A Model to Design Learning Escape Games: SEGAM

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Abstract: This article proposes a methodology to design Serious Escape Games (SEG) for teaching. It describes, through the proposed model, how to approach the various aspects related to this type of activity (constraints, pedagogy, parameterization, tests, background, etc.). The goal of SEG is not only to reinforce the knowledge and skills of students or to acquire them, but also to improve their intuition as to the choice of the skills to be mobilized according to the different situations. This methodology was implemented through an experiment carried out as part of a Masters combinatorial optimization course in an Engineering School, the aim of which was to increase the attractiveness of this very complex discipline manipulating a large number of digits. The evaluation of this experiment showed the advantages of this activity : manipulation of the notions in a playful way by the learners, increase of the motivation and improvement of their reactivity and practical sense.

1 INTRODUCTION

"Once upon a time there was a world of students and teachers, the world was once made of paper, ink, feathers, blackboards and chalks. But recently, this world changed and was invaded by barbaric tools." This brief hook could introduce a serious game, a type of Technology Enhanced Learing (TEL) to which teachers are confronted. These serious games, like MOOCs (Massive Open Online Courses) and ubiquitous TEL are related to the digital and technologic evolutions and impacted the teachers profession. But the investment required for their design is still an important obstacle to the majority of them. Among these TEL, serious games may be defined as: "[...] a device, digital or not, whose initial intention is to combine, with coherence, both serious aspects and playful springs from games, videoludic or not." (Alvarez et al., 2016) The design and / or production models and tools of serious games seem few in number and generally require strong computer skills, making their use complex. At the same time, the world of purely playful games is constantly evolving. Since a few months, the concept of Escape Game has arrived and quickly acquired a certain notoriety. We define an Escape Game (or Escape Room) as a multi-player life-size escape game, which typically involves escaping from a room or a succession of rooms in a limited time (Borrego et al., 2017). To do this, a group of players must find and collect a number of clues and objects in order to solve riddles.

This concept seems interesting to exploit. It proposes to the players a challenge to take up and requires the mutual aid and the cooperation of team members to solve the riddles. This type of activity seems suitable for us to be adapted in the form of a serious game, which we will call Serious Escape Game (SEG). The problem developed in this paper is to define a model and methods to design serious games of the type Escape Game (and therefore SEG) by involving teachers at all stages of the design. A first experiment was carried out and allowed the design of a SEG for a session of a combinatorial optimization course for an audience of engineering students of Masters.

2 MODEL

The idea of adapting Escape Games to teaching was imagined at the end of 2015 to meet the needs of teachers. Thus, the primary goal was to mobilize students' knowledge in a more attractive context. Other objectives were also targeted like : encouraging students to develop their intuition, or solving original problems in a limited time. To respond to these objectives while benefiting from the added value of the use of games for educational purposes (active participation, implementation of the course, immediate feed-

back, interactions between group members and emotional involvement), the need has been felt to define a methodology to design SEG for teaching without forgetting the intrinsic constraints of this type of device. Nonetheless, SEGs involve the "natural drivers of learning": the game, environmental exploration, and peer interactions (Alvarez et al., 2016), encouraging the acquisition of knowledge and skills. After executing a state of the art showing that few Escape Games are suitable for teaching (Dumont and Nadam, 2016), we created the SEGAM (Serious Escape GAme Model). To design this, we have taken elements of the DISC model (an acronym for Domain, Interaction, Scenario, Context) proposed by (Vermeulen et al., 2017) to produce role-playing serious games with steps. This model proposes a decomposition of the serious game into levels and then into independent case studies. For SEGAM, we have kept the decomposition into levels and transposed the case studies into riddles. These riddles can be exploited separately, while keeping a narrative link, as in the DISC model. We shall return to the narrative aspect in the rest of this article. The different constitutive elements (levels, riddles and clues) were organized according to Figure 1.

