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Reading Space Secrets – A Serious Game Centered on Reading Strategies

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Abstract. Serious games based on reading strategies are an efficient alternative for improving students' capabilities of text understanding. In today's industry and academic environments, there are various games that target reading strategies, but unfortunately most keep focus only on the educational component, leaving the user experience behind. These games are not appealing to young students and thus, may not fully achieve the desired outcomes. The serious game described in this paper puts emphasis on the user experience, tightly coupled with keeping a high standard of its educational focus. Preliminary validation experiments denote a high user acceptance of the proposed educational scenario as an alternative to the traditional scenario that consists of a lecture followed by a self-explanation of the input narrative text.

Keywords: serious games, reading strategies, comprehension skills, Unity game engine, ReaderBench framework, web services.

1. Introduction

Serious games are a developing business and have a major application in domains such as education, healthcare, and military (Susi et al., 2007). Today's serious games refer mainly to computer games. These are not intended to be played for amusement and most sacrifice the fun dimension in order to teach and support the user (Ritterfeld et al, 2009). One major advantage of serious games consists of enabling situations that are unavailable to users in real-life (Kobes et al., 2010) and that are overall harmless (Westera et al., 2008; Farrington, 2011).

In the educational field, serious games that enhance the users' ability to process information based on a given text are of particular interest. These

games are based on reading strategies and have been marked as one of the most efficient ways to improve the reading and comprehension skills of learners (Bokyeong et al., 2008). Serious games developers have a difficult task, and we are not referring to the complexity of the algorithms used, but to finding a balance between entertainment, education, and motivation in order to make the game attractive (Dempsey at al., 2009). All these three factors are important because the lack of one may lead to the user losing interest in the game.

The game described in this paper targets all the factors mentioned above in order to create a pleasant user experience, while keeping the user focused on the educational aspects.

2. Reading strategies and their capability to reflect user comprehension

Reading strategies are a key interest by providing insights with regards to the way users interact with and understand written text. These strategies are used consciously or unconsciously by the users when dealing with the acquisition, storage and retrieval of information (Singhal, 2001). By consciously reading, users can apply the same reasoning used in previous situations. They can adjust their effort and evaluate their success based on the previous reading experiences and can reapply the current case in the future.

According to Carrell et al. (1989), when consciously reading, one creates a semantic mapping of the text that involves writing concepts and establishing connections among them. This activates previous knowledge, improves vocabulary, and allows users to focus on the material they are reading. In addition, users can apply multiple techniques, including reading for meaning, a guided way in the cognitive process that uses discussions to link previous knowledge with what is available in the text. This technique involves three phases: first, the users discuss about their prior knowledge that somehow connects to the text they are about to read, so they can relate to it. Second, they read short parts of the text and are asked questions. Third, users are asked to create associations between their experience and the information received from reading the text.

A distinction can be made between reading strategies: ones that are used for

learning effectively, while other are employed to improve comprehension. In this article, we are focusing only on the second dimension, as we are interested in developing the users' ability to understand the read materials. The most frequently employed strategies are presented in detail in the following sub-sections: self-explanations, summarization, questioning and peer-assisted learning.

2.1. Self-explanations

Self-explanations are used in the process of explaining to oneself the meaning of a read text. This task can be done orally or in writing and it improves the comprehension of the text. Specific strategies for self-explanations can be employed by learners and one of the simplest ones is paraphrasing, in which users rewrite the text in their own words without trying to explain it or provide additional details or create inferences. Another strategy is elaboration, the process in which the user connects available information from the text with prior knowledge. In most cases, elaboration is used together with logic and common sense because users tends to match what they read with real-life situations or experiences (McNamara, 2009).

