The Red Circle project: How mathematics can be embedded in online gaming quests for enhancing learning and teaching

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'The Red Circle' is a part of a larger project that aims to promote learning through virtual, social and competitive environments by establishing a new gaming genre named EduMMORPG. The name derives from the word 'educational' and the already existing gaming genre of Massively Multiplayer Online Role-Playing Games. This project aims to investigate the quest line and a preliminary skill line of an RPG associated with mathematics. A high fidelity prototype is developed in order to create the base for the mechanics and feel of the game. The prototype is designed as a fantasy RPG with mathematical problems included as key elements of the gameplay. Quick reaction multiple-choice questions are integrated into the combat mechanics and more complex problems are embedded in the questing system. Pedagogic techniques of teaching mathematics are explored in order to provide realistic expectations for the impact of the game in today's education. An experiment where potential users shared their opinions on the current state of the game is further discussed.

'The Red Circle' is a demo game that explores how mathematics can be embedded in online gaming quests for the benefit of the current mathematical teaching practices. The wider project takes place in a PhD degree and aspires to introduce a new approach to learning, using pedagogic techniques of teaching mathematics in an attempt to create a multiplayer game that is worthy of comparison to alternative competitive games in terms of mechanics, balance and entertainment.

A fantasy world which accommodates a story line was built in UNITY environment and the scripts were written in C#. The educational level that it works with is GSCE and can assist adult learners who need to refresh their knowledge or learn mathematics.

Related Studies

As examined by Anagnostopoulou (2016), there are various studies that investigate MMORPGs as a teaching method for schools.

The educational value of MMORPGs, as studied by Wagner (2008), demonstrated that the social aspect of MMORPGs is an important motivational factor that can engage potential students in their learning in an analogy to their learning efforts for the mechanics of a game. Moreover, the strategic thinking and problem solving aspects of the MMORPGs can effectively be used in education.

Steinkuehler (2004) used Lineage MMORPG to study the informal online learning features of its environment and find which are productive and which are not. He examined how cognition can be socially and materially distributed and concluded that players shape their individual identities through interaction with community activities, values, and goals. The elements, components and structures of learning through games were also described by Tang et al. (2007).

Habgood (2007) studied the effective integration of learning content into digital games, through Zombie Division, a maths game for KS2 students. He concluded that intrinsically integrated games are more effective than extrinsically integrated games as they motivate the players to profoundly connect with the learning material. He also argued that the fantasy aspect of RPG games is not the main feature that the players engage with the game; fun is more essential.

Squire and Giovanetto (2008) used Civilization III, a history simulation game to examine the key structures of learning evolution in games and concluded that active participation in a game is fundamental to game-based learning systems.

In another study conducted by Trybus (2014), three systems of learning were compared and contrasted: traditional, practical, and game-based learning. Trybus concluded that game-based learning not only combines all the benefits of the other two systems but it can also be more beneficial and provide a faster learning curve.

Suh, et al. (2010) found significant differences in terms of achievement in English education for elementary students. Susaeta et al. (2010) designed a Classroom Multiplayer Presential Role Playing Game (CMPRPG) for teaching ecology as an afterschool classroom activity.

In ReLIVE 08 conference, hosted by the Open University (2008), researchers discussed multi-user virtual environments (MUVEs) in teaching and learning. The Open University purchased Cetlment Island in Second Life, a virtual world environment and examined the potential that this environment could offer for working with their students.

However, the results of these studies have not yet been successfully implemented and the game genre, EduMORPG, proposed within the scope of the current project is still absent from today's gaming industry. Moreover, the current educational system is evolving worldwide, in terms of technology enhanced learning and incorporating games in the teaching and learning practices. Hence, there is a gap in the education industry that an EduMORPG can cover.

Methodology

Aim

The project aimed to explore ways with which an engaging story line of an RPG can be used to provide motivation and assist the learning of mathematics. Specifically, in which parts of the game, mathematics can be embedded without diluting the entertaining aspect.

Method

A high fidelity prototype of a game was developed in UNITY, introducing unique game mechanics and innovative gameplay. The game was set in a medieval setting with a relevant story line, which follows a series of quests to guide each player through their knowledge path (fig. 1).

