INSTIGATING AN ONLINE GAME AS MATHEMATICS LEARNING SUPPORT TOOL

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Abstract

Mathematics inculcation should be a compulsory subject at any caliber in a school. Mathematics can broadly be defined as the science of understanding and apperceiving patterns and relegating them predicated on numbers or well defined mathematical structures. The cognition process of mathematics promotes one's analytical skills and critical cerebrating. Critical cerebrating is paramount to live a better life regardless of the nature of one's employment. This paper fixates on the design, Instigating 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 engendered in an endeavor to facilitate the edification of mathematics, a subject that is often regarded as perplexed by students of all ages. Apart from the game, an administration website was additionally constructed, so that the inculcator can configure the game, without that requiring any programming skills. More concretely, the edifier can utilize 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 authentic school settings, both through a pilot study with 12 students and a long-term intervention with 37 students that lasted 14 weeks. The results designated that the students' opinion about the game was positive, and suggest that with some extensions the game could be utilized as an efficacious learning implement. Determinately, some corresponding conclusions and future amendments to the game are being discussed on the substructure of the findings.

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

1. INTRODUCTION

Mathematics inculcation should be a compulsory subject at any caliber in a school. Mathematics can broadly be defined as the science of understanding and apperceiving patterns and relegating them predicated on numbers or well defined mathematical structures. The cognition process of mathematics promotes one's analytical skills and critical cerebrating. Critical cerebrating is paramount to live a better life regardless of the nature of one's employment. The architect of the U.S. constitution, George Washington, was a Mathematician (Deshabandu J, 2014).

Research into the edification of mathematics has long demonstrated that math learning difficulties is a mundane and paramount quandary among students of all ages. According to Garnett (1998), many students face math learning quandaries of variants; these learning

difficulties range from mild to astringent, and require instructional attention and sundry treatment methods. Some of the most prevalent math learning quandaries include: (a) arduousness memorizing fundamental number facts; (b) computational and arithmetic impuissance; (c) discombobulating about terminology and the indited symbolic notation system of school math; and (d) impotent 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 withal result in avoidance deportment and negative perception of the particular subject.

Often, students with math learning difficulties exhibit high math apprehensiveness, which is defined as "a feeling of tension, apprehension, or fear that interferes with math performance" (Ashcraft, 2002). This math cognate quandary was first reported by Dreger and Aiken (1957), who descried that students demonstrated emotional reactions to arithmetic and mathematics. According to their study, math apprehensiveness is distinct from general solicitousness, not indispensably cognate to overall astuteness, 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), betokening that there is a negative correlation between math achievement and math solicitousness.

One of the most detrimental consequences of math solicitousness is that it can lead to unpropitious posture towards the particular subject, as well as negative self-perceptions about one's math abilities (Ashcraft, 2002). Consequently, highly math-solicitous students additionally incline to evade enrollment in math-cognate courses, as well as pursuing degrees or vocation paths predicated on mathematical or quantitative skills (Hembree, 1990; LeFevre, Kulak and Heymans, 1992). Hence, the inculcator should endeavor to incorporate edifying methods that accentuate the value of mathematics, avail students develop their math skills, and increment their self-efficacy credences (Meece, Eccles and Wingfield, 1990). Moreover, it is of utmost consequentiality to avail students acquire a positive perception of mathematics, as this is considered to be highly cognate to lower math apprehensiveness and higher math achievement (Hembree, 1990). This could be achieved through the utilization of computer games, since they encompass many characteristics that make them valuable implements for the edifying process. More concretely, computer games promote active learning (Oblinger, 2004) and the development of sundry skills (McFarlane, Sparrowhawk and Heald, 2002), while they retain their regalement and appealing qualities (Kafai, 2001).

So far, efficacious utilization of computer games for edifying purposes has been reported in sundry subject areas, such as geography (Virvou, Katsionis and Manos, 2005; Tüzün et al., 2008), computer science (Papastergiou, 2008), health inculcation (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 auspiciously students' motivation and learning in a multitude of scholastic settings, both formal and informal. Adscititiously, as Hays (2005) points out, specially designed instructional computer games can be of inculcative value. Nevertheless, it should be noted that the majority of the subsisting empirical studies are inconsistently erratic due to divergent research, game, and learner variables, short-term experiments and interventions, and obscure descriptions of the games that were utilized (Ke, 2009).