2.2. Summarization

Summarization is a basic reading technique that consists of highlighting and potentially extracting the most important points from a text. The users are asked to describe what the original author wrote, concentrating on presenting an overview and not on drawing conclusions (as synthetization asks). Even though summarization is one of the most frequently used techniques, it often produces poor results because of two main points (Winograd, 1983). First, users are not aware that the purpose of summarizing is to collect the most important ideas in a short explanation. Second, users fail to identify the key information that should be included in a summary.

2.3. Questioning

Questioning (Cotton, 1995) directs the attention of the user on understanding the content by allowing them to answer questions like *when*,

why and *how* in relation to the generated events. This method has its limitations because users sometimes omit questions or even answer superficially. Another disadvantage of the method is that it is based on the prior knowledge of the user. If the users do not have that knowledge, they would not benefit from this technique. A solution to this limitation consists of relying on other peers, thus introducing peer-assisted learning (Xun, & Land, 2003).

2.4. Peer-assisted learning

Peer interaction has been introduced as a form of collaborative learning. It involves more than just questioning and receiving answers; it is a method to generate new ideas, resolve conflicts and negotiate meaning. This interaction allows users to engage in cognitive processing, reorganize information, correct misconceptions and develop new ideas. It is a benefit on both sides, even in cases of conflict, because it gives users the opportunity to justify their answers and agree on alternative responses.

3. Overview of serious games relying on Reading Strategies

In this section, we will describe several available games from the serious game industry that focus on reading strategies. The purpose of this description is to show how the user experience has improved over time.

3.1. Interactive Strategy Training for Active Reading and Thinking (iSTART)

iSTART is a web-based project that uses a virtual tutor guide, represented by multiple agents in the game, that is used to teach reading strategies to users (McNamara et al., 2007). The main method used is self-explanation. It has been proven that it is harder to evaluate users' responses based on their previous knowledge.

The game consists of three phases (McNamara et al., 2004). First, an introduction is provided to users including definitions and examples, thus introducing the five reading strategies used in this game: comprehension monitoring, paraphrasing, elaboration, prediction and bridging (McNamara et al, 2007). Second, the student is shown how to use the strategies in the

demonstration module. Here, a virtual student under the supervision of a virtual tutor is given a text to read and to explain. After the student provides an acceptable explanation, the virtual tutor asks the user what strategies another student had used. If the user loses focus or has difficulties in finding the answer, the virtual tutor asks follow-up questions or gives instructions. Third, a practice module provides the user an environment to exercise the reading strategies learned; based on the provided answers, iSTART returns personalized feedback, enabling learners to improve their usage of different reading strategies.

Figure 1. iSTART Selection Menu

The iSTART algorithm evaluates the users' text explanation on a scale from 0 to 3: 0 denotest that the explanation is too short or irrelevant, 1 – the explanation refers only to a sentence, 2 – the explanation introduces concepts from the entire text, and 3 – the explanation refers not only to the text, but to its theme. The feedback system uses a combination of word-based approaches and Latent Semantic Analysis (LSA; Landauer et al., 2007). The word-based approach uses a list of automatically identified words in the text and the LSA is based on benchmarks that compare the given explanation to different text features. The benchmarks include: the

title of the text, words in the given sentence and words from adjacent sentences.

