Implementing a Game for Supporting Learning in Mathematics

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Abstract: This paper focuses on the design, implementation and evaluation of an online game for elementary and middle school mathematics. Its aim is twofold: (a) the development of the prototype of a flexible and adaptable computer game, and (b) the evaluation of this prototype, as to its usability and technical aspects. The particular computer game was created in an attempt to facilitate the teaching of mathematics, a subject that is often regarded as complicated by students of all ages. Apart from the game, an administration website was also constructed, so that the educator can configure the game, without that requiring any programming skills. More specifically, the educator can use the administration website in order to alter several of the game's parameters, such as the content and total number of its questions.The game was evaluated in real school settings, both through a pilot study with 12 students and a longterm intervention with 37 students that lasted 14 weeks. The results indicated that the students' opinion about the game was positive, and suggest that with some extensions the game could be used as an effective learning tool. Finally, some corresponding conclusions and future improvements to the game are being discussed on the basis of the findings.

Keywords: 2D Digital Game Based Learning, Primary education, Secondary Education, Mathematics

1. Introduction

Research into the education of mathematics has long demonstrated that math learning difficulties is a common and important problem among students of all ages. According to Garnett (1998), many students face math learning problems of different types; these learning difficulties range from mild to severe, and require instructional attention and various treatment methods. Some of the most common math learning problems include: (a) difficulty memorizing basic number facts; (b) computational and arithmetic weakness; (c) confusion about terminology and the written symbolic notation system of school math; and (d) weak understanding of concepts due to visual-spatial organization deficits (Garnett, 1998). Apart from lower performance in math exercises and tests, these math learning disabilities can also result in avoidance behavior and negative perception of the particular subject. Often, students with math learning difficulties exhibit high math anxiety, which is defined as "a feeling of tension, apprehension, or fear that interferes with math performance" (Ashcraft, 2002). This math related problem was first reported by Dreger and Aiken (1957), who noticed that students demonstrated emotional reactions to arithmetic and mathematics. According to their study, math anxiety is distinct from general anxiety, not necessarily related to overall intelligence, and can contribute to poor performance in mathematics. These findings were substantiated and reinforced by more recent research (Richardson and Suinn, 1972; Tobias and Weissbroad, 1980; Wingfield and Meece, 1988; Ashcraft and Kirk, 2001), indicating that there is a negative correlation between math achievement and math anxiety.

One of the most detrimental consequences of math anxiety is that it can lead to unfavorable attitude towards the particular subject, as well as negative self-perceptions about one's math abilities (Ashcraft, 2002). Consequently, highly math-anxious students also tend to avoid enrollment in math-related courses, as well as pursuing degrees or career paths based on mathematical or quantitative skills (Hembree, 1990; LeFevre, Kulak and Heymans, 1992). Hence, the educator should try to incorporate teaching methods that emphasize the value of mathematics, help students develop their math skills, and increase their self-efficacy beliefs (Meece, Eccles and Wingfield, 1990). Moreover, it is of utmost importance to help students acquire a positive perception of mathematics, as this is considered to be highly related to lower math anxiety and higher math

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achievement (Hembree, 1990). This could be achieved though the use of computer games, since they encompass many characteristics that make them valuable tools for the educational process. More specifically, computer games promote active learning (Oblinger, 2004) and the development of various skills (McFarlane, Sparrowhawk and Heald, 2002), while they retain their entertainment and appealing qualities (Kafai, 2001).

So far, effective use of computer games for educational purposes has been reported in various subject areas, such as geography (Virvou, Katsionis and Manos, 2005; Tüzün et al., 2008), computer science (Papastergiou, 2008), health education (Dorman, 1997), and mathematics and sciences (Klawe 1999; Annetta et al., 2009). According to Ke (2009), who conducted a meta-analysis with 89 empirical studies on instructional gaming, computer games can affect favorably students' motivation and learning in a multitude of educational settings, both formal and informal. Additionally, as Hays (2005) points out, specially designed instructional computer games can be of educational value. Nevertheless, it should be noted that the majority of the existing empirical studies are inconsistent due to divergent research, game, and learner variables, short-term experiments and interventions, and unclear descriptions of the games that were used (Ke, 2009).