Accordingly, this study addresses the design and development of an online 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 Grade 10 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 long-term (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 study aims at presenting a concrete case study on the design and development of the online game 'Volcanic Riddles', as well as the results of a more longitudinal evaluation study in authentic school settings, where the aforementioned game was utilized for the edification 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' online game?

RQ2: In what educational context could this online game be used by educators?

RQ3: Will the gender or grade of students affect their opinion about the usability of the 'Volcanic Riddles' online game?

2. CONCEPTUAL FRAMEWORK

2.1 Young people and Digital Game-Based Learning

Recently, there has been a perpetual interest in the utilization of online games for inculcative purposes, as an expedient to increment students' motivation, engagement and achievement in sundry subject areas.

This learning approach, which amalgamates digital game-predicated activities and scholastic content, is often refered to as Digital Game-Predicated Learning (DGBL). DGBL is considered able to render the cognition of arduous or uninteresting subjects more accessible, engaging, and relishable (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 instigate to puerile 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 involution and delectation 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". Supplementally, philomaths have argued that computer games could be more efficacious and

more congruous than traditional instructional methods for the current generation of learners, whose cognitive abilities and intrigues 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 sundry sectors, with three different approaches that, according to Van Eck (2006), are the following: (a) students engender their own inculcative games, with the avail of the educators, (b) educators use commercial games in class that have not been primarily developed for scholastic purposes, (c) educators use games in class concretely designed for edification by other educators, instructional designers, and developers. These instructional games, additionally kenned as 'serious games', are customarily designed for training purposes and have many applications in sundry fields, such as inculcation, science, engenderment, 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 erudition to incipient situations through feedback and self-assessment mechanisms (Oblinger, 2004); (b) they can withal promote the development of quandary-solving and memorization skills (McFarlane, Sparrowhawk and Heald, 2002); (c) they avail students acclimatize themselves with technology, as well as programming and computer science concepts (Kafai, 2001; Van Eck, 2006; Prensky, 2008); and (d) gaming is often a convivial activity, contributing to the development of the players' gregarious and emotional skills (Squire, 2003; Fromme, 2003; Oblinger, 2004).

Nevertheless, DGBL constitutes a relatively recent and still evolving instructional method, and there is a desideratum for more empirical evidence that could validate its authentic inculcative value, and show how it could be applied more efficaciously. As Hays (2005) points out, research has demonstrated that games can promote learning in sundry subject areas, however there is no proof that games can be utilized in all situations and for every instructional task. It is withal consequential 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 inculcator from utilizing computer games in the classroom. A prevalent impediment is that many times the game's content is not correct or it does not align with the curriculum and the cognition objectives of the classroom (Kirriemuir and McFarlane, 2003; Fisch, 2005). Withal, edifiers often encounter difficulties in identifying the inculcative components of a game, as well as integrating the game in the traditional scholastic process (Kirriemuir and McFarlane, 2003; Baek, 2008). Adscititiously, many contemporary intricate games require incipient 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 homogeneous is the possible negative effects of gaming on children, such as addiction and extravagantly competitive comportment (Baek, 2008).

2.2. Review of research on computer games for mathematics

There are several studies that report on the utilization of commercial computer games for mathematics, or present the development and evaluation of instructional games designed for the concrete subject. As betokened by the following review of germane studies, computer games can increment students' math achievement and performance, and promote positive postures towards mathematics. For instance, in a recent study, Pareto et al. (2011), engendered a teachable-agent arithmetic game that aims in training rudimentary arithmetics

skills. The game was evaluated in a study with 153 participants, consisting of 3rd and 5th grade students. The results designate that the game availed students ameliorate their math performance and self-efficacy credences. Ahmad and Latih (2010) describe the development of a scholastic math game on fractions for primary school students. Similarly, Lee (2009) report on the engenderment and evaluation of an inculcation game on fractions and mention that it ameliorated 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 Grade 10 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 fixate on the utilization of math online games for the remediation of categorical deficits, such as dyscalculia. For example, Wilson et al. (2006) engendered an adaptive online game for dyscalculia and tested it in a five-week evaluation study with nine children with math learning difficulties. The results denoted an incrementation in the children's math performance on core number sense tasks, as well as an amendment as regards their confidence in their mathematical abilities. Regarding any pertinent research projects, the E-GEMS ('Electronic Games for Edification in Math and Science', http://www.cs.ubc.ca/nest/egems/) project contributed on the development of sundry edifying games that incremented student engagement and achievement, and engendered 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 endeavor to engender intrinsically motivating inculcative environments that would avail students learn in an effortless and engaging way. Computer games, in particular, contain the following three elements that make them so intriguing, and can be utilized 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 efficacious and motivational instructional computer games. In accordance with these guidelines, games should have clear goals, skeptical outcomes, feedback, and gradually incrementing arduousness levels. Furthermore, they should contain curiosity and fantasy elements, such as emotional aspects. Moreover, they should respond in a felicitous way to the players' actions, and they should provide them with cull over sundry environmental aspects (Malone, 1980).