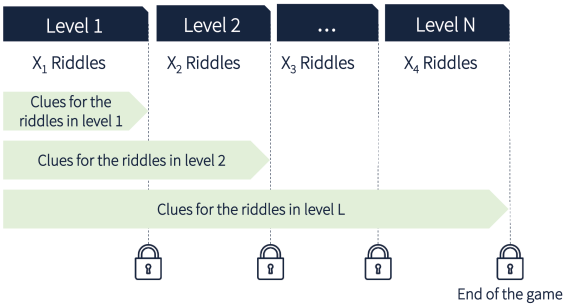

Figure 1: Model diagram.

According to this model, a SEG is divided into several levels, a level represents a stage of the game. To pass from a level L to a level L + 1, it is necessary to solve at least one riddle. Each level has at least one associated riddle and several riddles of the same level can be performed in parallel. Each riddle corresponds to one or more educational objectives (diagnostic, formative, summative or discovery of a notion). On the other hand, an riddle is connected to one index at least (called ' mandatory '), and can also be linked to ' optional ' clues. Some clues can be used to solve several riddles, so it is important to make each clue available before the first riddle (whether mandatory or optional). The possible area of distribution of the clues is represented by the horizontal arrows in Figure 1. When all the riddles of a level are solved, the learners have the necessary means to reach the next level, unlocking access to new clues. From this model, the difficulty and the playing time can be adjusted according to different parameters, such as the number of levels, the difficulty of the riddles, the distribution of the indices, the number of participants, etc. Moreover, it is important to integrate a playful aspect to immerse the learner in the atmosphere of the SEG, as well as to determine the pedagogical aspects and the acquisition of competences. We will detail these aspects in the next sections while respecting the constraints related to education. We reuse some elements of the ATMSG (Activity Theory-based Model for Serious Games) model (Carvalho et al., 2015) such as the representation of serious games according to three types of activities: "the gaming activity, the learning activity and the instructional activity". Knowing that for our Serious Escape Games, an riddle is composed of multiple activities, it is important to vary their type for more diversity.

3 CONSTRAINTS

The application of Escape Games in education brings a certain number of additional constraints compared to a classic Escape Game. Indeed, even if the target audience is identified and much more homogeneous, setting up this type of activity in a course confronts us with the following issues:

An Escape Game is usually created for a limited number of players (often between three and six), so to manage a large number of students, the time slots are multiplied. The same applies to the necessary rooms for the implementation of this activity, which can lead to problems of schedule.

A SEG may require a lot of material. Indeed, the more varied the media, the better the atmosphere and the plot (see Section 6. Background), the more creation time and / or money invested to buy the material will be important. Moreover, if the rooms are multiplied to favor the time constraints (several sessions played simultaneously), it will also be necessary to multiply the material accordingly.

For the proper functioning of the activity, at least one supervisor must master the notions of courses of the SEG (teacher, instructional designer, etc.) by simultaneous session to help or guide students in difficulty. It may be interesting to have an observer to analyze problem situations and other things to improve the device during reengineering phase.

Then, it is more or less obvious to transpose the learning contents into riddles. Some course content will lend itself more easily to the activity. For example, for the opening of a three-digit padlock, an

exercise whose result is a three-digit number can easily be transposed to that code. Conversely, problems where solutions are not unique and not numerical will require the development of mechanisms to restrict the possibilities and matching with numbers (eg, multiple choice questions whose answers relate to numbers. Note that it is preferable to keep a number of combinations large enough to avoid finding the solution by trial-error).

Furthermore, the implementation of a SEG requires a non negligible creation time compared to the effective time with the students. Indeed, the design as well as the production (material, graphic design etc.) added to the corrections made after the phases of test are very important. It is advisable to imagine a prototype fast to produce for the test phases in order not to lose time in the production of elements that would be modified or deleted.

Thus, it is essential to take into consideration all these constraints to schedule the installation of a Serious Escape Game.

