EAI Endorsed Transactions
on Serious Games

Research Article EAI.EU

Influence of Dissociated Mechanisms of Gamification on the Learning of Reading

Raphaël Marczak[1], Pierre Hanna[1,*], Christine Hanna[2]

[1]Computer Science Laboratory (LaBRI), University of Bordeaux, 351 Cours Liberation, 33405 TALENCE, France
[2]Ecole Elémentaire Malartic, 2 bd Malartic, 33170 GRADIGNAN, France

Abstract

The introduction of serious games as pedagogical supports in the field of education is a process gaining in popularity amongst the teaching community. This article creates a link between the integration of new pedagogical solutions in first-year primary class and the fundamental research on the motivation of the players/learners, detailing an experiment based on a game specifically developed, named QCM. QCM considers the learning worksheets issued from the Freinet pedagogy using various gameplay mechanisms. The main contribution of QCM in relation to more traditional games is the dissociation of immersion mechanisms, in order to improve the understanding of the user experience. This game also contains a system of gameplay metrics, the analysis of which shows a relative increase in the motivation of students using QCM instead of paper worksheets, while revealing large differences in students behavior in conjunction with the mechanisms of gamification employed.

Received on 12 September 2017; accepted on 30 October 2017; published on 4 January 2018

Keywords: Serious games, game-based learning, gamification.

doi:10.4108/eai.4-1-2018.153529

1. Introduction

The role of digital technology in education is the topic of numerous studies and experiments which seek to measure its impact and potential benefits for the learning process. Among the applications made possible, serious games are of increasing interest. Serious games are games whose main objective is the acquisition of one or more fundamental concepts [17], thus making a specific educational objective attractive and motivating. The first serious games were developed in the 1970s [2]. There is a wide range of apprenticeship areas; both in the workplace and for teaching basic concepts to children.

The use of serious games in teaching is a core topic of study through the implementation of experiments conducted in classes. These studies show an interest in serious games for learning, but with different results depending on the disciplines involved. Some experiments show very positive feedback [19], such as the reasoned use of interactive tables in first-year primary (or 1st grade) classes [14].

In place of "serious games", the term "gamification" is often used. However, fundamental differences exist, and even if the boundary between serious gaming and gamification is permeable, it is often difficult to determine with certainty in which category a pedagogical development takes place. Andrzej Marczewski tries to explain the difference between gamification and serious play [16]. For him, a serious game must absolutely be an entity based on a concept of gameplay: the pedagogy must be rethought at the heart of a game-design specifically designed for the acquisition of notions. Gamification, on the contrary, starts from an existing pedagogical method, and completes it with concepts derived from game studies. In section 2 of this article, one can note that the QCM project presented in this paper is closer to the notion of gamification than serious gaming.

Existing studies and experiments do, however, contain strong limitations, mainly due to the fact that a serious game idea is tested each time to evaluate its overall game-design, without really decomposing it

*Corresponding author. Email: pierre.hanna@labri.fr

according to its immersion components. Yet, players can have different sensitivities to the different dimensions of gameplay, thus making a single game-design unsuitable for taking into account all the children of the same class. In the study presented in this article, the aim is not to focus on the development of a particular serious game, but to evaluate students' interest while interacting with various types of gamifications. This is not, therefore, a question of proposing new serious games or new mechanisms of learning, but of studying their possible impacts on motivation, and also assessing differences in the players' behavior on different games with the same educational objective.

The pedagogical context of the study described in this paper is the consolidation of the learning of reading in the first year of primary class (or 1st grade), with children aged from 6 to 7 years. Personal worksheets, derived from the Freinet pedagogy, have been gamified according to several dimensions of immersion and then presented to the students. The questions raised by this work are numerous: can gamification help motivate autonomous work? What are the impacts of different gamification mechanisms on students? Does each student behave in a specific way to the games? To try to answer these questions, the article is divided into several complementary sections. Section 2 first presents the QCM game, the immersion mechanisms of interest and the gamification of the Freinet worksheets of personal work for the learning of reading. Then, in Section 3, the experimental context is detailed, before presenting in Section 4 the various observations recorded. These observations help establish a set of first conclusions and perspectives detailed in Section 5.

2. Serious Games for Learning to Read

The core idea of the serious game QCM is to study the impact on learning effectiveness of the main mechanisms of video game motivation, as theorized by Gordon Calleja (for immersion [4]) and Mihaly Csikszentmihalyi (for flow [6], adapted to video games by Jenova Chen [5]).

Gordon Calleja defines the principal dimensions of motivation as:

- *Narration*: The player is motivated by the story of the game. He wants to know how the story evolves, and ends.
- *Ludic*: The player is motivated by the ludic elements of the game. He wants to try to improve his score, unlock achievements, or overcome complex levels or puzzles.
- *Emotion*: The player is immersed in the game through the emotional complexity of the game, regarding artistic design, humor, tenderness, or darker emotions, such as melancholy or fear.
- *Social*: The player is motivated by the possibility of adopting social behaviors, whether with other players, or other (non-player) avatars.
- *Kinesthesia*: The player is immersed in the game through a symbiotic feeling with his avatar, thanks to controls sufficiently intuitive in order to give the impression of controlling the movements and actions with virtuosity.
- *Strategy*: The player is motivated by his in-depth knowledge of the game virtual world. He can then build strategies to achieve the goals of the game (knowledge of rules, places, items, etc).

Gordon Calleja also mentions two levels of motivation, or implication: micro-involvement and macro-involvement. The first contains the reasons motivating a player to pursue a game session, while the second explains the motivating rationale for switching on the game again once the session is over.

Another research essential to understanding the motivation in video games is the one surrounding the psychological state of flow, as theorized by Mihaly Csikszentmihalyi [6]. Flow is a psychological state of well-being felt by individuals when they perform a rewarding task. Initially observed in athletes or musicians who are self-motivated in the (long) process of learning, flow is also observed in video game players [5], when the game-design is thought to include an effective difficulty progression. According to Csikszentmihalyi, the state of flow is reached when an optimal balance is found between the difficulty of an objective and the confidence of the learner in his own abilities. The objective must be ambitious, to motivate the learner without being too complex, in order not to create anxiety. At that point, when a goal is reached, the learner gains confidence, and can try to achieve more complex goals, and so on. One of the main characteristics of the flow is the sensation of losing the sense of time and space. In video games, the flow can be achieved if the difficulty is progressive: we also use the term of "difficulty curve".

The main objective of QCM is to be able to separate these main axes of motivation in order to be able to study their impacts independently while responding to the diversity of players. Indeed, what motivates a player in a virtual world is not necessarily what motivates another player. For example, in an article on the analysis of musical key moments in the *Bioshock 2* [15] video game, fundamental differences in behavior were highlighted, which were made explicit in interviews with players. In figure 1, the time taken by nine players to reach key moments in the game's story is listed.

The point of interest illustrating the differences in motivation is the time taken between the second and the third events. Indeed, the second event represents the encounter with a boss of the game (named Big Sister) who fled at the end of the fight. This boss is encountered again during the third event. It takes most players between two and three minutes to meet the boss again. But figure 1 shows two players with highly dissimilar behaviors: player 1, taking one minute, and player 3 taking ten minutes. The player 1 explained his "ludic" involvement, by his desire to beat the game as quickly as possible. Once the boss fled, he pursued it relentlessly to overcome the fight. On the other hand, the player 3 explained that the fight with the boss did not interest him, and he was relieved to see the enemy escape. He was then able to spend time observing the virtual world and reading and listening to the different elements of the game (books, soundtracks) detailing the history and the past of the virtual city. This player was motivated by the "narrative" dimension.