Accordingly, this study addresses the design and development of a computer game that could be utilized as an adaptable tool for the educational process. The purpose of the particular game would be to support the teaching of elementary and middle school mathematics, as a complementary learning tool that could enhance students' motivation and engagement with the subject. Apart from the game, an administration website was also constructed, so that the educator can ensure that the game's content aligns with the curriculum and the learning goals of the current lesson. Moreover, the educator can easily edit the game's content and images, or upload new ones, without that requiring any programming or scripting skills. Concerning the game's design, basic educational computer game design principles (Malone, 1980; Prensky, 2001; Hays, 2005; Fisch, 2005) were taken into account, so that the game would be educationally and motivationally effective. The game prototype was then evaluated both through a pilot study and a longterm (14 weeks) intervention, in order to detect any technical flaws, and to assess its usability and educational aspects, so that it could be revised and improved in subsequent editions.

Hence, this paper aims at presenting a concrete case study on the design and development of the game 'Volcanic Riddles', as well as the results of a more longitudinal evaluation study in real school settings, where the aforementioned game was used for the teaching of formal curricular material. In order to investigate the criteria mentioned above, the research questions of the particular study are the following:

> ***RQ1:*** *What is the students' opinion regarding the usability of the 'Volcanic Riddles' game?*
>
> ***RQ2:*** *In what educational context could this game be used by educators?*
>
> ***RQ3:*** *Will the gender or grade of students affect their opinion about the usability of the'Volcanic Riddles' game?*

This paper is organized as follows: in the next section, the conceptual framework that inspired the design of the aforementioned game is being reported. More specifically, Digital Game-Based Learning, as well as several studies concerning the use of computer games in mathematics education are being thoroughly analyzed. Next, there is a presentation of the aforementioned game, and the principles that inspired its design. Afterwards, the basic features of a prototype of this game and the administration website are being presented, and, subsequently, there is a description of the evaluation studies of this game's prototype. Finally, the results of the studies are being discussed, and some conclusions are drawn on the basis of the findings.

2. Conceptual framework

2.1 Young people and Digital Game-Based Learning

Recently, there has been an ongoing interest in the use of computer games for educational purposes, as a means to increase students' motivation, engagement and achievement in various subject areas.

This learning approach, which combines digital game-based activities and educational content, is often refered to as Digital Game-Based Learning (DGBL). DGBL is considered able to render the learning of difficult or uninteresting subjects more accessible, engaging, and enjoyable (Malone, 1980; Kafai, 2001). Indeed, computer games play an integral role in today's children's lives, being part of their culture and one of their most frequent and favored activities (Mumtaz, 2001; Fromme, 2003). The reason for that could be their intrinsically motivational appeal and the fascination they provoke to young people, by encompassing elements of curiosity, challenge, and fantasy (Malone, 1980). Moreover, it has been suggested that computer games have the ability to immerse players in a state of 'flow' (Csikszentmihalyi, 1990), characterized by deep and full involvement and enjoyment in the activity. This state of 'flow' was described by Csikszentmihalyi (1990: 4) as "the state in which people are so involved in an activity that nothing else seems to matter". Additionally, scholars have argued that computer games could be more effective and more appropriate than traditional instructional methods for the current generation of learners, whose cognitive abilities and interests are influenced by digital games and technology (Facer, 2003; Srinivasan, Butler-Purry and Pedersen, 2008).

Given the benefits described above, DGBL has already been implemented in various sectors, with three different approaches that, according to Van Eck (2006), are the following: (a) students create their own educational games, with the aid of the educators, (b) educators use commercial games in class that have not been primarily developed for educational purposes, (c) educators use games in class specifically designed for education by other educators, instructional designers, and developers. These instructional games, also known as 'serious games', are usually designed for training purposes and have many applications in various fields, such as education, science, production, and health (Sawyer and Smith, 2008). Each of the three approaches to implementing DGBL has advantages of its own; however, the most prominent benefits that DGBL offers, in general, can be summarized as follows: (a) computer games can facilitate the acquisition and transfer of knowledge to new situations through feedback and self-assessment mechanisms (Oblinger, 2004); (b) they can also promote the development of problem-solving and memorization skills (McFarlane, Sparrowhawk and Heald, 2002); (c) they help students familiarize themselves with technology, as well as programming and computer science concepts (Kafai, 2001; Van Eck, 2006; Prensky, 2008); and (d) gaming is often a social activity, contributing to the development of the players' social and emotional skills (Squire, 2003; Fromme, 2003; Oblinger, 2004).