4 PEDAGOGY

The aim of this activity is primarily to provide or evaluate the skills and / or knowledge of the public concerned. It is therefore necessary to target the criteria to achieve the objectives previously set. The main components of a SEG are riddles, so it is essential to give them special importance. For this, several aspects must be taken into account:

Define the pedagogical objectives to reach: set out the objectives of the course, which will be highlighted in the SEG.

Define the corresponding course notions: this is to select the concepts to be processed during the session. Beware however to manage their number and difficulty so that all the objectives are reached in the playing time. For example, several notions can serve the same pedagogical purpose, so it may be possible to select only one concept per objective.

Choose the nature of the riddles: they are related to the pedagogical objectives and may have different purposes (learning, implementation, etc.) depending on the type of activity. In fact, the riddles will be constructed differently if it is a diagnostic, formative, summative evaluation or if it is a discovery activity. In addition, it will have a different impact on playing time. For example, the same notion will take longer in a discovery activity than in a summative evaluation.

Imagine concrete applications to set them up by varying media: paper, smartphone, tablet, computer, everyday objects, padlocks, decorations, etc. depending on the means available. Indeed, the adhesion of the learners throughout the session will be better by choosing and varying these elements according to the plot. Conversely, the lack of diversity of the materials could lead to student weariness.

Create several clues: for each riddle, it is necessary to define at least one compulsory clue (which will be hidden or not) so that the learners are able to solve the riddles with all or some of the clues. Several compulsory clues may be necessary for solving a riddle (the riddle should not be feasible without having found and used them). As for the optional clues, they are a complementary help to the understanding of the riddle (these clues are worth hiding).

Estimate the difficulty and define the prerequisites of the riddles: if necessary, it might be useful to identify the dependency between the riddles (for example: the riddle X must be solved before the riddle Y or, conversely, there is no dependency between these riddles). Moreover, it is advisable to estimate the complexity of the different riddles to be able to better organize them. This can help during the parameterization phase.

Debriefing is also an important step in enabling students to become more aware of their learning. By unrolling and explaining all the notions seen during the SEG, the teacher allows the students to see or review the steps of the SEG. They can ask questions and verify if their reasoning was correct during the game session.

5 PARAMETERIZATION

The parameterization and testing phase is essential. It is advisable to apply an Agile (as Scrum (Schwaber and Beedle, 2002)) method which consists in iteratively performing these two phases. In order to fit into the constraints defined in Section 3, the time, difficulty and linearity of the game must be adjusted. To do this, a number of parameters must be taken into account:

- the number of levels
- the difficulty of the riddles
- the number of clues and their access facility
- the number of multiple clues
- the guidance of the teacher
- the progress level of the game
- the distribution of clues
- the link between clues and riddles
- the number of participants

- time

The first constraint is how to divide learners according to available time slots and rooms. This will set the number of participants (eg 3, 4 or 5) as well as playing time. For a Serious Escape Game the recommended duration time is between 1h and 2h maximum to keep active and motivated learners.

Once the game time has been defined, it will be necessary to adjust the difficulty and the linearity of the game so that learners are able to finish the SEG in the expected time. Making the game too hard and non linear will lead to the failure of the majority of the learners; conversely, creating a game too easy and too linear will lead to success of almost all learners long before the expected time. The difficulty of the parameterization is to find the right dosage between these two parameters. Here are some precisions to better calibrate a SEG:

As for the number of levels, at least one is needed. Note that associating the validation of a level with the discovery of new elements (clues, rooms, other objects) generates a non negligible gain of interest of the players. It is therefore advisable to put several clues according to the overall playing time.

Then, if the riddles are varied, this will play on the flow state (Csikszentmihalyi, 1990) (Chen, 2007) of the learner. Indeed, a too difficult riddle at the beginning of the game can discourage the learners. A simple idea is to organize the riddles by increasing difficulty. Other alternatives are possible, for example: alternate a simple riddle with a more complex one to give a bit of respite to learners between two complex riddles. In addition, this will lead to an increase in motivation since they will solve the simple riddles faster, which will encourage them to face a more complex riddle.