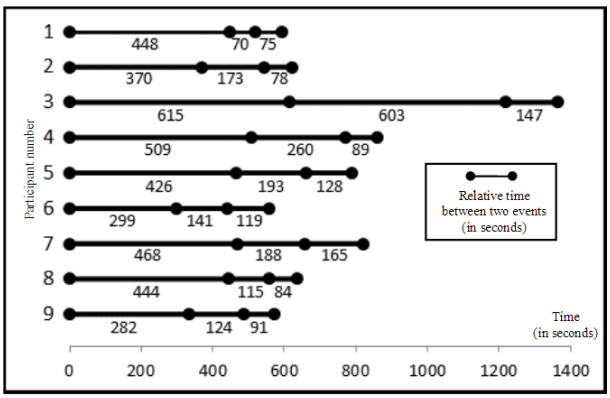

Figure 1. Time taken by Bioshock 2 players between four key moments of the game: first power acquirement, first encounter with the "boss", second encounter with the "boss", external vision of the city.

Within these games (serious or traditional), these dimensions (ludic, narrative, social, emotional, strategic and kinesthetic) co-exist in varying degrees and are necessary to create a complex virtual world in which players can immerse themselves. But it is then difficult to really determine with precision what motivates a student to interact with a pedagogical game and to offer tailored experiences that can take into account the diversity of player profiles. With *the Quest of the Masked Cucumber* (QCM in French), we tried to implement several reading games based on the same pedagogical objective, but revolving around different mechanisms of motivation.

Figure 2 illustrates the architecture chosen for the development of QCM, with the separated dimensions of involvement. In order to respect the pedagogy implemented by Freinet, the learning worksheets for reading remain unaltered in QCM: these are digital versions of the existing ones on paper. Thus, the pedagogical objective remains preserved. On the other hand, various video game overlays (on top of this pedagogy) have been implemented, and add dimensions of involvement without interfering with the initial pedagogical process.

Among the fundamental dimensions presented above, we chose to focus on three : the narrative, the ludic and the emotion, while also integrating the flow mechanism (the other dimensions are currently being implemented and will be released in future works). The narrative and the ludic dimensions represent two autonomous ludo-pedagogical experiments, using the reading worksheets within their gameplay. For example, it is necessary to answer a question to progress in the story - narrative, or it is necessary to answer a question to get a key - ludic. Emotion exists within the main menu and within each game. Indeed, the games and the menu are all in a *medieval/fantastic* mood, playing a role of *storyteller* for students. Lastly, flow is at the heart of the progressive difficulty given to reading worksheets and, to a lesser extent, to the evolution of the player in narrative games (a story which becomes more complex) and ludic games (actions to be carried out to move to more complex higher levels). These choices and developments are detailed in the following paragraphs.

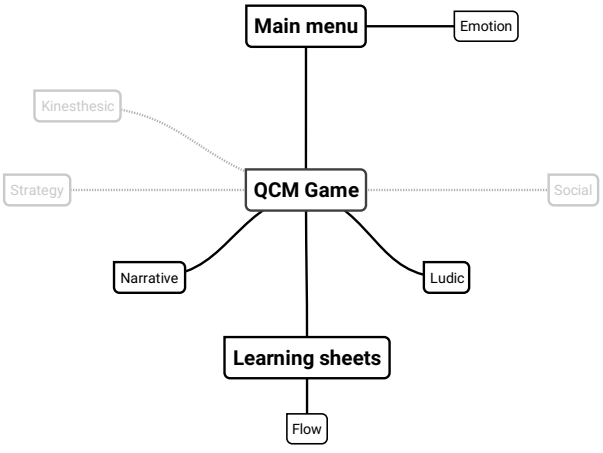

Figure 2. Illustration showing the general architecture of QCM, with the associated involvement dimensions.

Thus, the following section focuses on the presentation of the self-study learning worksheets with their work objectives, then the QCM application and its two main games based on these worksheets, emphasizing the chosen mechanisms of gamification.

2.1. Freinet Pedagogy and Individual Worksheets

The Freinet pedagogy [11] is a pedagogy based on free expression, which permits the child (learner) to work autonomously during sessions of short duration (20 to 25 minutes per day for the first year, up to 45 minutes in the fourth and fifth year of primary school). Worksheets designed for autonomy works were thus created around the different topics taught in primary school: Mathematics, Spelling, Language, Science, etc. The self-correction files proposed by the PEMF & Cie [1] editor are among the tools frequently used in Freinet pedagogy. To establish the educational foundation of QCM, we chose reading files adapted to first-year children (first grade), in primary school. There are 4 levels of worksheets, containing 48 files each, and ordered by increasing difficulty (the 4th file is proposed for a first year to second-year step). The pedagogical objective, as specified by the publisher, is mainly to give meaning to the written elements and to develop more and more expert reading strategies.

Figure 3. Example of a reading worksheet intended for personal work in autonomy in level of first year of primary school (edition PEMF& Cie).

Since the experiments involve a class of first-year children in primary school at the end of the year, we have chosen, following the advice of the teacher of the class, to consider the worksheets of levels 2 and 3. Figures 3 and 4 give an example of the worksheets considered. Two sections constitute a sheet. On the front side (figure 3), an illustration and a related sentence (or words) are displayed, possibly with partially hidden or missing words. The second part, on the back (figure 4), shows another situation illustrated, in relation to that of the front, with several textual affirmations. The child must choose from these propositions the sentence or word corresponding to the situation. The choice is made by selecting a symbol (blue square, red triangle, etc) linked to each proposal. The number of answers can vary, between 3 and 6.

[1] http://www.pemf.fr/pemfetcie

Figure 4. Example of a reading worksheet intended for personal work in autonomy in level of first year of primary school (edition PEMF& Cie).

The usual organization of a work session in personalized autonomy allows the child to take a sheet of the file on which he/she works, to think about it, to choose the corresponding answer on his/her result sheet containing all the 48 worksheets and then have the result sheet corrected to the teacher, once fully filled out. The teacher then simply indicates errors by means of a color code. If he has made a mistake, the child is asked to take the card(s) concerned and to think again about it and correct it. The games studied in this article were developed with the concern to respect this practice: after each answer given by the child, a simple correction of the type "true/false" is presented without further details. In the case of an incorrect answer, the form will be presented to the child again in a future session.

These reading worksheets have been scanned as digital images to serve as a basis for the serious games proposed during the classroom experiments. The pedagogical relevance of these worksheets is no longer to be demonstrated. Their simplicity and objective of working autonomously also support this choice. These digitized worksheets are deliberately presented in the most neutral way possible, so as to be as close as possible to the presentation of the worksheets in paper format. Thus the influence of the different dimensions of gamification does not directly disturb Freinet pedagogy, and the comparison between work on digital tablets and on paper forms is made possible.