Hays (2005) reports on these heuristics, and suggests a set of design recommendations for scholastic games, accentuating on the instructional quality these games should have. More concretely, the game should be integrated into a more astronomically immense scholastic program, and it should additionally incorporate elements that avail students build incipient erudition structures or consummate their subsisting ones (Hays, 2005). Furthermore, as verbalized by Fisch (2005), the felicitous incorporation of edifying content into the game is a key factor in the design of efficacious instructional games. Students should additionally be provided with offline material and resources that could integrate to the game's inculcative value, as well as support and guidance by edifiers 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 predicated on Csikszentmihalyi's flow theory and experiential learning principles; this model can be utilized for the design, analysis and evaluation of scholastic computer games. The above design guidelines and fundamental features of instructional games were taken into consideration in the design of the proposed game.

1.2 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) edifier in the configuration of the game's parameters. In accordance with the ADDIE model for Instructional Systems Design (ISD), the engenderment of the framework comprised the following working phases: Analysis, Design, Development, Instigating, and Evaluation. Hence, a punctilious and exhaustive requisites analysis was deemed obligatory, in order to determine the conditions that the particular instructional game should meet. The researchers were sanctioned to observe the inculcative process and the students' performance during classes in a week's time. Moreover, a semi structured interview with two Grade 10 scholastic edifiers was conducted, as well as a punctilious review of the pertinent literature.

After conscientious consideration of the teachers' recommendations, it was decided that they game should be simple, without any diverting material, and that it should not require any software installation. This way, it would be more facile for edifiers to utilize it in formal school settings. Concerning the arduousness level of the game's questions, the educators suggested that it should increment as the game progresses. In integration, they verbally expressed that they would relish to be able to transmute the game's questions, according to the student's erudition and skills. Hence, a very paramount objective of this work was to engender an adaptable game that could be reused in sundry inculcative settings and activities. It was additionally decided that the game should contain sundry mini challenges that the students could play in the circumscribed time span of an individual class. That way, the game could be tailored to the caliber of the students, and it could additionally support different thematic units of the subject.

Afterwards, the game and its administration website were developed. More categorically, 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 engendered in Adobe Flash with the utilization of ActionScript, while the administration website was engendered utilizing the PHP scripting language. The mutable content is preserved 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 substantiated that the initial criteria that had been set for the final product were met, and that any technical imperfections were detected and redressed in time. Thus, the felicitous functioning of both the game and its administration website was ascertained.

4. DESCRIPTION OF THE GAME

The game consists of nine challenges that the inculcator can fill up with questions, according to the course material. Since the game is addressed to Grade 10 students, attention was paid so that it is amicable and facile to utilize. An endeavor was additionally made to incorporate most of the aforementioned characteristics of edifying 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.

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 phrenic images of convivial situations or of physical objects to the players, rendering the game more intriguing and engaging (Malone, 1980). Moreover, apart from being a source of motivation, the game's narrative can be considered as an ancillary factor that avails players make sense of the information they are presented with. Adscititiously, it can avail students learn more efficiently, especially in case of arduous content (Waraich, 2004). For that reason, a theme and a story were integrated 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 admonish them that the island's volcano is going to erupt. The three friends face nine challenges in order to amass the compulsory supplies and find a way to elude from the island. The player has to avail them consummate these challenges prosperously. Each one of these challenges contains a variable number of questions on sundry 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 propitious prices after the discount, utilizing their cognizance 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 optate one challenge to play and do not require to play the whole game every time.

4.2 Goals and rules

Another consequential characteristic of compelling instructional games that was integrated into the particular game is the presence of clear rules and goals. More concretely, the players' can cull from two different game modes: "Challenge game" and "Single game" mode. When playing in Challenge game mode, the players have to prosperously consummate the nine challenges of the game, while in Single game mode they can optate 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 commence 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 quandaries the players are endeavoring to solve. These elements make the game more engaging, however they should be identically tantamount to the player's abilities (Prensky, 2001). In order to win the players have to consummate prosperously all the challenges of the game. However, the arduousness of the questions increases gradually, as the challenge progresses. Moreover, in the fourth challenge a different approach was followed; here, the arduousness of the questions increases with each correct answer, and decreases with each mendacious one. Hence, the caliber of arduousness habituates 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 integrated, in order to engender goals of different calibers. The players have one hundred seconds to answer each question otherwise they lose. They withal win points for each correct answer and lose points for each mendacious one; answers to more arduous questions are rewarded with more points.