Regarding the number of clues and their access facility: the more clues, the more it is possible to divide the problems and have combinations of clues. It therefore increase the probability that students will try false leads. And the more hidden are the clues, the longer the search time. If the clues are too well hidden, they may not be found, so it is advisable to carefully hide the clues. For example: important clues can be hidden in a simple cache, however, optional clues can be better hidden.

It is also important to focus on the number of multiple clues (used several times in the game): it is useful to specify before the start of the session whether this type of clues is present within the game or not, this will influence the difficulty of the game. In their absence, used clues can be put aside, which reduces the possibilities and simplifies the use of clues.

Next, the guidance of the teacher allows each group to progress at roughly equivalent speeds. This can generate frustration if learners block on a riddle. For example, since the pedagogical interest of the excavation is low, if they take too much time to find a hidden clue, it is advisable to help the learners in order not to slow down their advancement. It is therefore unnecessary for a group of players to lose too much time searching for clues. Secondly, a riddle posing a problem for a group of students will require the help of the supervisor for its resolution. Ideally, the teacher should be able to bring each group to the end, or close to the end of the game within the time allotted.

Another important aspect of this model is to implement a way for students to position themselves in the advancement of the activity. It is optional but allows better time management by learners and gives them a motivation to know that they are approaching the end of the game.

In regards to the distribution of the clues paired with the link between clues and riddles, this link is a concrete explanation of the fact that a clue belongs to a riddle. These two aspects play on the linearity and the difficulty of the game. If the link between the clues and the riddles is too strong and the clues are directly usable, this makes the game too linear and breaks the multiplayer aspect, which may induce the boredom of some learners. On the contrary, if there are too many clues and many riddles in parallel, the game will be very difficult and will require many thinking and pooling by the team. This will make the game much more time consuming. It is important to find a good gauge between the clues and the riddles to make the game challenging and not to let the players get lost, nor guiding them through a simple path.

Then, it is important to create enough content to occupy all participants at the same time throughout the game time. This will force the team to divide the tasks and prevent one student from leading andrending passive the others.

Finally, the game should be achievable within a limited time in the perspective where the participants are all harnessed to a different task. In practice, this is never the case, it is necessary to leave a margin for the excavation, the pooling of the clues, the collaboration and the common reflection on the riddles.
All these parameters are important for the design phase of a SEG according to SEGAM.

6 BACKGROUND

For immersion in the game, it is advisable to pay particular attention to the background (that is to say the context, the universe of the game). There must be

a red wire so that the learners can create links between the different elements and delve into history. We can associate this with the paradigm of narrative centered-learning environments (Rowe et al., 2011) which are defined as "a class of game-based learning environments that contextualize educational content and problem solving with interactive story scenarios". An interactive scenario of this type will have several properties from the game that will help the students to immerse themselves in the activity: competition, challenge, imagination, exploration of the environment, goal to be achieved, interactions (with objects and people), outcome, other people, the rules and the security (no consequences on the real world) (Caballé and Clarisó, 2016). All these elements of play are found in a SEG and thus allow a better involvement and motivation in the scenario. The story will thus connect all the elements between them, and stage a goal to be reached to motivate them. Indeed, as (Viau, 1996) says: "the perception of the value of an activity is the student's judgment about the importance, usefulness and value of a learning activity" [1]. To create the atmosphere associated with the story, it is advisable to pay attention to: decorations, used objects, the characters if necessary, the background music if applicable, etc. Moreover, it is possible to create a hook beforehand by giving them for example a message to put them in the atmosphere before they even cross the door of the room.

The more careful these elements are, the more motivated the users will be to complete the adventure as they will feel involved and immersed in the game.

