Comparing the effects on students’ behavior of two hint techniques embedded in a digital game-based learning tool

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Abstract— Hint techniques are implemented in many digital game-based learning tools to support learning and engage students during the learning process. However, these hint techniques can be of different nature and affect students’ behavior when interacting with the games. This paper aims to understand the effects of students’ behavior while using two different hint techniques (visual and phrase) embedded in a game focused on teaching the main concepts of the periodic table of elements. The results, obtained through an evaluation with students in their first year of high school, reveal that students using the visual approach obtained more points with less clicks, while those using the phrase approach achieved less points with more clicks. Although these data may suggest a greater level of comprehension through the visual hints, a post-test revealed a trend showing that those who used the phrase hints achieved a greater score.

Keywords- Game-Based Learning, Puzzle-Based Game, Hint Techniques, Periodic Table of Elements.

I. INTRODUCTION

The current generation of students is different from past ones mostly because of the expansion of and their dependence on technology in and outside of the classroom [10]. In that sense, the shift from a more traditional method to utilizing learning technologies to teach a subject matter has been highlighted as an important aspect to consider. More specifically, serious games are being proposed in the technology enhanced learning research domain as potential educational approaches that foster students’ motivation, increasing the learning effects, making learning meaningful to students and creating a learning culture which is more in correspondence with students’ interests [6]. According to Latorre, Saltiveri and Macias: “utilizing video games in education can increase students’ concentration and attention, thus enhancing and enriching the learning process” [5].

Frequently-cited arguments held by researchers for using serious games in education are: (a) they can invoke intense engagement in learners [11], (b) they can encourage active learning [2], (c) they can be effective tools for enhancing learning and understanding of complex subject matter, and (d) computers games can foster collaboration among learners [4]. Besides, educational games may become more learner-centred, enjoyable, interesting, and, thus, more effective [7, 9]. However, the problem with the design of most games is related to the time required by learners interacting with the games [3]. For this reason, a key point in game-based learning is to consider the design of appropriate help, feedback and hint structures to assist students into their learning experience [1].

The aim of this paper is focused on the role of hint techniques in digital games and understanding how different approaches may affect students’ learning and behavior when interacting with the games. The paper presents the design and implementation of an educational game, based on learning concepts about Chemistry (i.e. the periodic table of elements). The game embeds two types of hint approaches: visual and phrase. The visual hints increase the chance of selecting the correct answer, as it leaves only three possible choices, instead of 12. The phrase hints have a pop-up box with a sentence related to the correct answer, which gives the student a more difficult and challenging help to achieve the correct answer. To analyze students’ behavior when interacting with the game, in the visual or phrase modality, experiments were conducted in two high schools in Barcelona (Spain).

The remainder of the paper is structured as follows: Section 2 explains the design of the game. Section 3 shows the evaluation of the experiments in order to test each student’s behavior. Section 4 describes the results gathered from the experiments and Section 5 covers the discussions and conclusions after analyzing the gathered data.

II. DESIGN OF THE GAME

The design of the game follows a conceptual model that identifies the main characteristics to keep into consideration while designing puzzle-games that integrate hints to assist the learning process [8]. The games consist in different levels of puzzle solving different tasks in which: a) each activity has associated a score, b) students have to play with different puzzle pieces to solve a specific activity, and c) hints can be provided to players in order to guide them to achieve a correct solution. In that sense, the designed game presented in this work aims to teach the main concepts of chemistry and the periodic table of elements, and includes six levels for which the user have to match 12 element symbols (i.e. puzzle pieces) with corresponding element
names (level 1), atomic numbers (level 2), families (level 3), boiling points (level 4), melting points (level 5) and daily usage (level 6).

The aim of this work is to analyze the students’ behavior while playing with either the visual or phrase hint methods and realize which hint technique might be more effective for educational purposes. The visual method highlights three possible choices out of the twelve initial ones after the player answers incorrectly for the third time, thus increasing the chance to select the answer (see Fig. 1, a). The phrase method provides the user with a pop-up box that includes a phrase that relates to the correct answer, assisting the user to think about the right answer (see Fig. 1, b).