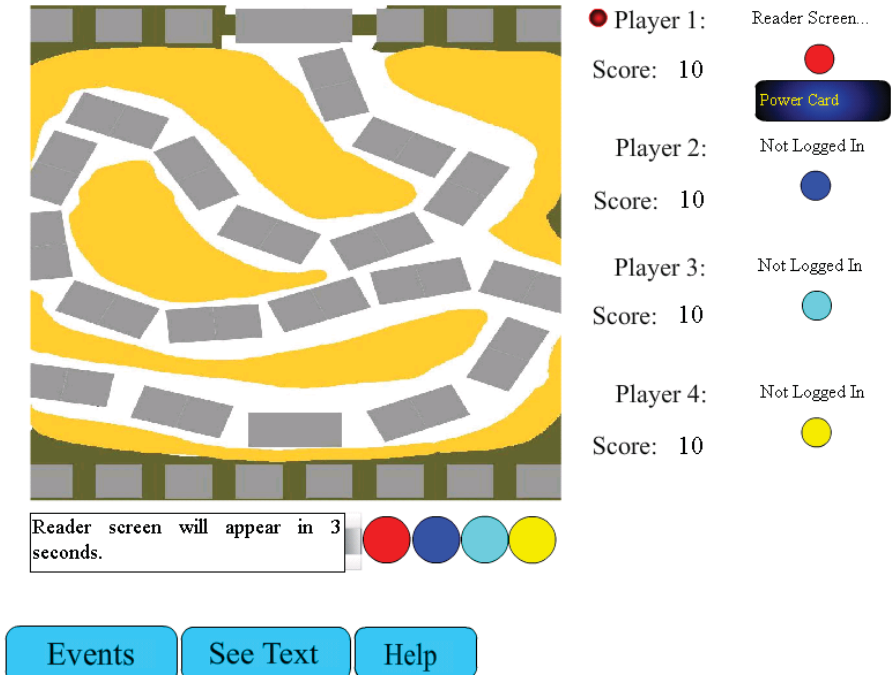

Figure 2. MiBoard Game Play

3.2. MiBoard: Multiplayer Interactive Board Game

MiBoard is an online, web-based multiplayer board game, an extension of iSTART, which promotes players' self-explanation strategies (Dempsey et al., 2009). Each round of the game has a reader who must use a certain reading strategy to self-explain a sentence while the guessers must identify the employed strategy. At the end of the round, users get a score based on their response. In this manner, the game stimulates competition, but also peer learning, creating an environment where students can enhance their reading abilities.

An addition to iSTART is the competitive environment. Both games use the same reading strategies, but MiBoard focuses more on the user

experience and provides an entertaining alternative. However, the time wasted while a reader waits for the guessers to provide an answer is a downside that may lead to the reader's loss of interest for the game.

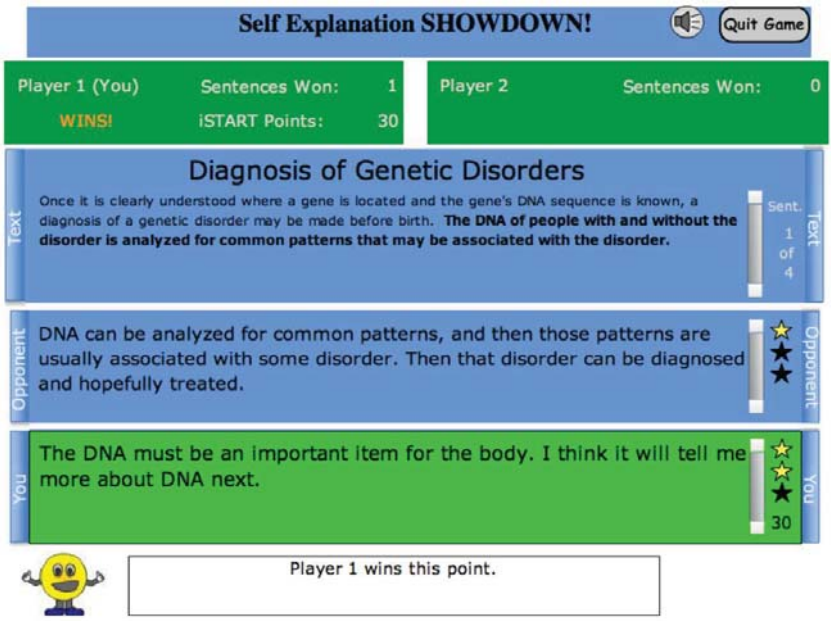

Figure 3. Self-Explanation Showdown Game Play

3.3. Self-Explanation Showdown

Self-Explanation Showdown (Jackson et al, 2012) is an improvement of MiBoard by integrating a single player mode, beside the multiplayer one, that enables learners to engage deeply, therefore leading to better development of individual assets. Moreover, the idle time while waiting for users' answers was eliminated, allowing multiple players to write their answer simultaneously (Brunelle et al, 2010).