7 EXPERIMENTATION

This model was applied as part of a combinatorial optimization course. Combinatorial optimization is a field of research related to complex problems due to the combinatorial explosion of the number of possible solutions to them. Since the enumeration of the totality of solutions is extremely time consuming, it is unthinkable to use conventional algorithms to solve these problems exactly. Categories of approximation algorithms such as metaheuristics including genetic algorithms and local searches are then used to find solutions of good quality.

The objective of this SEG was to put into practice the basic concepts of the whole course. In this experiment, we have defined four levels, each with an riddle:

1. Application of a selection (operator used in a genetic algorithm) leading to a code opening a suitcase.
2. Application of a crossing and a mutation (operators used in a genetic algorithm) resulting in the opening diagram of a tablet.
3. Simple application of a local search to geographical coordinates corresponding to the password of a computer.
4. Execution of a genetic algorithm whose understanding of the result leads to the final solution.

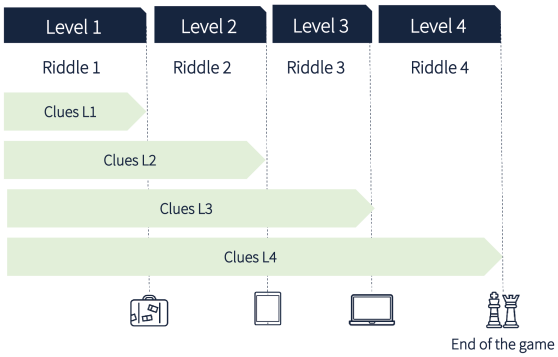

Figure 2: Adapting the model to the Escape Classroom.

With regard to the time slots, two sessions of 4 hours were necessary to pass a group of 20 students. As for supervision, a teacher and an educational engineer managed two rooms simultaneously for one-and-a-half-hour sessions.

Session 1	Part 1	Presentation (15 min)	Escape Classroom (two parallel sessions) (1:30)	Quick debriefing (and preparation of the next session) (15 min)
	Part 2			
Session 2	Part 3			
	Part 4	General Debriefing (2 hours)		

Figure 3: Organization of sessions.

As the tests progressed, the concept was improved: in the first version, there was no link between the riddles and the clues and no way for the players to situate themselves in the progress of the game. Moreover, too many clues were available at level 1. After five test sessions, corrections were made, including the addition of an important element: a chronological frieze with colored symbols corresponding to some of the clues, allowing the players to see their progress in the game and helping them to organize themselves in the use of the clues.

Following this, we implemented our SEG and debriefed with the students: after each session, but also in full session with the whole group to re-roll the whole game and allow all students to see (again) all

[1] Translated by the authors

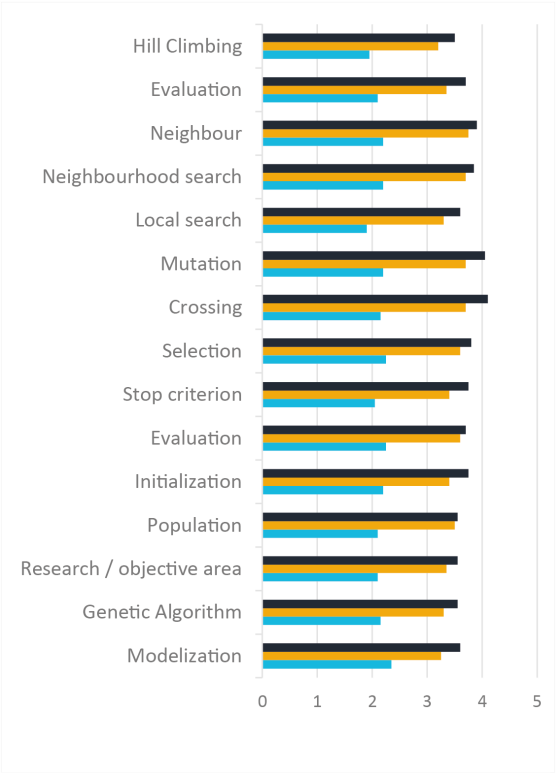

Figure 4: Comparison of the knowledge assumed by the students by chapters of the course before, after the session and after the debriefing.

the pedagogical aspects addressed in the game session.