Nevertheless, DGBL constitutes a relatively recent and still evolving instructional method, and there is a need for more empirical evidence that could validate its actual educational value, and show how it could be applied more effectively. As Hays (2005) points out, research has demonstrated that games can promote learning in various subject areas, however there is no proof that games can be used in all situations and for every instructional task. It is also important that students are provided with debriefing, feedback, and support from the educators during the DGBL activities (Hays, 2005). Moreover, there are many practical issues that may deter the educator from using computer games in the classroom. A common impediment is that many times the game's content is not correct or it does not align with the curriculum and the learning objectives of the classroom (Kirriemuir and McFarlane, 2003; Fisch, 2005). Also, teachers often encounter difficulties in identifying the educational components of a game, as well as integrating the game in the traditional educational process (Kirriemuir and McFarlane, 2003; Baek, 2008). Additionally, many contemporary complex games require new hardware and plenty of time, and thus they cannot be played in the classroom (Kirriemuir and McFarlane, 2003). Lastly, a frequent concern of educators and parents alike is the possible negative effects of gaming on children, such as addiction and overly competitive behavior (Baek, 2008).

2.2 Review of research on computer games for mathematics

There are several studies that report on the use of commercial computer games for mathematics, or present the development and evaluation of instructional games designed for the specific subject. As indicated by the following review of relevant studies, computer games can increase students' math achievement and performance, and promote positive attitudes towards mathematics. For instance, in a recent study, Pareto et al. (2011), created a teachable-agent arithmetic game that aims in training basic arithmetics skills. The game was evaluated in a study with 153 participants, consisting of 3rd and 5th grade students. The results indicate that the game helped students improve their math performance and self-efficacy beliefs. Ahmad and Latih (2010) describe the development of an educational math game on fractions for primary school students. Similarly, Lee (2009) report on the creation and evaluation of an education game on fractions and mention that it improved students' understanding and performance.

Concerning the use of commercial games for mathematics, Zavaleta et al. (2005) suggest in their study that the use of a commercial game for elementary school algebra enhanced students' achievement. Kebritchi, Hirumi, and Bai (2010) investigated the impact of commercial math games on 193 high school students' math performance, with positive results concerning the student's perception of mathematics, motivation, and achievement. Ke and Grabowski (2007) examined the effects of the use of adventure games on 125 5th grade students that were assigned to three groups: cooperative game playing group, competitive game playing group, and no game playing group. According to their findings, after the four-week intervention the two game playing groups had better math performance, while the cooperative game playing group had better attitude towards the subject, compared to the other conditions. In another study, Ke (2008) examined the effects of the use of computer games on 4th and 5th grade students that were enrolled in a five-week summer math program, with positive results concerning the students' attitude towards math. More recently, Kim and Chang (2010) performed regression analyses using 170,000 4th grade students, demonstrating that math computer games had a positive effect on male minority students.

Other studies focus on the use of math computer games for the remediation of specific deficits, such as dyscalculia. For example, Wilson et al. (2006) created an adaptive computer game for dyscalculia and tested it in a five-week evaluation study with nine children with math learning difficulties. The results indicated an increase in the children's math performance on core number sense tasks, as well as an improvement as regards their confidence in their mathematical abilities. Regarding any pertinent research projects, the E-GEMS ('Electronic Games for Education in Math and Science', http://www.cs.ubc.ca/nest/egems/) project contributed on the development of various educational games that increased student engagement and achievement, and produced several design heuristics (Klawe & Phillips, 1995).