3.4. Crystal Island

Crystal Island (Crystal Island, n.d.) is a web-based game with a specific theme, microbiology. The user plays the role of a medical detective

investigating a mysterious disease on an island. In contrast with the previous games, Crystal Island is the most focused on user-experience, implementing a story and making the user part of it. The first-person perspective gets the user emotionally involved in the game. Together with the evolved graphic interface, it achieves a goal that the other games lacked: keeping the user motivated and engaged while playing the game.

Even though the purpose of the game is similar to the previous ones, improving the reading and comprehension skills of users, it does not require the user to write input text. Each comprehension enhancement goal is implemented as a mystery, a puzzle that involves reading texts and then filling missing information, responding to questions that require choosing the best suitable option from a predefined list, or diagnosing diseases based on a text description.

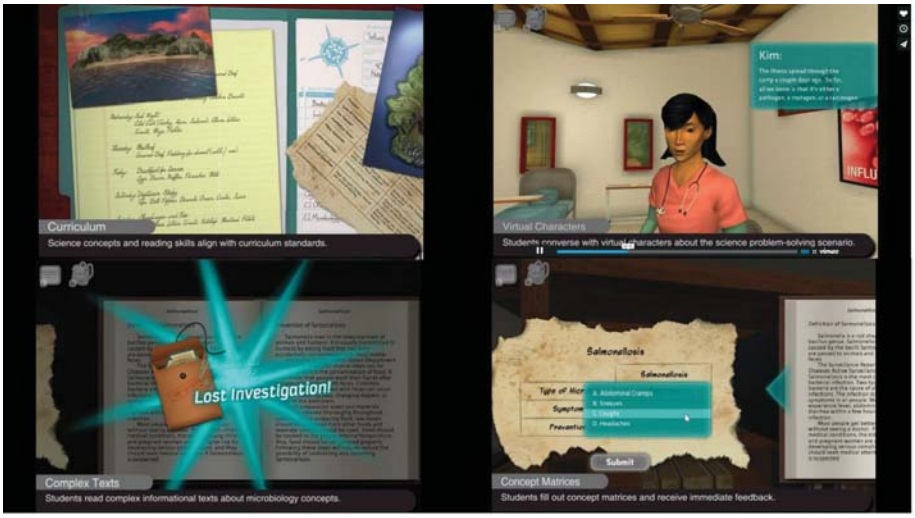

Figure 4. Crystal Island Game Play

4. Reading strategies identification with ReaderBench

ReaderBench (Dascalu, et al., 2013, 2015; Gutu et al., 2016) is an advanced natural language processing framework that can be used for extracting, marking and evaluating strategies from a submitted explanation of a text. The strategies targeted are: paraphrasing, text-based inferences, causality,

bridging, knowledge-based inferences, metacognition. Some strategies can be identified easier than others inside an explanation of a text. For example, causality is identified by certain groups of words: “because”, “thus”, “for”, “I believe that”. If the expression is marked as explained using causality strategy, the explanation segment that follows is checked against the original text for paraphrasing.

The paraphrasing strategy is the second easiest strategy to identify. The segments are compared for similarities by checking for synonyms and identical lemmas. Similarly to iSTART, the strategies that are the most difficult to find are the ones involving prior knowledge. A concept defined as being inferred is a word that cannot be considered paraphrased and for which three semantic distances are computed:

- Highest similarity to another word in the original text (Dascalu, Dessus, Trausan-Matu, Bianco, & Nardy, 2013), represented by the highest semantic distance in ontologies.
- The word’s relevance. Based on the word used in explanation and the similar one from the original text, a semantic cohesion score is deduced from two adjacent fragments of the explanation, in which the word is used.
- Knowledge inference mechanism. The previous similarities from the explanation are computed in a weighted sum which must exceed a semantic similarity threshold (currently set at .4) in order to consider the concept as being inferred. If the inferred element is found, the knowledge-inferred and bridging strategies can be identified within the self-explanation. In addition, ReaderBench identifies the number of times a strategy has been used, showing the points that need to be improved in the process of reading and improving the learner’s comprehension skills.