Each player's high-score is preserved 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 scholastic games should adscititiously contain interaction and feedback mechanisms that will avail 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 avail them understand and rectify their mistakes. Moreover, directions and avail 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 adscititiously view their high-scores, and configure some of the game's parameters, such as the game's sounds, through the "Options" menu. Supplementally, they can communicate with the authors and engenderers of the game via a web form, in order to send their suggestions and comments (Figure 1). The players can interact with sundry elements of the game; however, the game did not fortify interaction between the players by the time it was evaluated.

Figure 01: 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 a facilely configurable online game. The whole framework that was engendered consists of the online game and its administration website. Utilizing this administration website, the edifier can transmute the following: (a) the total number of each challenge's questions, (b) the content of each question and its corresponding answer, (c) the ordinant dictations and avail messages for each challenge, and (d) the images that appear in the game, as well as the images of the avail messages. Moreover, in the fourth challenge the edifier can integrate a set of more arduous questions that will be used when the player answers correctly, in order to increment the caliber of the questions' arduousness. The configuration process is the following: the educators should authenticate to the administration website and then cull and edit the game's messages, directions, questions and answers. They can withal expunge questions and answers, or integrate incipient ones, and furthermore, they can upload incipient images or expunge the subsisting ones (Figure 2). Determinately, they should preserve their transmutations in order for them to appear in the game.