To evaluate the contribution of this activity (on pedagogical and playful aspects), the students received several forms: one before the session, for a self-evaluation on the different chapters of the course; another just after the session, to gather their impressions and to assess whether the SEG facilitated the acquisition of certain elements of course; and finally a last one, just after the debriefing to measure the contribution of this one on the understanding of elements. Figure 4 shows an overview of their self-assessment. It can be noted that each step has had an impact on their learning according to their own feelings.

To conclude, this work designed as an Escape Game was a very interesting experience both in terms of pedagogy and motivation. This experiment tends to reinforce the theory of (Dale, 1954) explaining that learning would be favored by concrete action and simulation. This SEG has been positive not only for the students but also for the teacher. They all had a significant interest and motivation for this activity. The teacher saw a better general understanding of the course elements than in previous years. Although it is

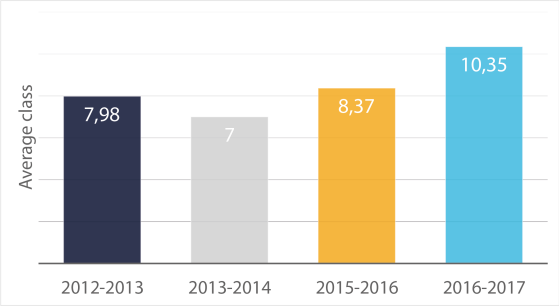

Figure 5: Evolution of the averages of the last promotions.

impossible to prove that the SEG is the only reason, the marks of the examination of 2016-2017 have increased compared to the previous years, as shown in Figures 5 and 6.

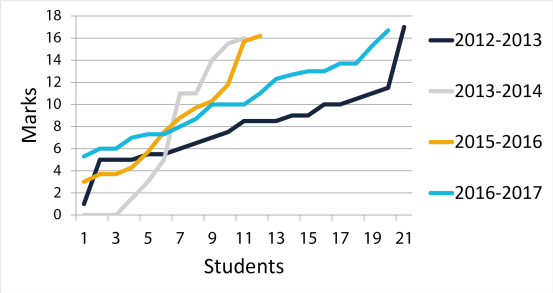

Figure 6: Marks on the last 4 years of the course.

Additional information on the establishment of this Escape Game is detailed in the article *Escape Classroom : un Escape Game pour l'enseignement* (Guigon et al., 2017).

8 PERSPECTIVES

The proposed model allowed the creation of a first successful SEG with the students of IMT Lille Douai. Other experiments carried out in class and followed by further analysis will allow us to refine the model. To this end, follow-up indicators will be defined and implemented, and a set of qualitative and quantitative traces will be collected following the experiments carried out with the students and by the teachers. This method of research is similar to the THEDRE (Traceable Human Experiment Design Research) method (Mandran, 2017) designed to accompany RICH (Human Centered Informatics Research) type of research and applicable to TEL. In our case, the collection of traces of use will impose the setting of appropriate computer tools, these latters also being a way of lightening the work of teachers of SEG. It should be noted that in most purely playful Escape Games players are

followed by various devices (video capturing, sound, indicators, etc.) (Wikipedia, 2017). There are many perspectives on the use of SEG. The model should allow us to simply carry out this type of activity for other subjects. It can be noted that other achievements have already been proposed in various disciplines (Dumont and Nadam, 2016), with different audiences and in different contexts. Nevertheless, a certain number of brakes specific to higher education still have to be raised up. In particular, the constraints related to the training and the numbers of students potentially present in a training are important. The aim is to define and design the tools to adapt a SEG to a larger number of students simultaneously, and thus allow the monitoring of sessions on whole promotions (more than one hundred students).

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