In the game presented in this article, the REST web services from the *ReaderBench* framework (Gutu et al., 2016) are used to submit explanation and receive feedback. The data sent to the service as JSON contain the following fields: the initial text, the text explained by the user, the language of the texts, semantic models used by the service - Latent Semantic Analysis (Landauer et al., 2007) and Latent Dirichlet Allocation (Blei et al, 2003) -, and two fields to enable part-of-speech tagging and in-depth dialogism-related computations.

The response returned from the server is also in JSON format with the following fields: success (a boolean representing the state of the response), error (a message in case of error) and the actual data that contains the user’s

explanation, colored accordingly to each automatically discovered strategy, together with the list of all strategies and their corresponding scores.

5. Reading Space Secrets

Reading Space Secrets is a novel serious game targeted at teaching players to properly use self-explanations, together with enhancing their user experience and the look and feel of the graphical interface. We are focusing mostly on deep reading strategies, namely bridging and inferred knowledge.

5.1. Game Flow

The idea behind the game is straightforward: learners self-explain a text that they discover while performing a mini-game. The discovery method is unique as users shoot meteors and discover random parts of the text based on the gathered points, namely the captain's log for the mission. There are three types of meteors, normal, ice and fire; shooting normal meteors reveals one word from the text, while shooting special ones (ice and fire) reveals three words.

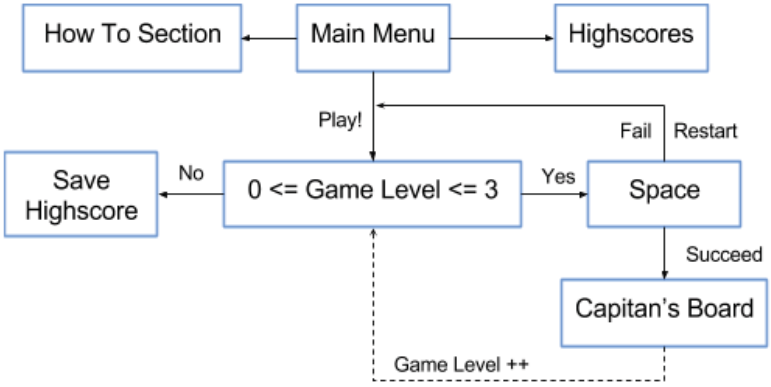

Figure 5. Reading Game Secrets Flow

The game consists of four levels, each divided into two stages. In the first stage, users shoot meteors and unravel words from the text. Once 75% of the text is revealed, users can go to the next step of the game where they

self-explain the text, namely write in the captain's board. The game flow is also shown in Figure 5. The texts vary in complexity and have a scientific subject, more precisely biology, physics or geography.

5.2. Scoring

On each level, a score is computed based on the user's results in the two sub-stages. In the first stage, the score consists of the total number of the meteors destroyed. Every common meteor values one point, while the special meteors (fire and ice) value five points. In the second stage, the score is computed based on reading strategies employed by the learner and automatically discovered within the self-explanation. The employed score formula for the second sub-stage is as follows:

$$Score = P * 150 + C * 150 + TBI * 50 + B * 400 + IK * 400 + M * 50$$

where the symbols are as follows: P – Paraphrase; C – Causality; TBI – Text based inferences; B – Bridging; IK – Inferred knowledge; M - Metacognition

The coefficient values were chosen based on the importance of the strategy we want the players to focus on. Text based inferences and metacognition were settled at 50, the lowest coefficient, while bridging and inferred knowledge got 400.