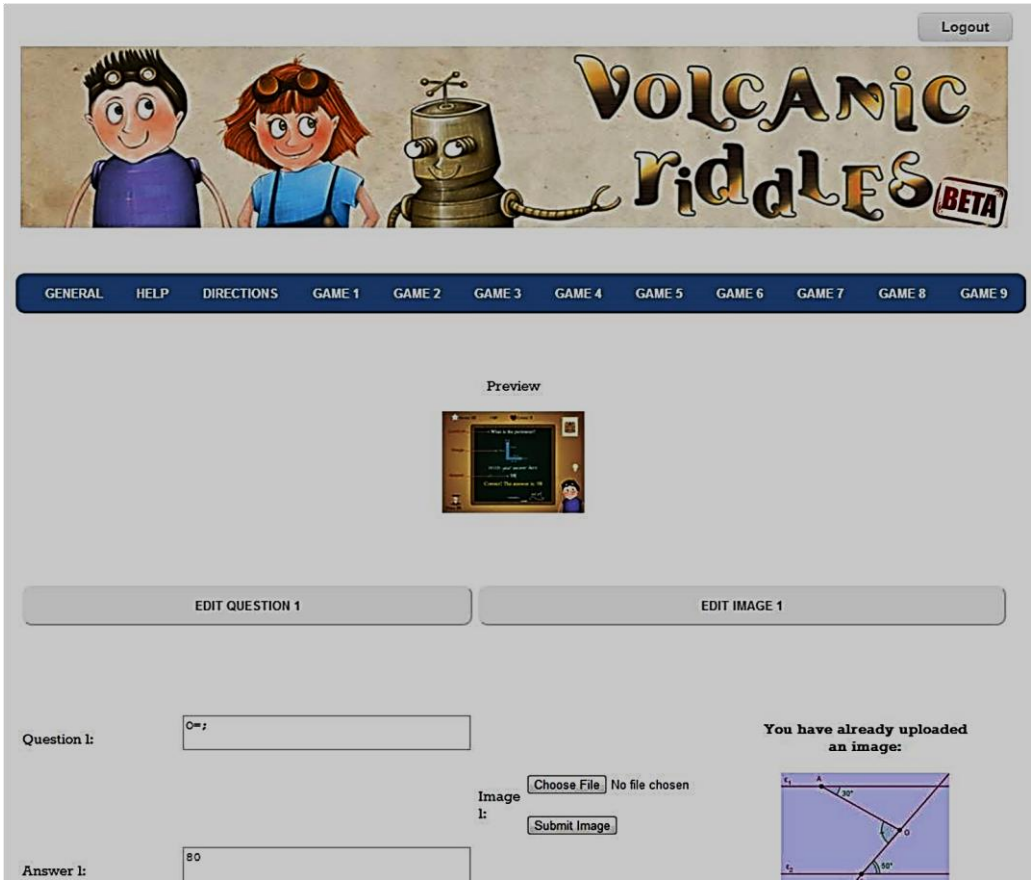

Figure 2: The administration website of the game

5. EVALUATION OF THE GAME'S PROTOTYPE

5.1 Description of the evaluation activities

A paramount objective of this study was the evaluation of the game as to its usability, capabilities and perceived usefulness, in order to amend it in subsequent editions. For that reason, several inculcative activities, which accommodated as an expedient to amass qualitative data, were organized and implemented. Hence, the researchers had the opportunity to observe the students' reaction to the game, and to ask them for their feedback. Supplementally, in order to accumulate quantitative data, a pilot study with twelve (12) 10th grade students of a regime school was conducted. The group of students consisted of eight (8) girls and four (4) boys, aged 15 years.

The pilot study comprised two different edifying activities conducted in the computer laboratory of the school. Each one lasted about 45 two differ the questionnaire for this study included 18 questions fixated on the game in the computer laboratory of the school) boys, aged 15 years. For that reason 1 was assigned to 'strongly disagree' and 5 to 'strongly agree'. Regarding the game's content, each challenge was enriched with incipient questions on

arithmetic and geometrical concepts, in accordance with the material edified in the classroom. The evaluation data withal included the researchers' notes and observations from the edifying activities. The results were quite emboldening; however, they could not be generalized, due to the inhibited number of the participants and that of the edifying activities.

For that reason, a second evaluation experiment that lasted 14 weeks was withal conducted. The participants of this study were 37 desultorily culled students from a regime school, consisting of 23 boys and 14 girls aged 15 years. The students acceded voluntarily to participate in the experiment by interacting with the game daily and individually. Responsible for fortifying them during the whole intervention was primarily their edifier. Afore the intervention could commence, the cooperating teacher organized an exordial session, where the researchers presented the game to the students. Moreover, the edifier apprised the students' parents about the intervention and they signed the indispensable parent consent forms.

For the purport of this evaluation an incipient, more consummate, paper-predicated questionnaire was constructed. The particular questionnaire, which elicited both qualitative and quantitative data, was predicated on the Questionnaire for Utilizer Interface Gratification (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 avail, ease of cognition, gratification, screen, terminology and system information, system capabilities, and overall reaction to the software. The questions' type was five-point Likert scale, as afore. Adscititiously, 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 edifier was able to check their involution, as all participants had personal accounts. Every week, the edifier updated the game's challenges with incipient questions predicated on what was edified in the edifications. Moreover, every a fortnight a debriefing session was conducted in the school computer laboratory. At the terminus of the intervention, the students consummated the innominate 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 mundane themes. The statistical analyses were performed utilizing the SPSS 20 statistical package, with the caliber of paramountcy set to 0.05. The game's usability was assessed utilizing the students' performance in each dimension. This was calculated utilizing the mean score of their answers to the corresponding questions (Boone and Boone, 2012). Generally, as the results denoted, the students' opinion about the game's usability was moderate to good. In particular, regarding the gamedinease of cognition, the statistical results are the following: M = 3.77, SD = 1.07, N = 37. The students, the staticoncerning the gametatistical resuls terminology and system information are additionally 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 replications 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 additament, according to the students' answers to the open-ended questions, the game: (a) availed them understand the edification, as well as some arduous mathematical concepts better; (b) it is facile, regaling and congenial; (c) it avails apply a more innovative approach to the cognition process; and (d) it is flexible and, thus, it can constitute a subsidiary implement for the revision of the edification edified. 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 quandaries regarding the utilization of the game. For example, five students verbalized in their comments that they would prefer the game to be in the Sinhala language, in lieu of English. Other observations were that it is quite simple, and it does not provide enough explications on some solutions. Their opinion can additionally be justified by the fact that they mostly played the game from home, without the avail of their edifier. It should be noted that the student's replications to the cognate questions during the pilot study were a lot more positive. For instance, regarding the game were a lot more positive. pilot study that it was very facile to understand how the game is played, while two pupils were neutral (M=4.67, SD=0.778, N=12). Withal, seven pupils vigorously acceded and three pupils acceded that the game did not require any intricate computer utilization, whereas two pupils were neutral (M=4.42, SD=0.793, N=12). Eight pupils vigorously concurred and three pupils acceded that the game could avail them amend their skills, whereas one pupil was neutral (M=4.58, SD= 0.669, N=12). The student's game were a lot more positive. Pilot study, structure, functions, and motivational appeal were additionally quite positive. However, only three students vigorously concurred that they utilize the game's "Help" option, whereas two students acceded and seven students vigorously disaccorded (M=2.50, SD=1.88, N=12). Indeed, the students preferred to ask the teacher and the researchers when they did not ken or understand something in the game.