3. Design of the game

3.1 Basic features of educational games

According to Malone (1980), instructional designers should try to create intrinsically motivating educational environments that would help students learn in an effortless and engaging way. Computer games, in particular, contain the following three elements that make them so interesting, and can be used in order to motivate the learner: challenge, fantasy, and curiosity (Malone, 1980). Malone (1980) draws upon these observations in order to develop a set of guidelines for the design of effective and motivational instructional computer games. In accordance with these guidelines, games should have clear goals, uncertain outcomes, feedback, and gradually increasing difficulty levels. Furthermore, they should contain curiosity and fantasy elements, such as emotional aspects. Moreover, they should respond in an appropriate way to the players' actions, and they should provide them with choice over various environmental aspects (Malone, 1980).

Hays (2005) reports on these heuristics, and suggests a set of design recommendations for educational games, emphasizing on the instructional quality these games should have. More specifically, the game should be integrated into a larger educational program, and it should also incorporate elements that help students build new knowledge structures or complete their existing ones (Hays, 2005). Furthermore, as stated by Fisch (2005), the appropriate incorporation of educational content into the game is a key factor in the design of effective instructional games. Students should also be provided with offline material and resources that could add to the game's educational value, as well as support and guidance by teachers and parents (Fisch, 2005). Prensky (2001), points out some features that engaging games have; these are the following: objectives, opposition, interaction, representation, and outcomes. Similarly, Kiili (2005) proposes an experiential gaming model based on Csikszentmihalyi's flow theory and experiential learning principles; this model can be used for the design, analysis and evaluation of educational computer games. The above design guidelines and basic features of instructional games were taken into consideration in the design of the proposed game.

3.2 Development of the game

The final framework consists of the configurable online 2D game and its administration website, which was constructed in order to facilitate the (non-programmer) educator in the configuration of the game's parameters. In accordance with the ADDIE model for Instructional Systems Design (ISD), the production of the framework comprised the following working phases: Analysis, Design, Development, Implementation, and Evaluation. Hence, a careful and thorough requirements analysis was deemed necessary, in order to determine the conditions that the particular instructional game should meet. The researchers were allowed to observe the educational process and the students' performance during classes in a week's time. Moreover, a semi-structured interview with two elementary school teachers was conducted, as well as a carefull review of the relevant literature.

After careful consideration of the teachers' recommendations, it was decided that they game should be simple, without any distracting material, and that it should not require any software installation. This way, it would be easier for teachers to use it in formal school settings. Concerning the difficulty level of the game's questions, the educators suggested that it should increase as the game progresses. In addition, they stated that they would like to be able to change the game's questions, according to the student's knowledge and skills. Hence, a very important objective of this work was to create an adaptable game that could be reused in various educational settings and activities. It was also decided that the game should contain various mini challenges that the students could play in the limited time span of an individual class. That way, the game could be tailored to the level of the students, and it could also support different thematic units of the subject.

Afterwards, the game and its administration website were developed. More specifically, the game's graphics and images were designed in Adobe Photoshop and Adobe Illustrator, and then the researchers proceeded with the development of the game's prototype. Regarding the game development software, the game was created in Adobe Flash with the use of ActionScript, while the administration website was created using the PHP scripting language. The changeable content is saved in text files that were uploaded to the web server, and can be edited via the administration website. In accordance with the ADDIE model, the product of each working phase was subjected to formative evaluation and revisions. This way, it was confirmed that the initial criteria that had been set for the final product were met, and that any technical flaws were detected and corrected in time. Thus, the proper functioning of both the game and its administration website was ensured.

4. Description of the game

The game consists of nine challenges that the educator can fill up with questions, according to the course material. Since the game is addressed to elementary and secondary school students, attention was paid so that it is friendly and easy to use. An attempt was also made to incorporate most of the aforementioned characteristics of educational games into the proposed game. In this section, the main features of the game

are being presented, in connection with the proportionate characteristics that inspired the game design. Afterwards, there is a brief description of the configuration of the game through the administration website.