5.3. Game Development

Reading Space Strategies was developed as a web application. The main technologies used are Unity 5.3.4 (Unity, n.d.) and JavaScript; therefore, while running the game in a browser, users should make sure they have installed the Unity Player plugin. The reason behind choosing these technologies is the ease of use on the development side - Unity provides object management while JavaScript is one of the most popular scripting languages, making the combination easy to maintain.

The game consists of four screens, the main menu, the space conquering sequence, Capitan's board and the high-score screen. The main menu is the first screen displayed to the user. It is the main point from which the user is redirected into the game scenario or into the high-score page. The space screen is the place where the user plays the mini-game (see Figure 6). It is divided into two parts: in the left part, we have the action area where the user shoots meteorites and in the right part, there is the text area containing

the progress, the score and the discovered text.

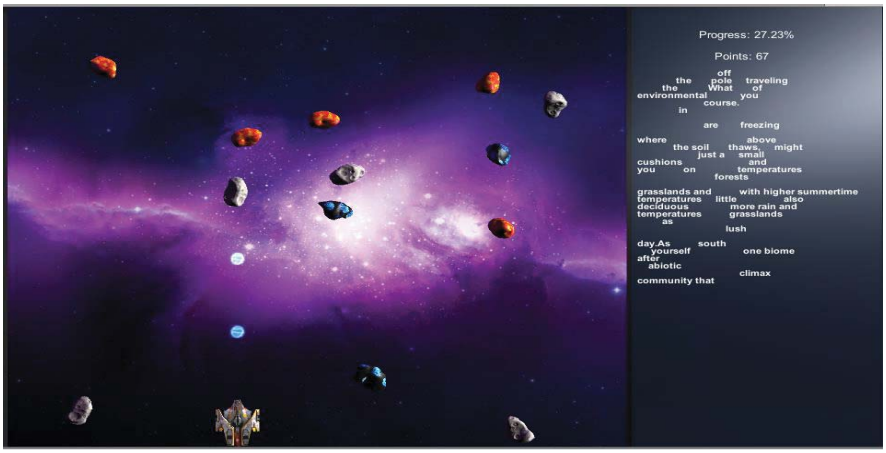

Figure 6. Reading Game Secrets Space Screen

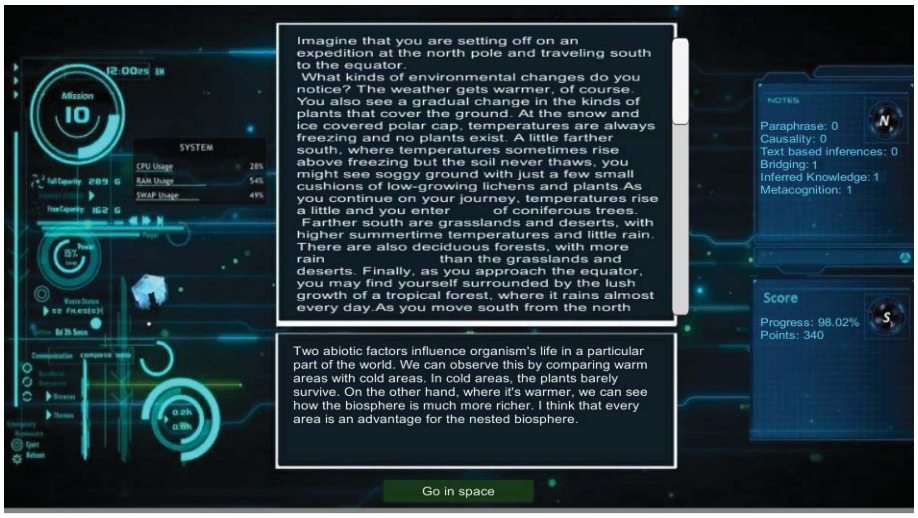

Figure 7. Reading Game Secrets Capitan's Board

The next scene of the game is Capitan's board. The user can reach this scene in two ways. The first way is by clearing meteors until the progress is 100% and the second one is by having at least 75% progress when getting hit by a meteorite. In this scene, the user reads the discovered narrative text and submits a self-explanation of it. Based on the game design, the user can

reach this scene with a progress of lower that 100%. In this case, an extra challenge is available: the user must fill the missing information from the text using inferred knowledge.

