponds to the resolution of the linear system x+y=15 and 2x+3y=37. This puzzle is a classic problem introducing the notion of a linear system of two equations. It can be solved by formulating and solving the linear system, but it can also be solved by trial and error combined with elementary arithmetic strategies.

We integrated the puzzles by writing down the problems in the traveller's notebook in a way that matched the narrative. To overcome the language difficulties, all problems were carefully expressed using mathematical language, and illustrated by pictures and sketches to clarify details (for example the construction of the pyramid). Instructions were given in advance. For every puzzle there were two helping clues. The first clue gave a hint on the mathematical reasoning but not the solution. The second clue offered the solution which was encrypted with an easy cryptographic system based on some material (cases of steganography used: mirror writing, scytale and open a lock I.e. puzzle 5).

1.2.4 Equipment

During the second session, we decorated the same room as a train wagon. A suitcase contained three boxes with souvenirs from India, Egypt and Mexico, a cd player, a tablet and a traveller's notebook. We chose the objects in the boxes to represent all five senses; some of the objects were related to the puzzles and others were just of cultural interest. None of the objects were necessary to solve the puzzles, although their manipulation could facilitate the concrete understanding of the puzzles. The notebook contained three traveller stories (the puzzles), together with images that matched the stories. To check their answers, the players could use an application on the tablet that checked if the answer was correct and allowed them to proceed to the next step (puzzle).

We also used a video projector, a microphone equipment and speakers. For one hour, a video of a train window view was projected on the wall, and audio related to train announcements was made by the actors. An extra element of suspense was added: when the players solved all the puzzles and therefore acquired the person's telephone number, they could call this number via the tablet. A ringtone could be heard, announcing the end of the game.

The interaction with the actors was also revised. We created a train restaurant where we hid all the clues, and from where we could observe the players without interfering. We also used three actresses (three volunteers, members of the library staff) already known to the players as they participated to educational activities organized in the past. The actresses interacted with the players to provide them with clues when asked.

1.2.5 Evaluation

We evaluated the learning objectives by observation, reflection and discussion with the players in the same manner as in the first iteration. They were also partially achieved: the players worked as a team, found the solutions to the puzzles, but for at least one puzzle, not all of them understood the reasoning. Moreover, this time we remarked that the narrative, the use of technology and the interaction with the actors made the game more exciting. Therefore, the players were very engaged to solve the puzzles. We also observed that the players (contrary to the first session) were less curious about the culture related objects, especially when the objects were not directly related to the puzzles.

More explicitly:

- Puzzle 1: They used trees and tables to find the answer and they understood the multiplication principle. The manipulation of the objects related to the puzzle was not particularly useful this time. No clues were asked. This may be related either to the increase of suspense at this session or to the different composition of the players group.
- Puzzle 2: They succeeded in breaking down the problem to pieces, the manipulation of the paper pyramid and the pictures proved again to be helpful for this part. They asked for the clues because they had difficulty calculating the result. They were particularly interested in the cryptographic riddle. One of them was so enthusiast that he quit the game to understand the cryptographic system, while the others continued playing.
- Puzzle 6: They showed no difficulty understanding the problem, but they did not succeed writing a linear system. The answer was found by one of them by applying an elementary arithmetic strategy and by trial and error. The others didn't seem to comprehend the solution.

Although not all the clues were used, the minors showed increased curiosity for the cryptographic systems after the session. This observation underlines the benefit of an interdisciplinary approach; given their language difficulties and the fact that the encrypted messages were textual, we were surprised by their level of interest. The use of cryptography also demonstrated another application of mathematics and its connection to language.

We noticed that, within the game setting, when the suspense increased by the narrative and the use of technology and sound, the players were more engaged to solve the puzzles. However, when they realized that an object was not related to a puzzle, they lost their interest in it, and as a result many objects of cultural value were disregarded during this session.

4 CONCLUSIONS

This paper presented a serious game for unaccompanied migrant children that was designed with the escapED framework and aimed to enhance their development of mathematical knowledge and skills. It was conducted through an exploratory action research and may inspire future studies for this understudied group.