4.1 Story and characters

In accordance with Malone's design heuristics (1980), one of the features that make games intrinsically motivating is the theme or fantasies that are incorporated. These two elements can elicit mental images of social situations or of physical objects to the players, rendering the game more interesting and engaging (Malone, 1980). Moreover, apart from being a source of motivation, the game's narrative can be considered as a supportive factor that helps players make sense of the information they are presented with. Additionally, it can help students learn more efficiently, especially in case of difficult content (Waraich, 2004). For that reason, a theme and a story were added to the game. In the game's story, three fictional friends, a boy, a girl, and a robot are vacationing on an exotic island, when the children's uncle sends them a letter to warn them that the island's volcano is going to erupt. The three friends face nine challenges in order to gather the necessary supplies and find a way to escape from the island. The player has to help them complete these challenges successfully. Each one of these challenges contains a variable number of questions on various algebraic and geometrical concepts. Special attention was paid so that the questions are well integrated into the game's story. For example, in one instance of the game, the three friends visit the island's store in order to buy supplies; the players have to buy the products with the most favorable prices after the discount, using their knowledge on solving equations with percentages. The players can read the game's story and information about the three heroes of the game via the 'Options' menu of the game. Each of the game's challenges is connected to the storyline of the game through its objectives and narrative. That way, the players can choose one challenge to play and do not need to play the whole game every time.

4.2 Goals and rules

Another important characteristic of compelling instructional games that was integrated into the particular game is the presence of clear rules and goals. More specifically, the players' can choose from two different game modes: "Challenge game" and "Single game" mode. When playing in Challenge game mode, the players have to successfully complete the nine challenges of the game, while in Single game mode they can choose a challenge to play. The players have a one hundred seconds for each question, as well as five available lives (chances) for each challenge. They lose one life for every mistake they make. According to the rules of the game, when the players play in Single game mode and they lose, they can restart the same challenge or start another one. Otherwise, if they were playing in Challenge game mode, they have to start from the first challenge again.

4.3 Opposition elements

Furthermore, the game contains several elements of challenge and opposition, which, according to Prensky (2001), are problems the players are trying to solve. These elements make the game more engaging, however they should be equivalent to the player's abilities (Prensky, 2001). In order to win the players have to complete successfully all the challenges of the game. However, the difficulty of the questions increases gradually, as the challenge progresses. Moreover, in the fourth challenge a different approach was followed; here, the difficulty of the questions increases with each correct answer, and decreases with each false one. Hence, the level of difficulty adapts to the player's skills and level. As it has already been mentioned, the players have five lives for each of the game's challenges at their disposal, and they lose a life each time they make a mistake. When they lose all of their lives, the game ends. Moreover, in accordance with Malone (1980), a score-keeping mechanism and a countdown timer were added, in order to create goals of different levels. The players have one hundred seconds to answer each question otherwise they lose. They also win points for each correct answer and lose points for each false one; answers to more difficult questions are rewarded with more points.

Each player's high-score is saved and can be accessed through the 'Options' menu, so the players can compare their high-scores.

4.4 Interaction and feedback

According to Prensky (2001), engaging educational games should also contain interaction and feedback mechanisms that will help the player learn. Interaction can be either between the player and the computer, or between players (Prensky, 2001). The proposed game provides the players with immediate feedback messages, in order to help them understand and correct their mistakes. Moreover, directions and help messages appear in each of the game's challenges, so that they players understand how the game works and learn to navigate through it. The players can also view their high-scores, and configure some of the game's parameters, such as the game's sounds, through the "Options" menu. Additionally, they can communicate with the authors and creators of the game via a web form, in order to send their suggestions and comments (Figure 2). The players can interact with various elements of the game; however, the game did not support interaction between the players by the time it was evaluated.