Figure 1: Questing area (Olivotos, 2019).

The quests were essentially the main learning part. They contained mathematical questions ranging from short to long questions, covering basic algebra, geometry, trigonometry, logic, probability and statistics.

Mathematics was embedded in the quest line in the following ways:

Medium questions were asked by NPCs (Non-Player Characters) who interacted with the player through a dialogue box, giving directions for the quest (fig. 2).

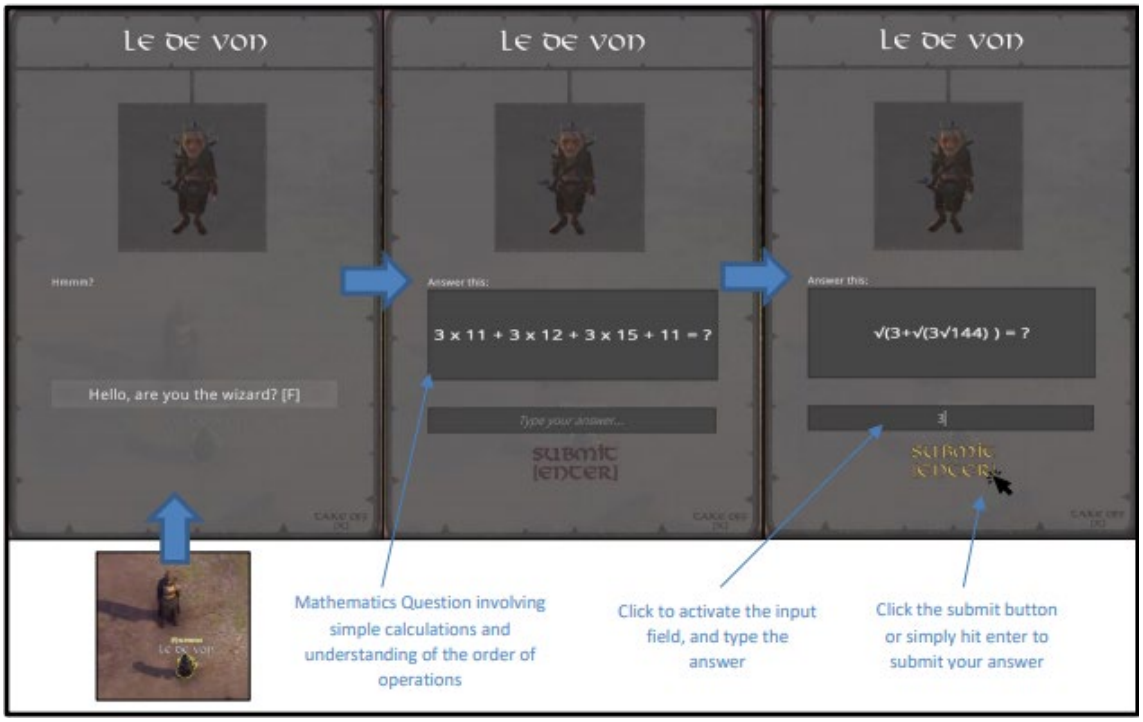

Figure 2: Medium questions by NPCs (Olivotos, 2019).

Interactive items, like chests to be unlocked, contained long questions (fig.3). The player had to find the correct answers which comprised the combination of the lock. For each correct answer the central 'L' shaped bar was rotated to fit in the 'L' shaped hole in order to open the chest.