We detailed the game creation process and the two iterations played. According to our observations, the perception of geometrical objects is fuzzy when it comes to unaccompanied migrant minors, mostly because of language barriers; in this research an interdisciplinary approach has been proven helpful to solve related problems. In our game design, the puzzles were stated in a clear, simplified language to overcome language difficulties. The interaction of the actors with the minors was also clearly defined, as we didn't want to undermine their independence or increase their frustration. The narrative was conceived in a way to eliminate any stress factors, while the use of technology and the integration of a time limit increased the narrative's suspense and the players' motivation. As a result, the UMM showed increased motivation, got engaged in the game and partially achieved the learning objectives.

To answer our research question, we can conclude that the game helped the UMM to clarify some geometrical figures and notions, to explore elementary arithmetic techniques, to understand the multiplication principle, to familiarize with mathematical language and rigor, and to gain confidence into mathematical problem solving. However, we don't claim that the students managed to master abstract mathematical knowledge such as the resolution of linear systems; but we didn't expect either that a single instance of a problem within a game setting would lead to such positive learning outcomes. Nevertheless, contextualizing the abstract problems into specific instances and integrating them into an interdisciplinary game setting, allowed for experimentation and intuitive understanding of the mathematical objects and for the development of problem-solving skills.

The escapED programme and its features have been essential to our course. Nevertheless, we would like to mention that in our game the six main areas of the escapED framework weren't developed linearly: we developed the Participants and the Objectives first, and then developed simultaneously the Puzzles, the Theme and the Equipment areas. In our game, the Puzzles, the Theme and the Equipment areas were interdependent, in the sense that when we worked on one of these, we took the other two into consideration.

Transforming the mathematical problems into puzzles and integrate them into the narrative was challenging. First, we had to choose between a linear and a parallel structure. By linear structure we mean that solving one puzzle leads to the next one (for example for the first puzzle you have to open a box and inside the box you find the second puzzle). This structure provides a natural way for the players to check their answers; an answer is correct if it allows passing to the next step. However, a linear structure is much more restrictive when it comes to its integration into the narrative and the equipment. By parallel structure we mean that the puzzles are independent and that the combination of all the puzzle answers allows for the final resolution of the game. This structure doesn't provide a natural way of testing every answer, but it allows a more creative realization as the puzzles are independent. For our game, we chose the parallel structure and provided the players with a tablet which allowed them to verify their answers.

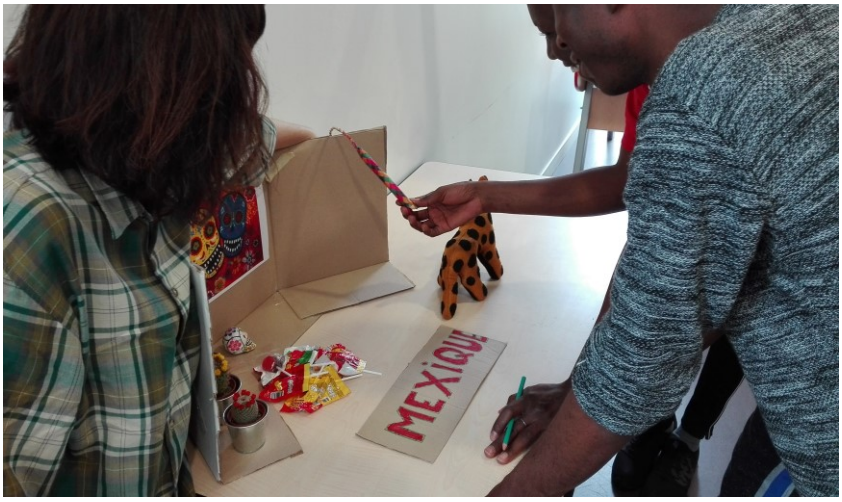
The game presented in this paper is parameterized by puzzles of high-school level mathematics. However, it can be adapted to more (or less) advanced levels according to the level of the intended participants. For example, if the owner of the suitcase is a professional chess player in the second narrative, one could develop puzzles about logic and probabilities, or if he is an archaeologist, one

could develop puzzles about conversion to different number based systems. Future work could extend our game with puzzles that fit different levels of knowledge for migrant children.