2.2. Narrative dimension

The first game developed within QCM is essentially based on the narrative dimension. A screen of the narrative game is presented in the Figure 5. This narrative invovlvement, as formalized by Gordon

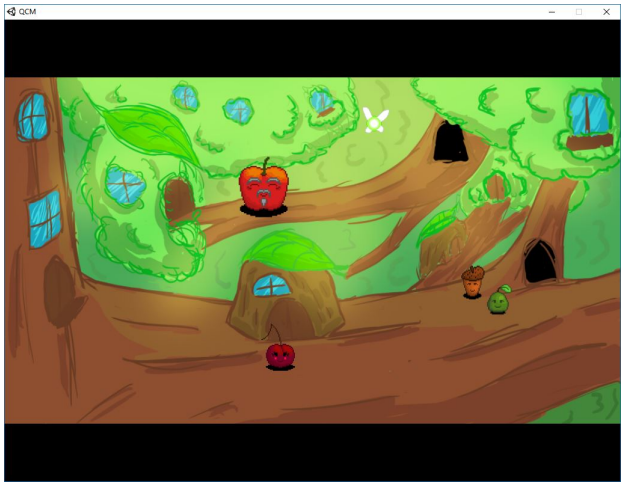

Figure 5. Experimented games in classroom: screenshot of the narrative game.

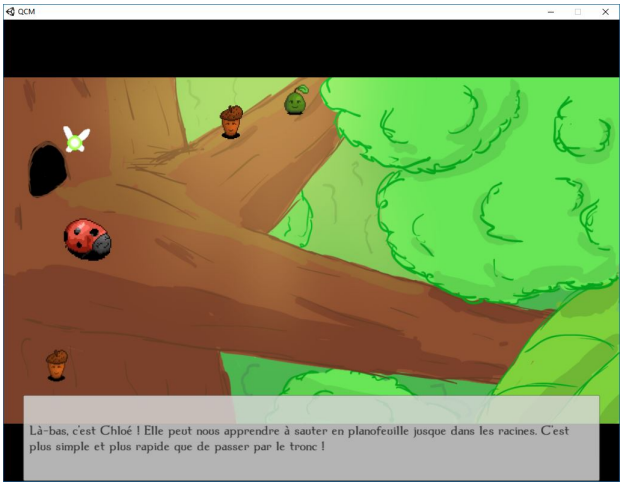

Figure 6. Narrative game: screenshot of a game session with text.

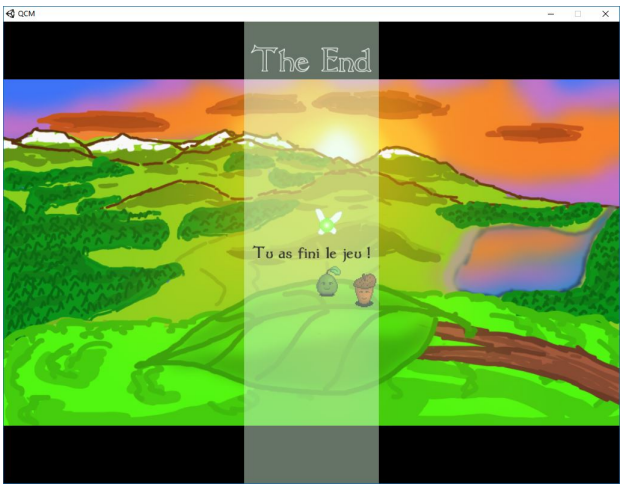

Figure 7. Narrative game: the final scene, "game over" is written (in french).

Calleja [4], stems from a player's interest in the narrative structure of video-game content. From the point of view of micro-involvement, it is a question of motivation stemming from a player's curiosity about the immediate progress of the game's story. If we take the example of reading a "novel", it would be the involvement allowing a reader to continue reading the paragraphs until the end of a chapter.

From the point of view of macro-involvement, narrative involvement is the one that will make a player play the game again in order to reach the final outcome. Taking the example of reading, the narrative macro-involvement concerns the instant when the reader stops reading at the end of a chapter, marks the page with a bookmark, and decides to close the book to resume later.

Gordon Calleja [4] deepens his analysis of narrative immersion by including also the player within it. Since the intrinsic nature of video-game media is to be activated by a player [1], it is possible for the same player to "relate" interacting with a game system. He is able to show actions he chose to realize, and the reasons justifying them. Thus, it is important to think of the narration of a game as having multiple connections, in order to allow a player to have the feeling to control the narrative sequence of the game, and thus create his own narrative of his experience.

The narrative experience proposed in QCM addresses the issues raised in the previous paragraphs in order to optimize the player's commitment to the game system. The story is that of a small seed lost on a tree, and Who does not yet know how to speak. "She" meets various friendly characters, ready to help her in her quest for her origins, along seven hand-drawn scenes[2]. The drawing "by hand" allows, from the point of view of emotional engagement, to approach the artistic style of young children.

When the child interacts with a character, the character speaks to him/her. The child hears the dialogue (recorded voice), synchronized with a scrolling text (see Figure 6). It is thus possible for the child to make the link between what he/she can hear and the accompanying transcription, either autonomously for the "expert" readers or with the help of the teacher for the others. The character offers him a quest, and a worksheet appears. If the student answers correctly, the quest is successful, and the story follows a positive branch. If the student is wrong, the quest is not fulfilled,

[2]graphics by Henri Toussaint

and the story will have a more modest outcome. In any case, the story ends on a positive note, the goal being not to frustrate a player who still has difficulty reading at this stage compared to other classmates. At the end of the game, the avatar of the player and the characters encountered are found on the top of the tree (see Figure 7), and tell the seed its future: to continue to populate the forest.

This game involves the child through narration, thanks to the following mechanisms:

- A simple but immersive story, allowing the children to be motivated to reach the next stage (micro-involvement);
- A story with connections to allow the children to create their own narrative, and to discuss it with their friends;
- A childish visual to connect with the player on the level of emotional engagement;
- A simple and relaxing sound universe, so that the player feels comfortable, and in good conditions to read and answer questions;
- When the child is wrong, the dialogue clearly indicates that the quest remains unfinished, but the story continues on a positive note, so as not to frustrate the children who still have reading difficulties;
- Each dialogue is subtitled, to allow the child to link the writings and their spoken correspondences, some in an autonomous way and others with the help of the adult.

2.3. Ludic Dimension

The second game implemented is based on the ludic dimension [4]. It represents the need for a player to untie a puzzle, complete one or more goals, and/or achieve a high score. This dimension is essential and is an integral part of any game (video or not). Even for narrative-based play, the desire to find the "right" end can be perceived as a ludic dimension. To limit the influence of the ludic dimension in the previous game, we avoid any mention of scores, times, or objectives to unlock.

Like the narrative dimension, the ludic involvement can be *micro* or *macro*. In the so-called *micro* phase, the player tries to complete the current puzzle or goal. The idea is not to leave the game *unachieved*. It is, therefore, necessary to have distinct levels, objectives, or phases of play so that the player can identify the moments when a challenge is successful. At the *macro* level, the player wants to improve his score or to unlock successes, or wants to replay because the levels have a replayability property (ie the player can replay them without getting bored). Gordon Calleja also explains that one of the forces of ludic engagement lies in the ability to offer self-challenging mechanisms for players. This means that players can create their own challenges, or even propose them to others. For example, Super Mario Bros games contain stopwatches. When it reaches zero, the player loses. But the presence of this chronometer also allows players to challenge themselves, like "I want to finish the level in less than X seconds" or to tell friends "I finished the level in Y seconds, can you do better? ".

The gameplay, proposed by QCM, fits in the properties listed previously. Figure 8 shows a screenshot of this ludic game. First of all, it is a labyrinth game, clearly identifiable by children as a puzzle whose rules they master: find the exit without crossing the walls. To get out of the labyrinth, you must recover keys (one at level one, two at level two, etc), which are disseminated there. Once the key is found, a question of the reading worksheet is presented to the child. If he/she answers correctly, he/she gets the key. If he/she is wrong, the key is teleported elsewhere in the labyrinth.

