Role-Playing Game-Based Learning in Mathematics

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Abstract: *Computer based role-playing games are able to provide a fun and motivating environment for teaching and learning of certain subjects. Role-playing games allow students to assume the role of a character in the game world and to determine the actions of their characters based on the characterization. This would provide an exciting and motivating strategy for students to practice skills that they have already learned. This paper describes the development of a role-playing game in learning mathematics. Due to its interactive and stimulating nature, the game is suitable for school children in learning this subject. The focus of the game is on decimals since most school children have difficulties in understanding this topic. This game is able to engage these children and at the same time assist them in learning the topic. Spiral methodology together with Flash 8, Photoshop CS2 and vector image editor have been employed in the development of the game. Educational elements have also been added from time to time without compromising the enjoyment of playing the game. A heuristic evaluation was conducted and positive results have been obtained.*

1. Introduction

Students learn in a lot of ways. Some students learn by seeing and hearing while others learn by reflecting and hearing. Some of them learn by intuitively figuring things while others use reasoning and logic. Some students learn by memorizing, visualizing and drawing analogies while some learn by building mathematical models [1]. Technology advancement has allowed educators to create lessons that will interest and engage students during the learning process.

Computer based role-playing games are able to provide a fun and motivating environment for teaching certain subjects. Computer games, formerly referred to as PC-based games are software artifacts that combine multimedia and other computing technologies such as networking to enable the game player to experience goal directed play in a virtual environment [2]. Role-playing games (RPG's) is a game in which the participants assume the roles of an avatar (fictional characters) and collaboratively follow and/or create stories [3]. In other words, RPG's allow students to assume the role of a character in the game world and to determine the actions of their characters based on the characterization. This would provide an exciting and motivating strategy for students to practice problem solving skills that they have already learned.

Most students think that mathematics is a difficult, complicated and confusing subject because it involves formulae and calculations. Others see mathematics as a boring subject which sometimes is unrelated to their real-life situations. On the other hand, conventional learning instruments for learning mathematics such as text book, revision book, and courseware are not very effective in ensuring a mastery of the subject.

Among the problems associated with the conventional learning instruments are:

a) Lack of motivation - Most students do not study because they want to study, but more like they were asked or forced by others. They did not realize the benefits of studying due to no direct rewards or consequences from the action.

b) Not very interesting / Boring - Most of conventional learning instruments are just merely text and full of exercises. With linear learning models, students can only accept and digest all the inputs without being able to respond and interacts to it.
c) Little encouragement for self-learning - It does not provide enough stimulation for students to initiate learning on their own and restrict the students' freedom to find the answer of their inquiries and also to explore their world in their own way.
d) Less meaningful - Weak relationship between what the students have learnt so far from their study to what they have experienced in their everyday life.
e) No continuity - It takes some time to gain enough concentration and focus on their study from conventional learning instruments. By stopping for a while, all the motivation is gone and they will need to regain focus from the beginning if they want to continue their study at a later time.

Therefore, there is a need to find a solution to help students understand mathematics better and make it interesting and fun to learn. According to [4], people learn best when they have a strong and immediate motivation to acquire new knowledge, and when they are having fun. Game based learning is able to create a fun, motivating, and interactive virtual learning environment. However, studies on how mainstream games could be used in school found that the most frequent obstacles encountered are: i) it was difficult for teachers to identify quickly how a particular game is relevant to some of the curriculum, as well as the accuracy and appropriateness of the content within the game; ii) the difficulty in persuading other school stakeholders as to the potential/actual educational benefits of computer games; iii) the lack of time available to teachers to familiarize themselves with the game, and methods of producing the best results from its use; iv) the amount of irrelevant content or functionality in a game which could not be removed or ignored, thus wasting valuable lesson time [5]. A study discussed in [6] had recommended that game designers design games that mimic closely specific contents of the curriculum.

This paper describes the development of a role-playing game, Math Quest, in learning mathematics. Due to its interactive and stimulating nature, the game will be suitable for school children in learning this subject. The focus of the game is on decimals since most school children have difficulties in understanding this topic. Research has shown decimals are difficult not only for school children to learn [7] but also for teachers to teach [8].