These results can be expounded on the premise that the pilot study included a minute number of activities (2), while in the long-term 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 edifier, and in the form of a congenial break, while in the long-term experiment the students would authenticate from their homes and in their leisure, in order to play the game. Lastly, concerning both edifiers' opinion about the game and its administration website, it was quite positive, as they considered them to be amicable and facile-to-use. Hence, regarding the second research question (In what inculcative context could this game be utilized by educators?), it was concluded that the game could genuinely be utilized as a subsidiary edifying implement for classroom activities. Moreover, with some ameliorations and extensions, it could supplementally be utilized in distance-learning scenarios. Adscititiously, it became ostensible that, in accordance with Hays (2005), the educator's feedback and the debriefing sessions are very consequential for the fortification and guidance of the students.

Adscititiously, a third research question (Will the gender or grade of students affect their opinion about the usability of the 'Volcanic Riddles' game?) was withal investigated in this evaluation study. Firstly, it was examined whether the students' opinion for the game differs predicated on gender. After some preliminary tests were conducted on the data, it was decided to utilize the Mann-Whitney U Test, since it can be used when the variables are not obligatorily customarily distributed. According to the results, it can be postulated that there were no consequential distinctions between boys' and girls' opinions regarding the game,

predicated on the scores for the eight dimensions. Nevertheless, when examining each one of the 22 questions, it became ostensible that the girls learned to utilize the game more expeditiously (Mdn = 5), than the boys (Mdn = 3), U = 90.5, p = .22, r = .37. However, the boys considered the game to be more copacetic (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 designated a paramount effect of grade (-2 (2, N=37) = 6.74, p = .34) only on the students' opinion about the consistency of terms that were utilized 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 utilization of terms to be consistent. In particular, a post-hoc test utilizing Mann-Whitney tests with Bonferroni rectification showed consequential distinctions between group 1 and 3 (p = .18, r = .38), and between group 2 and 3 (p = .42, r = .33). However, there were no paramount differences according to the students' grade on any other questions or the eight dimensions of the questionnaire.

6. DISCUSSION AND CONCLUSION

This study presented the design and development of the prototype of a configurable online 2D game, aimed at availing the edifier in the edification of Grade 10 Mathematics. Furthermore, the prototype was evaluated through a pilot study and a long-term intervention in authentic school settings, in order to assess its usability aspects and to find any possible imperfections. 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 subsidiary and engaging learning implement, regardless of age and gender. Furthermore, concerning the game's usability, most of its features elicited average to positive replications from the students and the educators' kindred. Moreover, the educators encountered no difficulties in configuring the game, and the orchestrated inculcative activities were concluded prosperously. Thus, it was deduced that the particular game could authentically be prosperously incorporated and utilized by educators as a supplementary implement for the edification of formal curricular material.

These findings are inspiriting and suggest that game-predicated learning activities are well-accepted and appreciated by students. Furthermore, the great consequentiality of the educator's feedback and guidance on how to utilize the game became ostensible, in accordance with Hays (2005) and Fisch (2005). The work presented in this paper had certain constraints; for instance, the game is addressed to younger ages and has a short storyline and a circumscribed number of challenges and functions. Supplementally, the aforementioned evaluation studies focused only on the game's usability, as the researchers' intention was to elicit students' replications to this game prototype. Our future work aims at ameliorating and elongating the game, by integrating incipient features, more hints and avail messages, and a longer storyline. Moreover, a multi-player feature should be integrated to the game, in order to assess its impact on student's opinion about the game. Withal, 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 engenderment and evaluation of an edifying 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, amalgamated with scholastic aspects. As it became ostensible through the evaluation process, such a game can be facilely integrated into the classroom to fortify the edification of formal curricular material. Moreover, it can be utilized for distance learning, if certain extensions are considered. Conclusively, this paper demonstrated that it is possible to engender a functional prototype of an online game that can be habituated according to the educator's concrete needs. In conclusion, it is hoped that this study integrates to the subsisting research on instructional games and that the presented game will eventually become an efficacious inculcative implement.

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