Several choices of game design support the ludic dimension in addition to the puzzle/labyrinth aspect, ludic by nature:

- first, a stopwatch is present on the interface of the labyrinth. This one is ascending, in order not to stress the player who could otherwise answer "too fast and false" instead of "quietly and pertinently". On the other hand, the presence of this stopwatch offers a ludic dimension, allowing players (supported by the teacher) to compare themselves with the other students. At the end of the five levels of the game, a summary (score) is displayed, level by level (see Figure 9).
- In addition to the keys, small characters may appear (such as a malicious cucumber). The player can meet them. He/she must then answer a question, to "unblock" this character. This makes use of the motivation of collection (manage to have all the characters), also linked to the concept of success.
- Levels are also generated procedurally. This means that it is impossible to predict the shape of the labyrinth upstream. This means above all that the game has a high replay value, since each level, will be randomly different from the previous one. Thus a player who has finished the five levels can replay them and can have to handle a different challenge.
- Finally, the graphic style of each labyrinth evolves according to the levels (walls, libraries, etc), as well as the musical atmosphere. The music is

initially composed only of the bass, then drums are added, and finally the instruments of the foreground. Thus, the more advanced the player, the more "rewarded" by a music provided. It is a ludic involvement that is more unconscious but above all a strong signal indicating that the player is progressing.

It is important to note that no narration is offered to the player. The levels are connected without transition, other than a graphic, sound and change in difficulty. Thus, the narrative dimension has little influence on this game, and motivation can be tested independently.

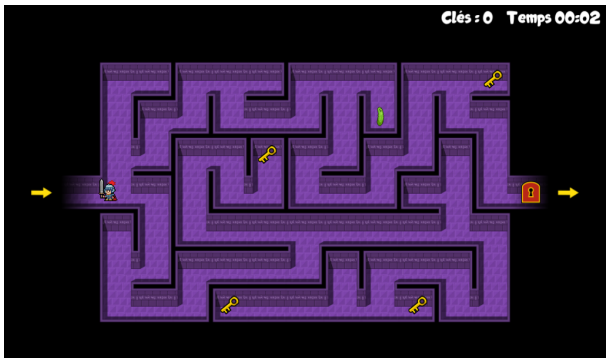

Figure 8. Ludic game: screenshot of a game session.

Figure 9. Ludic game: end of the game with results.

2.4. Selection Menu

Immersion within a video game starts from the main menu. Sometimes considered as not important, the main menu represents the entry point of the player in the virtual universe. It allows, within seconds, to bring the player into the magic circle [13], ie to integrate the fact that its actions will have an impact on a world with clearly defined rules, with consequences foreseeable by these same rules.

The two games presented previously have a spatial and temporal coherence. The ludic game takes place in a medieval world; and the narrative game is based on a quest system, in a world devoid of technology. These two games can, therefore, be classified as part of fantastic universes. In order to respect this coherence, the menu of choice (see Figure 10) is also fantastic/medieval in inspiration. Thus, there is no interruption of the immersion for the player, between the menu and the game he/she has chosen. This choice, therefore, makes it possible not to influence the player's emotional and spatial commitment to the video game system.

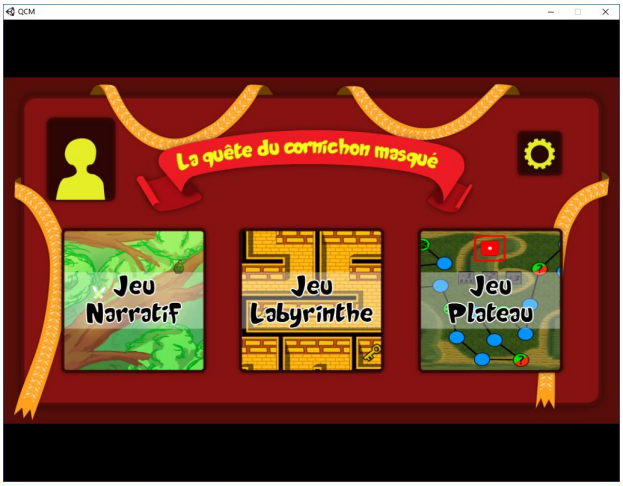

Figure 10. Experimented games in classroom: the main menu.

3. Experimental Protocol

The games within QCM, based on the autonomous learning worksheets for reading, have been experimented in class. The class concerned is the first year of a primary class of the Malartic Elementary School in Gradignan (Gironde, France). The class consisted of 23 students, between 6 and 7 years old, including 8 girls and 15 boys. Two groups of 11 and 12 children were formed. The distribution of the children was done in agreement with the teacher of the class in order to obtain two groups comparable in terms of reading skills. Experiments lasted 2 weeks in June 2016. The games were installed on digital tablets, format 10 inches, equipped with headphones. Each child had his/her own tablet, labeled with his/her name, allowing to collect the relative (and personal) usage information. It should be noted that students had never used digital tablets in this context of the class, but sometimes had access to serious games on two computers, in free use during autonomous sessions. The photographs in Figures 11 and 12 illustrate the experimental environment. The group of students working on paper worksheets was in the classroom, while the group working on the digital tablets was in the room adjacent to the classroom.

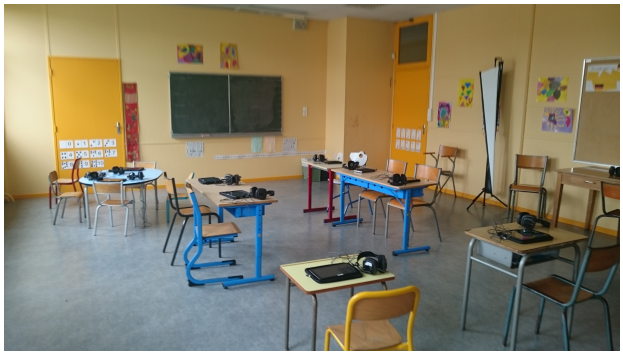

Figure 11. Experiments in class: the room adjacent to the classroom, dedicated to the use of digital tablets.

Figure 12. Experiments in class: a group of children manipulating serious games QCM.

The two weeks of experiments were split into two phases, each week being dedicated to one of the two groups of children. We denote these two groups *A* and *B* for the following discussion. Beforehand, the teacher presented the various games QCM proposed to the children using a video projector, as well as the experimental protocol and the composition of each group. Each week begins with a dedicated session on Monday afternoon: while one group uses serious games, the other group works on paper reading worksheets. The two groups work independently, the teacher corrects the worksheets in paper format, while one of the co-authors assist children on digital tablets in case of a technical problem. A session duration of 20 to 30 minutes was envisaged in consultation with the teacher. As a result of these two sessions (one at the beginning of each week), also an interview with the children allowed an opportunity to gather their opinions.

The choices of the reading worksheets, chosen on the basis of the serious games QCM, are adapted: the first week, all children have access to the worksheets (paper or digital format) from level 2. During the second week, The children who have completed the level 2 worksheets will be suggested level 3 worksheets, while those who have not completed yet are given level 2 worksheets that they have not processed yet or not successfully completed.

During the first session, the two games, ludic (labyrinth game) and narrative (narrative game) were available, giving the choice to the children. The board game presented in the menu in Figure 10 has been made available only for other autonomous work sessions, as this game involves several players. Due to difficulties with usage records for this game (collective use), the study on the use of this game is not detailed here but will be done as part of a future research project.