During the different stages of the game creation process, we were assisted by a number of artists, psychomotor therapists, programmers, actors, journalists, library staff and many others. They participated in both the conception and the realization parts of the two sessions. Although their participation concerned mostly their domain of expertise and most of them had little scientific background, we observed that the interdisciplinary approach of the game increased their motivation to understand the mathematics behind the puzzles. Some of them even came up with ideas for new puzzles or helped to find various statements and representations of the puzzles we used. The fact that they showed such motivation to learn and to participate to the mathematical part, was due to the interdisciplinary approach of this project (which made mathematics look less intimidating). They were an integral part of the success of this project.

ACKNOWLEDGEMENTS

We would like to thank Evangelia Pipila, Artemis Provou, Elena Casellas, Romain Roulin, Ricardo Garcia Lara, Maxime Grimbert, Bastien Dion, Rachelle Gosselin, Chloé Bertrand, Constance Bourges, Quentin Le Guevel, Marielle Lloret, Gwenaelle Royer and all the others who helped us conceive and realize this project. This project wouldn't have been possible without you. In addition, we would like to thank all the teachers from the Paris d'Exil team and the staff of the Louise Michel library, who supported us in every possible way.



REFERENCES

[1] I. Frechon, L. Marquet, "Unaccompanied Minors in France and Inequalities in Care Provision under the Child Protection System" in *Social Work & Society, no 2.* vol 15, 2017.

[2] M. Butkute, B. Janta, "Education for unaccompanied migrant children in Europe", *European Platform for Investing in Children (EPIC),* Publications Office of the European Union, 2018.

[3] LOI n° 2018-778 du 10 septembre 2018 pour une immigration maîtrisée, un droit d'asile effectif et une intégration réussie.

[4] G.Sturm, MR.Moro, T.Baubet "Mental Health Care for unaccompagnied minors in France : Towards a comprehensive approach to the needs of a vulnerable minority » in *Inequalities in Health Care for Migrants and Ethnic Minorities. COST Series on Health and Diversity*, vol 2, pp 207-220, 2012.

[5] C.Crowley "The mental health needs of refugee children: A review of literature and implications for nurse practitioners", in *Journal of the American Academy of Nurse Practitioners,* no 6, vol. 21, pp 322–331, 2009.

[6] I.Derluyn, C.Mels, E.Broekaert, "Mental Health Problems in Separated Refugee Adolescents", in *Journal of Adolescent Health*, vol. 44, pp 291-297, 2009.

[7] J. Alvarez and D. Djaouti, *Serious game: An introduction.* Paris: Questions Théoriques, 2010.

[8] S. Clarke, D.J. Peel, S. Arnab, L. Morini, H. Keegan and O. Wood, “EscapED: a framework for creating educational escape rooms and Interactive Games For Higher/Further Education”, *International Journal of Serious Games*, vol. 4, no. 3, pp. 73–86, 2017.

[9] E. Sanchez, *Le paradoxe du marionnettiste*. Paris: Université Paris 5 Sorbonne Descartes, 2014.

[10] G.E. Mills, *Action Research: A Guide for the Teacher Researcher.* Upper Saddle River, NJ: Merrill Prentice Hall, 2003.

[11] S. Kemmis, R. Taggart and R. Nixon, *The action research planner: Doing critical participatory action research*. Singapore: Springer Science & Business Media, 2013.

[12] P. Wouters, E. van der Spek and H. Oostendorp, “Current practices in serious game research: a review from a learning outcomes perspective” in *Games-based learning: Techniques and effective practices (*T. M. Connolly, M. Stansfield and E. A. Boyle, eds), Philadelphia: IGI Global, 2009.

[13] T.M. Connolly, E.A. Boyle, E. MacArthur, T. Hainey and J.M. Boyle, “A systematic literature review of empirical evidence on computer games and serious games”, Computers & education, vol. 59, no. 2, pp. 661–686, 2012.

[14] C. R. Kothari, *Research methodology: Methods and techniques (second revision)*. New Delhi: New Age International, 2014.

[15] G.Chaumel “Dessin mystere” in *Revue Hypercube.* Num. 30, pp 27, 1999.

[16] C.Edmonds-Xathen,T.Trinick and V.Durand-Guerrier, “Impact of differing grammatical structures in mathematics teaching and learning” in *Mathematics Education and Language Diversity,* pp 23-46, Spinger, 2016.