2. Theoretical Framework

Game-based learning can be used as a teaching tool in the classroom to facilitate learning mathematics. According to [9], the use of game-based learning can stimulate the enjoyment, motivation and engagement of users, aiding recall and information retrieval, and can also encourage the development of various social and cognitive skills. As students play, they can look at the nature of the action they are following and the results yielded by the actions. Hence, learning mathematics can be more enjoyable. According to [11], mathematical games can also improve young children's number knowledge. Besides that, through games and the activities, students will learn to be more flexible and will be involved in active learning.

Games are almost similar to simulation in terms of their basic structure. There are three main parts; the introduction, the body of the game and the conclusion. Figure 1 depicts the general structure and the flow of games [5].

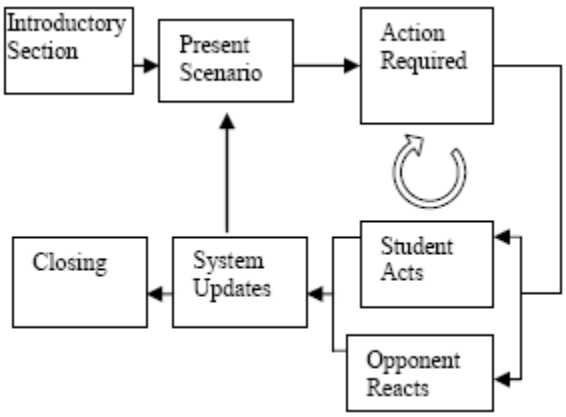

Figure 1 The general structure and flow of games [8]

Research has also shown that games have been explored as a pedagogical approach to enhance mathematical learning. According to [11], the two major components in RPG models are (i) pedagogical (difficult to learn, psychological needs, critical thinking, exploration, challenge, engagement, competition, practice, goal setting and motivation) and (ii) games design (interaction, storytelling, interface, simulation, construction, feedback, literacy, communication, motor skill, memory and outcome evaluation. From the perspectives of learning theories, game-based learning should have the following characteristics [2]:

- Motivating and engaging but not necessarily entertaining
- Requires participation from learners
- Has clear objectives defined in the game-play and scenarios presented while knowledge can be imparted through storytelling and narrative.
- Provides freedom to interact in the game world through a set of defined actions
- Provides clear defined feedback for every action taken
- Match learners pace and intellectual ability
- Highly scalable so can be used for educating large numbers of learners concurrently.

Table 1 shows the comparison between some existing games that are available in the market. However, few studies have actually measured the impact of games on student learning [12]. Bubble Puzzle is a game-based interactive learning activity aimed at assisting elementary school children in understanding fractions [13]. Techniques such as visual feedback and scaffolding were used in the design to promote reflective cognition. Two studies with 47 elementary school children were conducted to evaluate the educational effectiveness and the design features of Bubble Puzzle. It was found that playing the game helped children gain a better understanding of the underlying mathematical concepts, and led to statistically significant improvements on test scores. The results suggest that Bubble Puzzle provided a motivating learning environment, and that the entertainment features of the game matched children's interests and were conducive to children's enjoyment of the learning activity.

Singh et al. [14] had developed a game to introduce basic programming principles to children age between 5 and 7 years. A simple 2D game prototype consisting of 7 different scenarios was developed. Preliminary evaluations of the game have shown positive comments about using the game to learn programming.

In another research [15], Scupper's island has been developed based on RPG. It was based on a pirate code of conduct as the major part of the game play. The purpose of the game is to let the players interact as pirates and learn about values, ethics and differences in each other's ethical

beliefs. The availability of these games as well as the above studies forms the motivation for the design and development of Math Quest.