As a result of this first session, the children in the group who had used the digital tablets were able to use again the tablets over periods of independence during the rest of the week. These periods of individual activity depend on the time left after collective work and may vary according to the children. In addition, children could choose from several activities in addition to the use of digital tablets: playing construction toys, card games based on calculation, puzzles, reading, drawing, working on other stand-alone materials for reading, etc. To identify autonomous-learning children, a sheet was available to them, and they were asked to register before performing each task. This process leads to the definition of six periods of autonomous work each week.

The evaluation of a serious game is often limited to basic information, such as the time spent on the game, and whether it was finished or not [8]. The serious game is then considered as a black box, dealing only with session data. Here one objective is to deal with more precise information on the use of games, in particular, to try to understand and evaluate the behavior of the children facing QCM games.

For this, authors have used "gameplay metrics", which are time-stamped quantitative data directly generated according to the source code of games, and reporting the different actions performed by a player in the game (eg jumping, moving, use of an object, discussion with a character, etc) [9]. The gameplay metrics provide an exhaustive description of the interactions between a player and a game system, and simplify the analysis of the experience, presenting a summary of the session. Authors then obtain quantitative data that are comparable with each other and propose a more precise analysis than a complete observation made during the game session. Moreover, a direct observation can add a bias, players not interacting the same way when they know they are observed by an outside viewer.

Authors developed, using the Unity3D video game ngine [18], a module of an automatic log of metrics. These metrics are stored in a file, with the player's ID, the precise date (in milliseconds) of each action performed, and the identifier of the action (with potential variables, such as the success of an action true/false, or the x and y positions of an avatar,

etc). This module is also able to record metrics on a web server, to do telemetry, but we did not use this possibility during the classroom experiments.

For the QCM games, here is the non-exhaustive list of metrics that were decided to be retrieved and processed during this study. Each metric being time-stamped, this information is not specified in the following list:

- **General**

  Start the game (GAME_START, true)

  End the game (GAME_END, true)

  Pause (GAME_PAUSE, true / false)

- **Main Menu**

  Launch the main screen (MAIN_MENU_START, true)

  Exit from the main screen (MAIN_MENU_QUIT, true)

- **Narrative**

  Launch the narrative game (STORY_START, true)

  Enter a new scene (STORY_SCENE_START, number)

  Exit stage (STORY_SCENE_END, number)

  End Screen (STORY_END_SEQUENCE, true)

- **Labyrinth**

  Launch the labyrinth game (LABYRINTHE_START, true)

  Exit the labyrinth game (LABYRINTHE_END, true)

  Current level (LABYRINTHE_LEVEL, level number)

  Collision objects (LABYRINTHE_(KEY / BONUS / DOOR), true) (LABYRINTHE_DOOR_POS, x, y, z) (LABYRINTHE_KEY_POS, x, y, z) (for each key) (LABYRINTHE_BONUS_POS, x, y, z).

- **Worksheets**

  Start the question (QUESTION_START, true)

  Sample screen (QUESTION_EXAMPLE, link to image)

  Answer screen (QUESTION_QCM, true)

  Player answer (QUESTION_ANSWER, number of choice, correct / wrong answer)

The experiments carried out in the classroom resulted in the acquisition of about 140,000 lines of metrics, which were then processed in order to obtain information to highlight the behavior of the learners. The main results are presented in the next section.

4. Results

The results of the classroom experiments are presented in this section, trying to consider three main problems: the children's ability of becoming familiar with new digital supports, the influence of gamification mechanisms on student involvement, and the diversity of behaviors in relation to the different gameplay dimensions.

The evaluation of serious games in the school context is complex and can be adressed from several points of view. Indeed, numerous evaluation methods exist, but they are often specific to each video game [3], which explains the difficulty of proposing generic methods of evaluation [12]. Generally, the evaluation is performed with respect to the time spent on a learning task [10]. In the experiments presented in this article, the task of learning occurs between each game sessions. As regards to the pedagogical aspect, the results presented are, therefore, mainly related to the number of worksheets processed by children, the time spent on these learning tasks and the number of errors.

4.1. Usage of the video games

A first part of the observations concerns the use of serious games on digital tablets, with regard to the originality of the support and the lack of experience in the use of digital tablets in the context of learning. The first session of each week lasted about 30 minutes, with all children playing on the digital tablets until the teacher indicated the activity has to be stopped. At first, most children were quite eager to start, showing great curiosity. This motivation was maintained since, when asked if the children wanted to continue the activity, all without exception responded positively with enthusiasm. The silence during each session was very marked, only disturbed by technical demands (for example, to increase/decrease the sound) or by the desire of certain children to share successes, especially on the ludic game. This last point confirms the interest of considering experiments on the social dimension of games (comparison of scores for example) in the future.

Regarding the handling of the digital tablets, ease of use was noted, certainly supported by the experience of games on digital tablets for most children at home. Some, however, indicated that they did not use any tablet at home, without showing any particular difficulty in interacting. The aid requests were mainly related to adjustments (volume, headphone for example) or to the management of rare problems of execution during the video games. The children also did not seem to be destabilized by the paper worksheets, which they had never used before.

At the first digital tablet session of each of the two test groups, all the students tested both games: ludic and narrative. Most of them started with the ludic

game, whereas presented in second place on the menu (see Figure 10): only 5 children over 23 started with the narrative game. There are different behaviors: some children have first tested each of the two games before choosing one, While others preferred to finish one of the two before testing the next game. Many also tried the board game during the autonomous work sessions in the experiment week: at least two-thirds of the children were curious about this other game and tried it with classmates.

The analysis of the usage data makes possible to highlight some important elements. First, the number of worksheets completed (ie, processed by the children, with the correct answer) is 418 for the paper format, while 692 for worksheets in gamified digital format. The difference is significant: 60% more for digital worksheets made through serious games. On average, 26 paper worksheets were processed by each student, compared to 43 in digital format for the same period of time [3]. Figure 13 shows the variations in the number of unique worksheets processed by the different children, according to the two contexts. Students who are most comfortable with reading have completed the two worksheet levels regardless of their formats, such as *A*, *F*, or *R*. On the other hand, a few students, such as students *N*, *O* or *Q*, who have not processed a lot of paper worksheets are then more active, which often results in making up for the lost time of the first week on paper forms.

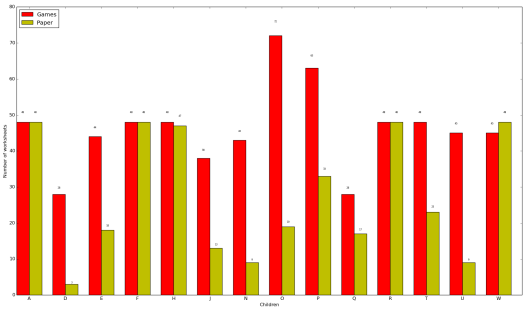

Figure 13. Variations in the number of unique worksheets handled by the different children according to the two contexts (paper and digital games). Due to errors in activity records and absences that may distort the results, the student group is reduced here to only 14.