**III. EXPERIMENTS EVALUATION**

Experiments were conducted in two different high schools in Barcelona (Spain). The focus of the project was to determine whether there is a significant difference in the students’ behaviour when interacting with the game between the two hint methods (visual and phrase) embedded within the games. The different experiments were conducted in one hour time periods. Each experiment included four tasks (see Fig. 2):

- 5 minutes pre-test (14 questions) to understand student’s previous knowledge of the periodic table of elements.
- 10 minutes “learn” session, in which students had to learn and memorize the information about the periodic table of elements (i.e. element names, symbols, families, usage, boiling and melting points).
- 30 minutes playing the game in either the phrase or visual hint modality.
- 5 minutes post-test of 14 questions to determine the students’ level of comprehension.

The results were compared from the students who played with the visual hints versus the students who played with the phrase hints. Therefore the hypothesis will be as stated: There is significant difference between the visual and phrase hints on the student’s performance and behaviour according to:

- H1. The pre-test versus the post-test scores;
- H2. The total points achieved;
- H3. The total clicks used while playing the game;
- H4. The Weighted Actions Points on the game. Weighted actions points are more specific point counter according to correct answer (+2 points), correct after hint (+1 point), or incorrect even after hints (-1 point).

The total amount of students who participated in the experiments from both high schools was 34 (14 girls and 20 boys) between the ages of 15 and 17. They had just started their first lessons about the periodic table of elements. In the first high school, 23 students participated (10 played the phrase hint method, and 13 used the visual mode); while in the second school, 11 students (7 using the visual mode and 4, phrase mode).

**IV. RESULTS FROM THE EXPERIMENTS**

In order to test the aforementioned hypotheses, in each experiment the following data was gathered through a log:

- Total amount of points achieved in each level;
- Total amount of clicks used in each level to be able to pass to the next level in the game;
- The weighted actions (tested on 7 Visual students and 4 Phrase students, as the log for these points was only recorded in the second experiment).
- Furthermore, a comparison was done between the answers in the pre-test questionnaires and the answers in the post-test questionnaire.

| TABLE I. COMPARISONS BETWEEN VISUAL AND PHRASE HINTS |
|---------------------------------|--------------|--------------|
| Pre-test scores                | Visual Hints | Phrase Hints |
| 9.46                           | 8.70         |
| Post-test scores               | 9.92         | 10.80        |
| Total clicks (normalized)      | 134.60       | 152.90       |
| Total Points (normalized)      | 126.23       | 118.00       |
| Total Weighted points          |              |              |
| Plus two                       | 10.47        | 10.70        |
| Plus One                       | 1.47         | 1.29         |
| Minus One                      | 1.52         | 2.79         |
Thus, we compared the scores of the pre-test and post-test scores (H1), the total points (H2), total clicks (H3), and weighted points (H4) of both Visual students and Phrase students (see Table 1).

The pre and post questionnaires were designed according to a Likert type scale (1-4 answer choice) in order to easily gather the results. These results show that the mean of the scores from the pre-test are slightly lower (9.57) than the mean of the scores from the post-test (11.30). Interesting to notice that the students using the visual hints scored higher on the pre-test questionnaire but later after playing the game scored lower than the students using the phrase hints. According to the total clicks used, there is a tendency that the students with phrase hints used more clicks while gaining less points in the game than the students using the visual hints, which gained more points by using less clicks. Last, in regard with the weighted points, we rated the total amount of points in each of the weighted actions (+2, +1 or -1) for all six levels of the game and then divided by the students using the visual hints and the students using the phrase hints (noticed, as we mentioned before these results are only based on the students in the second experiment). The amount of points gained or lost by the visual modality were higher in the weighted action +1. In the other weighted actions the students using the phrase hints gained more of the +2 points but also lost more of the -1 points.

V. DISCUSSION AND CONCLUSION

This paper is focused on understanding and comparing students’ behavior and the learning outcome of two versions of a digital educational game to teach the periodic table of elements: one integrating visual hints and the other embedding textual hints.

After conducting the experiments, analyzing the data from the logs and comparing the two hint modalities, the results showed that the phrase hint seems to be a more successful technique in teaching information found on the periodic table of elements. In that sense, the main conclusions show that students using the visual hints started with a better previous knowledge of the subject, scored higher points by using fewer clicks while playing the game but scored lower on the post-test; therefore maybe students guessed more while playing the game. While instead the students using the phrase hints, used more clicks and received fewer points while playing the game, but then had higher post-test scores, therefore it seems that students used more cognition skills to memorized and understand the concepts of the subject matter to be able to answer correctly. Overall, from the results of the experiments, creating a more challenging hint method resulted in a better way for the students to learn and comprehend the concepts of the chosen subject.

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