Table 1 Comparison between existing available games

Competitors/ Feature	Massive Multiplayer Role Playing Game	Mini Educational Game	Conventional Product
Overview	An online game with massive global subscriber base. People pay monthly fees to participate in the virtual world.	Web-based game hosted online to attract traffic to the site. Games offered are mostly arcade type and some are educational.	Conventional learning instruments that are being used at schools to assist students in their learning process.
Example Product	- World Of Warcraft - Final Fantasy - Ragnarok	Often hosted by website such as: -FunBrain.com -Mathplayground. com	- Text Book - Revision Book - Exercise Book - Courseware
Purposes	For entertainment only	Entertainment and education	For education only
Characteristics	-RPG genre -Long playing duration -Fun & Addictive -Allow continuity -Large size (>1GB)	-Arcade genre -Short playing duration -Considerable fun -No continuity -Small file size	-Duration depends on user's sustainability -Uninteresting and boring.
Features	-Multiplayer -Long and immersive storyline -Impressive Visuals -Character's leveling and improvements.	-Single player -Short and compact storyline -Average Visuals -Performance based on score	Not Applicable
Learning Effectiveness	Not Applicable	Moderate -Encourage self-learning -Have fun elements -Interactive	Moderate -Systematic and structured syllabus -Non-interactive / Linear Model
Technology	-Tools : 3D software, heavy engine, sophisticated system -Centered data storage -Non homogeneous application	-Tools: Light Flash engine, simple system. -No data storage -Homogeneous application	Printed materials published into books.
Learning Curve	High (complicated)	Low (easy to use)	Low (easy to use)
Accessibility	Online & Offline	Online	Offline
CPU Specs. Requirement	-Requires high computational power -Internet Access -Cutting edge Graphic Card and large cpu memory	-Requires low computational power -Internet Access -Normal cpu memory	Not Applicable

3. Maths Quest

Math Quest has been developed using role playing game. The game incorporates the Role-Playing Game genre along with the teaching of a mathematics subject for primary school students. Maths Quest is considered a computer game. According to [9], computer game can be characterized by six key structural elements which, when combined together, strongly engage the player. These elements are: rules, conflict/competition/challenge/opposition, goals and objectives, interaction,

outcomes and feedback, representation or story. The types of games include action games, adventure games, knowledge games, simulation games such as management and strategy games, drill-and-practice games, logical games and maths games [16].

In designing games based learning, it is important to present learners with learning material in the form of narrative and storytelling so that they can learn through game-playing and study the properties and behavior of in-game components and at the same time able to solve the problems in the defined scenario [2]. The development of Maths Quest has also taken into consideration some learning theories such as behaviorism, cognitivism and constructivism.

Spiral development methodology has been used in the development of the prototype. This is depicted in Figure 2.

Figure 2 Spiral methodology

The tools used in the development are Adobe Flash 8, Adobe Photoshop CS2 & Macromedia FreeHand and Sound Forge & Audacity.

4. Results and Discussions

4.1 Maths Quest

Maths Quest is developed as a means of introducing a supplementary material in teaching Mathematics subject in particular in the topic of fraction. Figure 3 shows the levels of the games structure. In this game, a player is given a main mission which is to bring peace to the land by bringing back the knowledge of Mathematics to the people. In order to do that, the player will have to master each aspect of mathematics throughout the journey inside the game, by cracking ancient puzzle and riddles, defeating enemies with mathematical calculation, or helping the people solve their everyday problems. Soon, as the people learn and apply the knowledge of mathematics, they can survive the attacks of evil forces which in the end they are capable to take them down and start a peaceful civilization.

As shown in Figure 3, the game is best described as a linear game where there is only one ending possible ending, yet the player still has a great deal of freedom inside each of the “pearls” that make up the main spine of the story. The Math concepts at each of the levels form part of the

Mathematics curriculum for the primary schools in Malaysia. Students are expected to understand these concepts at the end of Year 6 in their primary education.