This difference in the number of files processed according to the format can be explained in part by the curiosity brought by the digital format. This justification can be tempered, however, because the children had not handled paper forms before. A curiosity, therefore, existed also for this format. More practically, the correction of the worksheets in paper format by the teacher induces a displacement in the class with a potential wait, slowing down the learning process for children working on paper. In addition, a single copy of each worksheet is generally available in paper format, which can slow or disrupt some children, who sometimes need to follow an established order, such as a reassuring organizational routine. In the end, the number of worksheets processed by children over the same time interval supports the practical advantage of worksheets in digital format over paper-based ones.

However, it is also necessary to study the impact of the gamification of learning worksheets in order to assess whether the increase in the number of worksheets processed is due to the passage of the worksheets in digital format or whether the gamification induces additional motivation. By analyzing the children's worksheets processed, it appears that some children have answered the whole worksheet of the proposed level, and, by continuing to play, have had to process again worksheets that they have already processed. Some have also chosen to resume the serious games during periods of autonomy work in the week and decided to process again worksheets already answered. In addition, no child (even having completed a worksheet) has decided to stop playing. On the sample studied 10 children over the 23 composing the entire group ended the file and nevertheless continued to play. For example, the student *R* has processed more than 140 worksheet questions while the worksheet level contains only 48 different questions. It is interesting to note here that this child had pointed out himself as not playing on the digital tablet at his home. For these cases, the motivation is clearly linked to the gamification rather than the willingness to complete the proposed work.

Another element concerning error rates deserves to be highlighted. The number of bad answers to the worksheets is measured, and an average error rate is deducted. Figure 14 represents the number of correct and false answers for each student when working on serious games. The discrepancy between the error rates for digital and paper forms is large and clearly lower in the paper format. Indeed, the error rate on paper is 4.5% while it reaches 22.5% on digital format. Several explanations can be investigated, but the main one seems to be related to the attention carried in search of the good answers. The ludic context seems to make some students less rigorous in reading. The difference in behavior is quite marked on this point. The student *F* for example, identified among the other students most comfortable in reading, seemed much less focused on serious games, getting 25% of errors, while he had not gotten any on the worksheets in paper format. Conversely, some students, less numerous, did not seem

[3] Taking account of absences and errors, the comparison between paper form and digital format is considered only on a subset of 14 children.

to be sensitive to the change of context. For example, the student *H* committed only 2 errors on his 133 worksheets processed (a single level of 48 worksheets, but with processing the same worksheets again and again). By working on the paper format, this child made 4 errors on the 48 files processed, even though for this student worksheets from level 3 file processed during the games sessions were more complicated than worksheets from level 2 file processed on paper.

These two children are very serious students, particularly concerned to provide quality work. This difference in behavior facing the digital tool - many more errors than on paper for *F* and only a few ones as on paper for *H* - can find an explanation in the representation of the task that each of the two students has built. The student *F*, whose access to the digital tablet in his home is very controlled, had formulated the fact that the "real work" is the one made on paper. In his view, the digital format represented a "simple game" and therefore did not require any particular involvement, according to his own criteria. On the contrary, the child *H* was fully aware of being in a learning situation, in both cases. They therefore applied the same rigor, the same concentration on digital or paper format.

This increase in the error rate, quite marked for some students, deserves to be studied more in depth to highlight all the elements that can disrupt the experience of certain players, such as the readability of the worksheets on digital tablets.

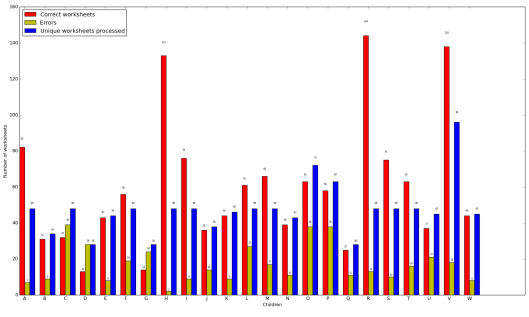

Figure 14. Variations in the number of correct answers, the number of errors and the number of unique worksheets processed by the different children on the worksheets of the serious games.

Despite the higher number of errors in the processing of the worksheets in the serious games, it appears that in the end, the total number of worksheets correctly processed by the students is more important in this digital context: 692 unique worksheets have been correctly treated for only 418 in paper format. This means that the children processed again the wrong worksheets and answered correctly. A more consistent study with a larger number of students would help to understand the origin of increases in error rates for some students, and to see if a usage pattern would smooth the error rate and the excess of motivation observed. It would also be interesting to measure the impact of the work done with games on the assimilation of reading strategies. The first experiments presented here, however, make it possible to put forward already the level of interest of the gamification on the influence of their involvement and clearly highlight the differences of behavior between pupils in such a digital context.

4.2. Involvement

In this section, we present the impacts on the involvement induced by the serious games presented above. As indicated in the protocol presented in section 3, after a first supervised work session (serious games or paper), the children were then able to choose the reading worksheets during periods of autonomous work, among other usual activities (building games, mathematical card games, puzzles, reading, drawing, ...). According to their group and the week chosen, the children had either access to worksheets in paper format or to serious games on digital tablets. For these periods of autonomy, the children had to register by indicating that they would carry out an activity in autonomy (without specifying which one). Tablet activity data shows the proportion of students who chose to work using serious games. The experimentation over two weeks allows to observe the evolution of the behavior on these periods of autonomy, according to the possible access (or not) to the serious games on digital tablets. The table 1 summarizes the number of works performed autonomously for each group, each week.

Group	Week 1	Week 2
1	**47**	39
2	30	**48**

Table 1. Evolution of the number of works performed autonomously in the class according to the groups during the two weeks of experiments.

A significant increase (p-value of 0.038 in test χ^2) of the number of autonomous activities of children having access to serious games on digital tablets (group 1 for week 1, group 2 for week 2) compared to students with access to paper worksheets is observed. Access to serious games on digital tablets seems to induce an increase in activities and motivation. It is important to note that the curiosity that could be involved here in the modification of behaviors also affects paper worksheets (not previously used by students). It is obviously necessary to balance the conclusions with the

short duration of the experiment presented, the small number of students concerned and this possible effect of curiosity. Longer experience could confirm or deny these early trends.

Concerning involvement, differences in behavior between students can be observed. For example, child *G* has done twice as much self-employment in week 2 as in week 1, even though he is in the group 1, that is to say with access to games on the week 1. Similarly, child *M* realized 50% more independent works on week 1 than on week 2, whereas he had access to the serious games during week 2. For these examples, it is likely that paper forms interested them or that they no longer want to resume serious games. On the other hand, children *E* or *U* were much more active during the periods of autonomy during the week during which they had access to serious games on shelves.

These observations seem to indicate that for some pupils, the numerical format of the learner cards induces a surplus of motivation. Some students are less sensitive to this format. It is, however, interesting to study more closely the behavior of pupils in relation to games and to analyze whether there are also differences in behavior depending on the games, that is to say sensitivities different from the ludification dimensions chosen in this experience. The following section details this issue.

4.3. Personalization

In this section, different reactions of children facing the proposed games are recorded. This is used to demonstrate the varied links between players and serious games, depending on the dimensions of gamification. Figure 15 lets you view the different game sessions for each child. A new segment indicates a new game session, while a change of color indicates a change of game: three different colors are used for the three games offered: playful, narrative and collaborative (collective board game). The duration is represented by the length of the segment.