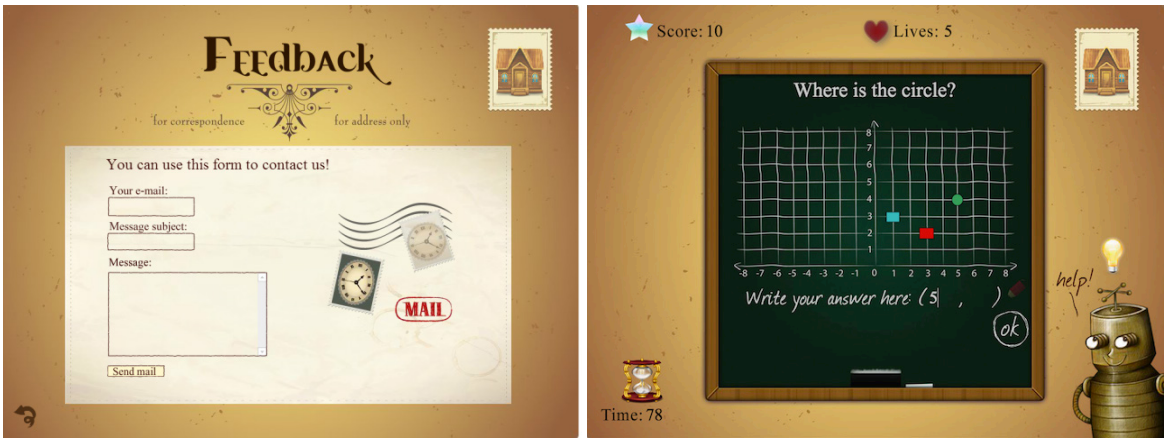

Figure 2: Various screens of the game.

4.5 Configuration options

As it has already been mentioned, one of the main purposes of this work was the development of an easily configurable online game. The whole framework that was created consists of the online game and its administration website. Using this administration website, the educator can change the following: (a) the total number of each challenge's questions, (b) the content of each question and its corresponding answer, (c) the instructions and help messages for each challenge, and (d) the images that appear in the game, as well as the images of the help messages. Moreover, in the fourth challenge the educator can add a set of more difficult questions that will be used when the player answers correctly, in order to increase the level of the questions' difficulty. The configuration process is the following: the educators should login to the administration website and then select and edit the game's messages, directions, questions and answers. They can also delete questions and answers, or add new ones, and furthermore, they can upload new images or delete the existing ones (Figure 3). Finally, they should save their changes in order for them to appear in the game.

Figure 3: The administration website of the game.

5. Evaluation of the game's prototype

5.1 Description of the evaluation activities

An important objective of this study was the evaluation of the game as to its usability, capabilities and perceived usefulness, in order to improve it in subsequent editions. For that reason, several educational activities, which served as a means to gather qualitative data, were organised and implemented. Hence, the researchers had the opportunity to observe the students' reaction to the game, and to ask them for their feedback. Additionally, in order to gather quantitative data, a pilot study with twelve (12) 6th grade students of a private school was conducted. The group of students consisted of eight (8) girls and four (4) boys of various nationalities, aged 10-12 years old.

The pilot study comprised two different educational activities conducted in the computer laboratory of the school. Each one lasted about 45 two differThe questionnaire for this study included 18 questions focused on the gamein the computer laboratory of the school) boys of various nationalities, aged 10-12 years old. tions. For that reasonere 1 was assigned to 'strongly disagree' and 5 to 'strongly agree'. Regarding the game's content, each challenge was enriched with new questions on arithmetic and geometrical concepts, in accordance with the material taught in the classroom. The evaluation data also included the researchers' notes and observations from the educational activities. The results were quite encouraging; however, they could not be generalized, due to the limited number of the participants and that of the educational activities.

For that reason, a second evaluation experiment that lasted 14 weeks was also conducted. The participants of this study were 37 randomly selected students from a typical public secondary school, consisting of 23 boys and 14 girls aged 12-14 years old. The students agreed voluntarily to participate in the experiment by interacting with the game daily and individually. Responsible for supporting them during the whole intervention was primarily their teacher. Before the intervention could begin, the cooperating teacher organised an introductory session, where the researchers presented the game to the students. Moreover, the teacher informed the students' parents about the intervention and they signed the necessary parent consent forms.

For the purpose of this evaluation a new, more complete, paper-based questionnaire was constructed. The particular questionnaire, which elicited both qualitative and quantitative data, was based on the Questionnaire for User Interface Satisfaction (QUIS) (Chin, Diehl and Norman, 1988), and on Lund's USE Questionnaire (USE) (2001). The 22 questions that were included in the questionnaire corresponded to the following eight dimensions: perceived usefulness, ease of use, ease of learning, satisfaction, screen, terminology and system information, system capabilities, and overall reaction to the software. The questions' type was five-point Likert scale, as before. Additionally, the questionnaire included two open-ended questions about the best and worst aspects of the game.