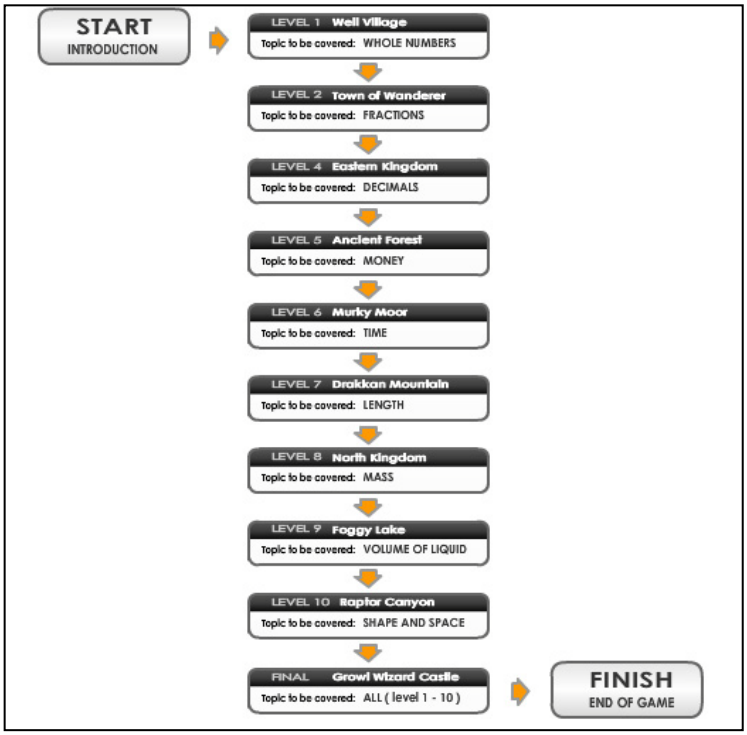

Figure 3 Maths Quest level of structure

4.2 The Interface

Figure 4 shows the Maths Quest's logo. Then users can view the topics that have been designed in the courseware. Users have the choice to learn a new topic by visiting a few places that have been created. This is depicted in Figure 5.

Figure 4 Maths Quest Logo

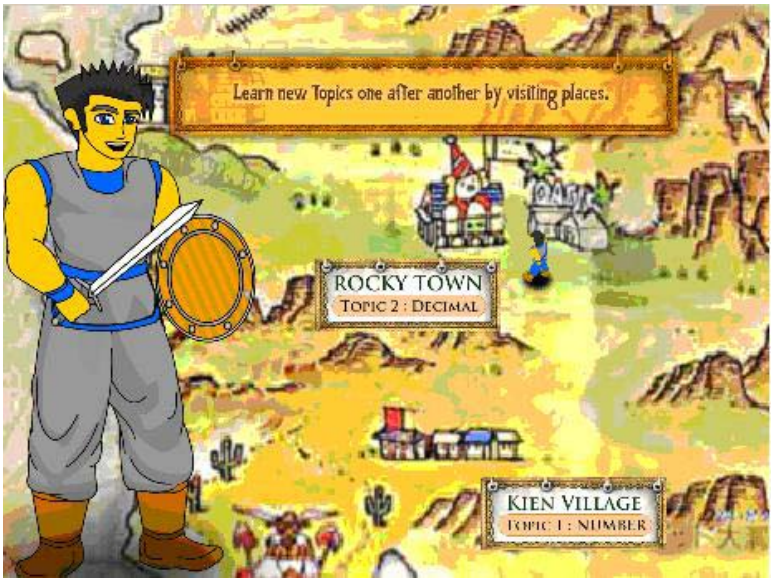

Figure 5 Topics

Figure 6 shows the main interface which a user will see in most parts of the game. On this screen, users will be shown a series of animation, text, images and sound to immerse the player into the game's storyline. There are several components on the screen that relates to the game play; this is depicted in Table 2.

Figure 6 Main Interface

Table 2 Main Interface Components

NO.	COMPONENT	DESCRIPTION
1	**Title**	The title shows the current location and chapter of the game.
2	**Animation screen**	The story of the game will be displayed in this area in a form of animation, graphic, text and sound. It also shows the character's movement and interaction as being played by player.
3	**Game option**	Player will have menus of options such as start, pause, save, load, and exit the game.
4	**Character's Status**	Main character's current information on life points and strength is shown here. Players need to make sure that the life point did not get to zero as it means 'Game Over'.
5	**Inventory**	When this button is clicked, a new pop-up will appear to display all items that the player possessed during the game.
6	**Notifier**	The orb will glow at any time during the game to indicate a new event has occured such as getting a new learning object, or new quest available.
7	**Book of Knowledge**	When this button is clicked, a new pop-up will appear to display learning objects available for the player to learn, do exercises, puzzles, and games and thus assess their current understanding on certain topic.
8	**Quest Log**	Showing current quest or mission that the player needs to accomplish.

Learning mathematics on the topics of decimals would be more systematic since the content is based on the syllabus. Students will be guided throughout the courseware. Figure 7 shows the icons that have been designed in the courseware. The subtopics can be viewed on the left, while on the right side the users can view the icons for exercise, puzzles & games, assessment and online modules.