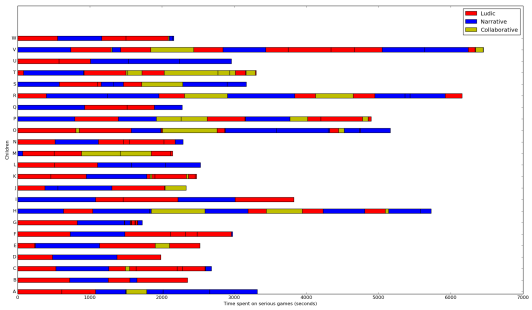

Figure 15. Visualization of game sessions over time for each child.

First, this representation makes it possible to highlight the differences of choice between certain children. For example, the student *K* only played the narrative game once. He finished the narrative game in the first session but did not want to start this game again. During the end of the week, he launched the ludic game 7 times but only once the narrative game. This can be explained by the possible interactions with the other children, in particular to obtain a better score (time to finish levels) and thus to compare himself/herself with his/her classmates. This motivation mechanism linked to the social dimension must be tested in a future experiment. Another example is student *D* who plays the game of the labyrinth during the first session, then tests the narrative game without finishing it, and finally prefers to return to play the ludic game. These children who have mainly played several times the labyrinth game are, therefore, more sensitive to the ludic dimension.

Other students make completely different choices, paying particular attention to the narrative game. For example, children *A* and *H* have launched the narrative game 8 times for only 3 (or 4) times the ludic game of the labyrinth. So child *A* started the first session with this game, finished it, started it again before starting the narrative game. From then on, this child did not return to this game and then played mainly to the narrative game. The explanation probably stems from the fact that this child *A* did not have enough time on this first session, and then during the other autonomous sessions, to go through the narrative story. It is conceivable that the motivation to see the end of the story was an important factor in the choice of the game. Student *H* alternated between narrative, ludic and collaborative games. But it is important to note that each time he played the narrative game, the time spent was important, progressing through the story at each session.

During the ludic game, a bonus (in the form of a cucumber) appears in the labyrinths. It has no use for accessing the next level, but just allows to unlock a character (motivation of collection). The collection of cucumber triggers a series of two questions, as for the taking of the keys. By analyzing student behavior on this element of the optional game, it appears that the bonus was taken 134 times out of the 169 sequences during which it was available, which represents a significant catch rate (80%) for this optional element of the game. This rate is even undervalued, as much of the remaining 20% is essentially due to a lack of time to complete the current level. This result is all the more interesting because at the time of the experiments in class, the mechanism of collection was not yet connected in the ludic game: getting a cucumber did not unlock new characters. The children still tried to catch this object, certainly in a wish to finish the

level at 100%, and by the ludic semantics adjoining this element of gameplay.

A question about the difference in behavior between girls and boys can be raised. Comparing the use of games, there are no significant differences: 25% of girls completed the narrative game, for 28% of boys. Boys were 79% to finish at least once the ludic game, compared to 50% of girls. This slightly higher ratio for the ludic game might indicate a slight preference for boys for ludic games, which can be explained by the behavior observed during the first session: some boys seemed motivated to compare the scores obtained in the ludic game. An experiment on a larger number of children would confirm or inform this hypothesis.

On the first session of play, all children made between 2 and 3 game sessions. Some have finished one game before starting the next, while others have first tested both games before trying to finish one. At the end of the sessions, 6 children have at least completed the narrative game once, while 15 children have finished at least once the 4 levels of the ludic game. Only 4 students finished the two games: *E*, *H*, *P* and *R*. An essential observation is the difference of behavior in front of the 2 different games, since some were motivated to finish one of the two games, but not the second one. In addition, from the 4 children who completed both games, there are two children *E* and *P* who are not among the most comfortable reading students. The gamification of the worksheets seemed to motivate them. However, for student *P*, this motivation resulted in a surplus of errors. For him, the desire to progress seemed to take precedence over the concentration and quality of the answers.

As mentioned in the section 3, many data elements have been obtained when the students used the games: interactions, time spent, worksheets processed, etc. These various data categories allow to obtain, after specific analysis, important pedagogical elements, whether at the level of the class or at the level of each child. At the level of the class, data analysis allows, for example, to have a precise vision of the skills acquired or the difficulties encountered on certain questions. This may reflect either a collective need to deepen certain skills related to the worksheets concerned, or a difficulty in understanding when reading certain forms (formulation of sentences, instructions, clarity of the task to be accomplished). To illustrate this, all children's responses were compiled to establish an error rate per record. This error rate for the 96 used worksheets is represented by figure 16. Significant variations in the error rate can be observed. These variations are not linear depending on the difficulty of the cards, which may reveal specific learning difficulties. For example, a fairly large error rate (the third highest rate) is observed for question 49. On this question, the student has a choice of 4 sentences with some letters hidden. The analysis of the false answers is particularly interesting: the expected answer is *c'est un gros livre* (*it is a big book*) whereas the analysis of the errors indicates that 7 children of the 8 that made a mistake answering *c'est un grand livre* (*it is a great book*). Compared to the other answers and with regard to hidden letters, it seems here that the difficulty arises from the two empty letters: *s* at the end of the word *gros* and *d* at the end of the word *grand*. This ability to understand the silent letters (looking for a word from the same family in which this letter is understood: *gros/gros(se)*, *grand/grand(e)*) is a skill worked up to the end of the second year and remains a recurrent difficulty in first year, as it is being acquired. The analysis of errors seems coherent, giving an important element that can be taken into account pedagogically.

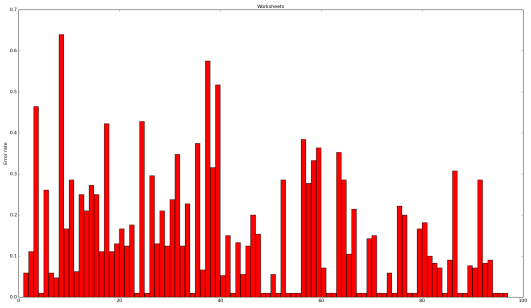

Figure 16. Variations in the error rate for the various learning worksheets.

The metric analysis obtained for each child also allows to highlight possible difficulties in relation to the group. For example, if one considers the time spent resolving questions for each student, there are significant differences: on the first session, the ratio is 3 between the fastest child *H* (median time 33 Seconds) and the slowest child *Q* (median time of 10 seconds). Thus, by directly relating the error rates, it is possible to obtain the figure 17, which proposes a visualization of the error rate as a function of the median time spent on the resolution of the worksheets. Two different colors were used to differentiate the two groups of children and to ensure that there was no bias introduced by differences in experimental conditions. The width of the point is proportional to the number of worksheets processed by the child: the larger the point, the more worksheets are treated by the child and the more reliable the data. At the top right-hand side of the figure you can see the children who respond quickly and correctly, while at the bottom the children who have more difficulties reading these questions. Thus, child *H* is an example of a child who is comfortable with reading, and who responds to questions in the majority of cases both correctly and quickly. But this analysis

allows to highlight a particular behavior of children. For example, it may be useful to advise students C, D, G and P to take a little more time to answer the worksheets, possibly also the students M, S or V, Who certainly have a good success rate, but who could perhaps do better by taking more time for thinking. Child P, with little confidence in reading, usually has a slow but relevant pace of work. These results, therefore, indicate a change in behavior likely to be induced by the change of support and the gamification. Similarly, the child V, one of the best readers of the class, serious and disciplined in the work to make no mistakes, was visibly disturbed by the gamification. Gamification has caused him to accelerate his pace of work and he has made more mistakes than could have been expected. A longer experiment would allow to verify if a greater habit of serious games would attenuate this effect. Doing the same type of analysis for each child would also allow for more details on whether certain questions required more time, or whether the concentration was less on certain periods of time, resulting in a shorter response time but in an increased number errors. Individual advice can thus be directly deduced from these analyzes.