The participants played the game from home daily during the 14 weeks of the intervention. The teacher was able to check their involvement, as all participants had personal accounts. Every week, the teacher updated the game's challenges with new questions based on what was taught in the lessons. Moreover, every two weeks a debriefing session was conducted in the school computer laboratory. At the end of the intervention, the students completed the anonymous questionnaire. In the next section, the results of the analysis of the questionnaire are being analytically presented.

5.2 Results

The students' answers to the Likert type questions of the questionnaire were analyzed by descriptive statistics, and their answers to the open-ended questions were grouped according to their common themes. The statistical analyses were performed using the SPSS 20 statistical package, with the level of significance set to 0.05. The game's usability was assessed using the students' performance in each dimension. This was calculated using the mean score of their answers to the corresponding questions (Boone and Boone, 2012). Generally, as the results indicated, the students' opinion about the game's usability was moderate to good. In particular, regarding the gamedinease of learning, the statistical results are the following: M = 3.77, SD = 1.07, N = 37. The studentsg, the staticoncerning the gametatistical resuls terminology and system information are also positive, as the statistical results are M = 3.67, SD = 0.84, N = 37, and M = 3.63, SD = 0.77, N = 37, respectively. Furthermore, their responses to the rest of the questionnaire's dimensions were all above average, while the mean score for the students score est of the questionnaire= 37, and M = 3.63, SD = 0.770.96, N = 37). However, the lowest score was observed in the dimension concerning the system capabilities (M = 3.33, SD = 0.98, N =37).

In addition, according to the students' answers to the open-ended questions, the game: (a) helped them understand the lesson, as well as some difficult mathematical concepts better; (b) it is easy, entertaining and pleasant; (c) it helps apply a more innovative approach to the learning process; and (d) it is flexible and, thus, it can constitute a useful tool for the revision of the lesson taught. Thus, concerning the first research question (*What is the students' opinion regarding the usability of the 'Volcanic Riddles' game?*), it was deduced that the students were quite positive.

However, some students encountered minor problems regarding the use of the game. For example, five students stated in their comments that they would prefer the game to be in the Greek language, instead of English. Other observations were that it is quite simple, and it does not provide enough explanations on some

solutions. Their opinion can also be justified by the fact that they mostly played the game from home, without the aid of their teacher. It should be noted that the studentld responses to the related questions during the pilot study were a lot more positive. For instance, regarding the game were a lot more positive. pilot studyd that it was very easy to understand how the game is played, while two pupils were neutral (M=4.67, SD=0.778, N=12). Also, seven pupils strongly agreed and three pupils agreed that the game did not require any complex computer usage, whereas two pupils were neutral (M=4.42, SD=0.793, N=12). Eight pupils strongly agreed and three pupils agreed that the game could help them improve their skills, whereas one pupil was neutral (M=4.58, SD= 0.669, N=12). The students game were a lot more positive. pilot studyducture, functions, and motivational appeal were also quite positive. However, only three students strongly agreed that they use the game's "Help" option, whereas two students agreed and seven students strongly disagreed (M=2.50, SD=1.88, N=12). Indeed, the students preferred to ask the teacher and the researchers when they did not know or understand something in the game.

These results can be explained on the premise that the pilot study included a small number of activities (2), while in the longterm intervention the students had 14 weeks to explore the game. Moreover, in the pilot study, the activities took place during class with the assistance of the teacher, and in the form of a pleasant break, while in the longterm experiment the students would log in from their homes and in their free time, in order to play the game. Lastly, concerning both teachers' opinion about the game and its administration website, it was quite positive, as they considered them to be friendly and easy-to-use. Hence, regarding the second research question (*In what educational context could this game be used by educators?)*, it was concluded that the game could actually be used as a useful educational tool for classroom activities. Moreover, with some improvements and extensions, it could also be used in distance-learning scenarios. Additionally, it became apparent that, in accordance with Hays (2005), the educator's feedback and the debriefing sessions are very important for the support and guidance of the students.