Figure 7 Icons of Modules

Figure 8 shows the interface of the Learning object; here students are introduced to the concepts of Decimals. Figure 9 shows the introduction of the concepts of decimals step by step by showing the animation. Students can always repeat the animation if they want to see it again.

Figure 8 Topic on decimals

Figure 9 Step by step instruction

Figure 10 shows the interface of Combat. Combat occurs where the player needs to deal with enemies they have encountered. When this happens, the player will be transferred into a new combat screen where the player can make a decision whether to attack the enemy, defend himself/herself or use items for his/her own good. If he/she decides to attack, a random Mathematics questions will be loaded onto the main screen in objective format. By answering it correctly, the player will be able to do damage to the enemy and once the enemy's life reaches zero,

combat mode will end, and the player will be returned to their previous screen. In this combat, students can test their theories and strategies along with providing practice in multi-steps problem solving. According to [17], the games can offer repeated use of strategies and practice of skills that have already learned. These practices will be more effective because students have to be actively involved in their own learning. In Figure 11, the reward will be given to the player when he/she has defeated the enemy.

Figure 10 Combat Interface

Figure 11 Reward of Combat

5. Heuristic Evaluation

There are different types of evaluation developed to assess the interface design of a system. Since this is only a prototype, a heuristic evaluation has been conducted in order to identify the usability problems in the user interface design. The set of heuristics adapted was based on the traditional guidelines proposed by [18]. Six participants were involved in the evaluation. According to [19], for a heuristic evaluation, on average of just five evaluators can detect almost 75% of the usability problems. This suggests that the heuristic evaluation with 6 respondents is enough for the usability evaluation. The respondents involved are teachers. As indicated by [20], the evaluation involving expert users will lead to the identification and evaluation of user interface problems with relatively low cost at the initial stages since this is only at prototype level. They were given a demo and hands-on access to the prototype. They then filled in the form once the review was completed. The questions are based on Likert scale of 1 to 5 (1 means strongly disagree while 5 indicates strongly agree).

The questionnaire is based on learnability, satisfaction, screen design and performance effectiveness. The results are shown in Figure 12. The average mean was 4.3 which can be considered as satisfactory. Therefore, it can be concluded that in general, the participants are satisfied with the prototype. Some of the usability problems highlighted by the evaluators were: the users should be informed about what is going on, users should be free to select the task when appropriate, instructions should be made clear and make help easily available to users. Some of the comments are to include more activities that will be able to help users to understand the content, to provide learners with constructive feedback on their task, to support learning through the interaction and finally to replace the environment of the interface to a Malaysian scenario. All the feedback obtained from the evaluation will be used in the full development of the courseware.

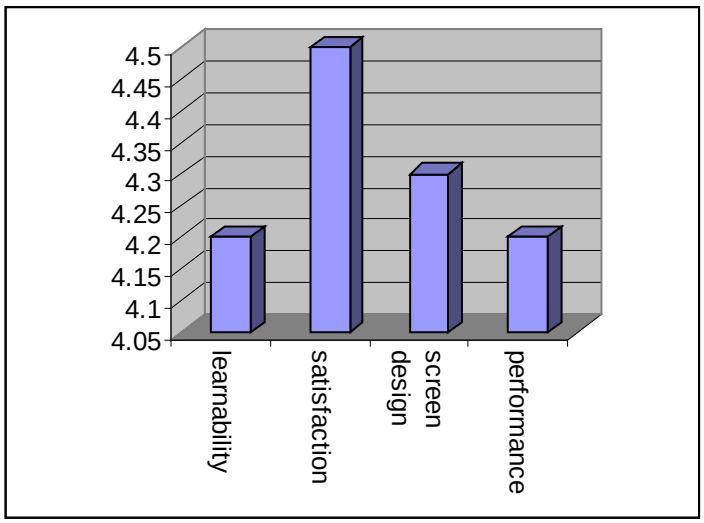

Figure 12 Usability result

6. Conclusion

This paper has discussed the design and development of a prototype of a role playing game, Maths Quest, in learning mathematics. Positive feedback has been obtained from the heuristic evaluation. Our research work will further proceed by testing the game prototype with 3 different groups; students, teachers and parents.

For further recommendation, the game which is currently single player will be extended to multi players. The storyline will also consider using a non linear rather than a linear structure.

8. Acknowledgement

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