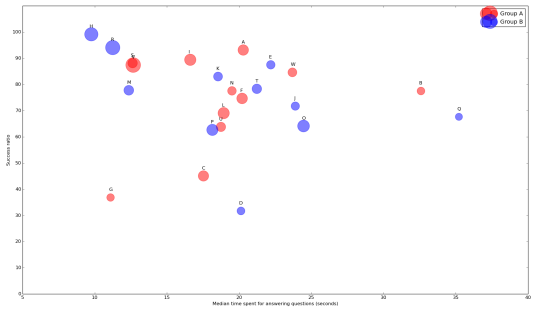

Figure 17. Variations in the error rate as a function of the median time spent answering the questions in the worksheets. The width of the point is proportional to the number of worksheets treated by the children and two different colors allow to visualize the two different groups of children.

5. Conclusions and Perspectives

Two gamification mechanisms based on the ludic and narrative dimensions have been experimented in a first year infants' class. The results are encouraging, especially concerning the motivation. If they are still exploratory, they open the way for future work to study their validity on a larger scale (number of children, number of worksheets, duration of sessions, etc).

The main points highlighted by the results obtained concern differences in behavior between children facing serious games: some are disturbed by gamification, some are motivated, some are particularly sensitive to a single dimension of gamification, and so on. These observations support the need not to propose a single type of serious games, but to diversify the mechanisms of learning so that each student finds an interest in it in relation to his style of learning. Thus, a specific exercise with a pedagogical objective, such as the autonomous reading worksheets in the studies presented here, could be gamified in different ways, using different immersion mechanisms. The mechanisms tested in this paper are based solely on ludic and narrative dimensions, but should be extended to other dimensions (social, kinesitic, emotional, or strategic).

The new needs induced by these multiplications of gamifications would be the automation of the search of games and, above all, the recommendation of the different games, depending on the learner's profile and/or the pedagogical objectives of the teacher. On the one hand, it would be necessary to be able to improve these mechanisms in order to be able to propose different types of games centered on the same pedagogical problem. But it would also be necessary to be able to guide the children and the teacher in front of the number of games and their different types, and thus go towards recommender systems adapted and personalized. This would involve the development of recommendation engines combining not only the aspects of learning, but also the pedagogical aspects.

In addition, other innovative perspectives can be envisaged, in particular related to the *learning analytics*, that is to say the processing of the data processed from the logs of use, making it possible to investigate the improvement of the personalization, the automatic validation of acquired knowledge, or decision support for the choice of gamified learning to be considered [7]. The automatic generation of games from digital teaching materials, based on several mechanisms of gamification is also a prospect to consider.

6. Acknowledgements

The authors would like to thank the teaching team of the Malartic elementary school in Gradignan, the students of first year (CP) who participated in the experiment and the Bordeaux laboratory for research in computer science (LaBRI) to fund the necessary equipment. They also thank the students of the ENSEIRB-MATMECA engineer school who contributed to the QCM project as part of their PFA (End-Year Project): Hugo Borel, Florian Fichant, Léo Grelet, Yves Le Moigne, Thomas Montaigu, Marie -Julie Rakotosaona and Henri Toussaint. And Bevin Yeatman for proofreading the paper.

References

[1] Aarseth, E. (2001) Computer Game Studies, Year One. *Communications of the ACM* **1**(1): 31–34.

[2] Abt, C.C. (1970) *Serious games* (Viking Press New York).

[3] All, A., Nuñez Castellar, P.E. and Looy, J.V. (2014) Measuring Effectiveness in Digital Game-Based Learning: A Methodological Review. *International Journal of Serious Games* **1**(2): 3–21. doi:10.17083/ijsg.v1i2.18, URL http://journal.seriousgamessociety.org/index.php?journal=IJSG{&}page=article{&}op=view{&}path[]=18.

[4] Calleja, G. (2011) *In-Game: From Immersion to Incorporation* (The MIT Press).

[5] Chen, J. (2007) Flow in games (and everything else) - A well-designed game transports its players to their personal Flow Zones, delivering genuine feelings of pleasure and happiness. *Communications of the ACM* : 31–34.

[6] Csikszentmihalyi, M. (2000) *Beyond Boredom and Anxiety: Experiencing Flow in Work and Play* (Jossey Bass), 25th ed.

[7] Del Blanco, Á., Marchiori, E.J., Torrente, J., Martínez-Ortiz, I. and Fernández-Manjón, B. (2013) Using e-learning standards in educational video games. *Computer Standards and Interfaces* **36**(1): 178–187. doi:10.1016/j.csi.2013.06.002.

[8] Derosa, P. (2007) Tracking Player Feedback To Improve Game Design. *Gamasutra* .

[9] Drachen, A., Canossa, A. and Seif El-Nasr, M. (2013) Game Analytics - The Basics. *Game Analytics* .

[10] Duncheon, J.C. and Tierney, W.G. (2013) *Changing Conceptions of Time: Implications for Educational Research and Practice*, **83**. doi:10.3102/0034654313478492, URL http://rer.sagepub.com/cgi/doi/10.3102/0034654313478492.

[11] Freinet, C. (1964) *Les techniques Freinet de l'École moderne* (Librairie Armand Colin), collection ed.

[12] Girard, C., Ecalle, J. and Magnan, A. (2013) Serious games as new educational tools: How effective are they? A meta-analysis of recent studies. *Journal of Computer Assisted Learning* **29**(3): 207–219. doi:10.1111/j.1365-2729.2012.00489.x.

[13] Huizinga, J. (1955) *Homo Ludens: A study of the Play Element in Culture* (Boston, MA : The Beacon Press).

[14] Kubicki, S., Pasco, D. and Arnaud, I. (2014) Utilisation en classe d'un jeu sérieux sur table interactive avec objets tangibles pour favoriser l'activité des élèves: une évaluation comparative en cours préparatoire. *Sticef* **21**: 1–32. URL http://sticef.univ-lemans.fr/num/vol2014/07-kubicki-evajs/sticef{_}2014{_}NS{_}kubicki{_}07.htm.

[15] Marczak, R., Hanna, P., Rouas, J.L., van Vught, J. and Gareth, S. (2014) From Automatic Sound Analysis of Gameplay Footage [Echos] to the Understanding of Player Experience [Ethos]: an Interdisciplinary Approach to Feedback-Based Gameplay Metrics . *Proceedings ICMC|SMC|2014* .

[16] Marczewski, A. (2013) WhatâĂŹs the difference between Gamification and Serious Games? *Gamasutra* URL http://www.gamasutra.com/blogs/AndrzejMarczewski/20130311/188218/Whats_the_difference_between_Gamification_and_Serious_Games.php.

[17] Michael, D.R. and Chen, S.L. (2005) *Serious Games: Games That Educate, Train, and Inform.* (Muska & Lipman/Premier-Trade).

[18] Unity Technologies (2017) Unity 3D game engine. URL https://unity3d.com/.

[19] Wouters, P., van Nimwegen, C., van Oostendorp, H. and van der Spek, E.D. (2013) A meta-analysis of the cognitive and motivational effects of serious games. *Journal of Educational Psychology* **105**(2): 249–265. doi:10.1037/a0031311, URL http://doi.apa.org/getdoi.cfm?doi=10.1037/a0031311.