Additionally, a third research question (*Will the gender or grade of students affect their opinion about the usability of the 'Volcanic Riddles' game?*) was also investigated in this evaluation study. Firstly, it was examined whether the students' opinion for the game differs based on gender. After some preliminary tests were conducted on the data, it was decided to use the Mann-Whitney U Test, since it can be used when the variables are not necessarily normally distributed. According to the results, it can be presumed that there were no significant differences between boys' and girls' opinions regarding the game, based on the scores for the eight dimensions. Nevertheless, when examining each one of the 22 questions, it became apparent that the girls learned to use the game more quickly (*Mdn* = 5), than the boys (*Mdn* = 3), U = 90.5, p = .22, r = .37. However, the boys considered the game to be more satisfactory (*Mdn* = 4), than the girls (*Mdn* = 3), U = 100, p = .49, r = .32.

Lastly, the students were divided into three independent groups, according to their age and grade. Thus, the first group consisted of 12 1st grade students, the second goup of 13 2nd grade students, and third group of 12 3rd grade students. A Kruskal-Wallis test was then applied to evaluate differences among the three grade conditions. The results of the analysis indicated a significant effect of grade (χ^2 (2, N=37) = 6.74, p = .34) only on the students' opinion about the consistency of terms that were used throughout the game. Indeed, the follow-up tests that were conducted to evaluate pairwise differences among the three groups revealed that the 3rd grade students did not consider the use of terms to be consistent. In particular, a post-hoc test using Mann-Whitney tests with Bonferroni correction showed significant differences between group 1 and 3 (p = .18, r = .38), and between group 2 and 3 (p = .42, r = .33). However, there were no significant differences according to the students' grade on any other questions or the eight dimensions of the questionnaire.

6. Discussion and conclusions

This paper presented the design and development of the prototype of a configurable online 2D game, aimed at assisting the educator in the teaching of primary and secondary school Mathematics. Furthermore, the

prototype was evaluated through a pilot study and a long-term intervention in real school settings, in order to assess its usability aspects and to find any possible flaws. According to the results of the two evaluation studies, the students' opinions about the game were mostly positive, and they considered it to be a useful and engaging learning tool, regardless of age and gender. Furthermore, concerning the game's usability, most of its features elicited average to positive responses from the students and the educators alike. Moreover, the educators encountered no difficulties in configuring the game, and the planned educational activities were concluded successfully. Thus, it was deduced that the particular game could actually be successfully incorporated and used by educators as a supplementary tool for the teaching of formal curricular material.

These findings are encouraging and suggest that game-based learning activities are well-accepted and appreciated by students. Furthermore, the great importance of the educator's feedback and guidance on how to use the game became apparent, in accordance with Hays (2005) and Fisch (2005). The work presented in this paper had certain limitations; for instance, the game is addressed to younger ages and has a short storyline and a limited number of challenges and functions. Additionally, the aforementioned evaluation studies focused only on the game's usability, as the researchers' intention was to elicit students' responses to this game prototype. Our future work aims at improving and extending the game, by adding new features, more hints and help messages, and a longer storyline. Moreover, a multi-player feature should be added to the game, in order to assess its impact on student's opinion about the game. Also, it would be worth investigating whether cooperative or competitive game playing can enhance students' engagement and motivation. Lastly, further research should be conducted in order to examine how the educator's material could be more efficiently integrated into the game's storyline and narrative.

The contribution of this paper is that it described a concrete case study on the creation and evaluation of an educational game designed according to instructional game design principles. In more detail, the game included interaction and feedback elements, a background story, clear rules, objectives and outcomes, combined with educational aspects. As it became apparent through the evaluation process, such a game can be easily integrated into the classroom to support the teaching of formal curricular material. Moreover, it can be used for distance learning, if certain extensions are considered. Finally, this paper demonstrated that it is possible to create a functional prototype of an online game that can be adapted according to the educator's specific needs. In conclusion, it is hoped that this study adds to the existing research on instructional games and that the presented game will eventually become an effective educational tool.

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