Besides the two text areas, in the right side of the page, the user has notes and scores. Notes represent the evaluation received for the text explanation. It also displays the strategies available and the number of times the user has used a strategy. After sending the information to the ReaderBench server, the score is computes as defined in section 5.2.

6. Results

Eighteen users aged between 21 and 30 years old, graduate students from the IT&C domain, were asked to play the game and provide feedback regarding the experience they had.

The users were asked to answer to the ten questions presented in Table 1 that also introduces the average and standard deviation of scores. They could choose a score from a [1; 5] Likert scale (1 – strongly disagree; 5 – fully agree) for specific aspects of the game that are used to capture the general idea of how users perceive the game.

#	Question	Average score (Stdev)
1	The game seemed interesting.	3.94 (1.21)
2	The game was too complex.	1.00 (0.00)
3	The game was easy to follow and the levels were intuitive.	4.11 (0.76)
4	The game needs more instructions.	1.06 (0.24)
5	I feel like I've learned something by playing the game.	2.56 (0.92)
6	I found many flaws while playing the game	1.89 (0.68)
7	I think the game can help children improve their comprehension skills.	3.39 (0.85)
8	The game is entertaining and it kept me motivated to finish it.	2.83 (1.04)
9	I consider this game to be too hard.	1.5 (0.71)
10	I felt lost while playing a certain level.	1.78 (0.88)

Table 1. Feedback form – questions

Two open-answer questions were also included (see Table 2), enabling users to tell us what they liked about or game and what improvements they envision.

#	Question	Sample Response
1	What did you like/enjoy about our game?	"I liked that there is a good balance between difficulty and entertainment. The game is not too hard and not too easy, it seems like it was well thought."
2	What would you improve?	"A Pause button would be nice."

Table 2. Open-answer questions

Cronbach's Alpha (*Zaiontz, 2013) of .972 for N = 18 raters denoted a strong agreement among our users.* The inter-rater agreement scores were also high as the Intraclass Correlation Coefficient single measure for a two-way mixed model, as presented by Uebersax (2007), was of .659.

Based on the gathered feedback, we deduced the strong and the weak points of our Reading Space Secrets serious game. All the players enjoyed the graphics of the game and the atmosphere, which was our key point when we started developing the game. Beside the good user experience, the game proved to be easy to play, entertaining and captivating. The users were motivated enough to replay the levels when they failed, thus enabling them to finish the game. However, players pointed out that the game does not offer many features. They suggested adding power-ups to speed-up progress, penalties, and small quizzes while shooting meteorites. On the game functionality, they wanted a pause button and the ability to switch on/off sounds and music. Regarding the reading factor, most users found the experience useful and the majority claimed they learned something after playing the game. Still, our goal is to improve this area even further in the future.

7. Conclusions

Reading Space Secrets was created with the purpose of teaching learners to improve their reading and self-explanatory strategies. Most of the games available on the market have a very strong content on the learning part, but they lack focus on the user experience and on the entertainment side. Therefore, our proposed architecture addresses these gaps by offering an interactive interface and a more entertaining flow.

The results of the first feedback phase proved that the game achieved its purpose. As future extension, we plan to add more features, including ship customizations, more hazards, power-ups, penalties and quizzes, as well as

the suggested functionality improvements. Because the current testing phase included only one iteration of gameplay, in the next phases we target to monitor users' progress and their motivation while playing the game.

Acknowledgments

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