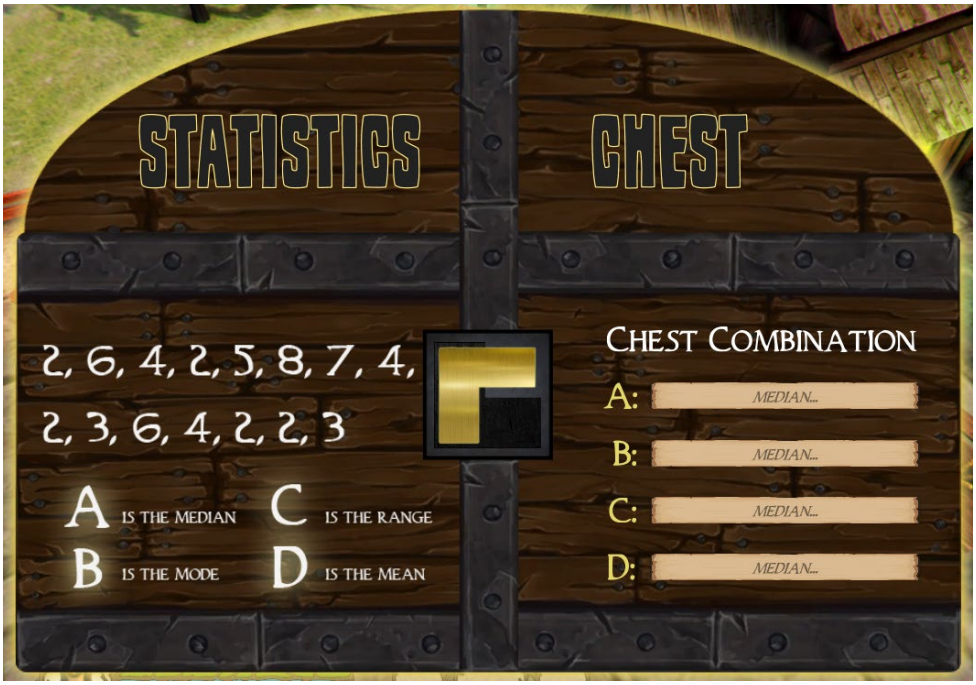

Figure 3: Long questions that unlock chests.

The quest line also contained logic questions like the one shown in fig.4. The player had to explore the map and interact with more than one NPC to get the right answer.

1. There is exactly 1 false statement in this list.
2. There are exactly 2 false statements in this list.
3. There are exactly 3 false statements in this list.

Exactly how many false statements are there in the list above?

Figure 4: Logic question that require map exploration (brilliant.org, 2019).

Short multiple choice questions were introduced with the activation of certain abilities (skills) of the player. A resource called 'energy' (blue bar in fig. 5) was dissipated when the player used their abilities. Each skill required an amount of energy to be casted. When the blue energy bar emptied, no skill could be casted and recharging was needed. By pressing 'S' in the keyboard the skill bar was changed to a wheel with short and quick multiple choice questions with 3 possible answers, as shown at the bottom picture of fig. 5. For each correct answer a part of 'energy' was regained. To prevent players from guessing, there was a short stun effect as a penalty for choosing the wrong answer.

Figure 5: Short multiple choice questions in the combat wheel.

Interactive 'billboards' were set on the scene, where the player could find the relevant information to solve mathematical questions, if needed.

Data

Data was collected in two phases.

Phase 1: As an initial testing phase of the game, which would inform for any improvements or hot fixes, a short experiment was conducted involving 8 participants and fifteen minute session of gameplay. The participants had considerable knowledge in both gaming and mathematics and were asked to score, from 0 to 10, four focused areas: effectiveness of user interface and hotkeys, extent of intuitiveness, quality of entertainment and degree of integration of mathematics in game mechanics.

Phase 2: The participants were asked to play the game and complete the quest line. The gameplay duration varied from 30 to 50 minutes, depending on how experienced the players were. The participants were adults, with age range of 20 to 70 years old. The sample was selected to be comprised by both gamers and having no game experience, and having mathematical prior knowledge and little maths skills.

Upon completion of the game, the participants were asked to complete a questionnaire. Data from the questionnaire was collected and analysed.

Data collected was anticipated to answer the following questions:

- How engaging was the game? Which parts did the players find more enjoyable? Would the players play this game again? Would they recommend it to a friend?

- Was the quest line clear? Did the players know what they were asked to do? Were the players able to find information in game to complete the quests?

- How difficult was it to navigate and use the UI?
- How much did the maths questions distract their entertaining experience?

Results

The results of *Phase 1*, shown in fig.6, provided a general positive feedback with "quality of entertainment" to be rated higher. Open questions feedback informed and advised on modifications that would improve the game intuitiveness and the integration of mathematics in the mechanics. A new improved version was then built implementing suggested changes; for example, the map feature was improved to show the location of player and the location of the next quest.

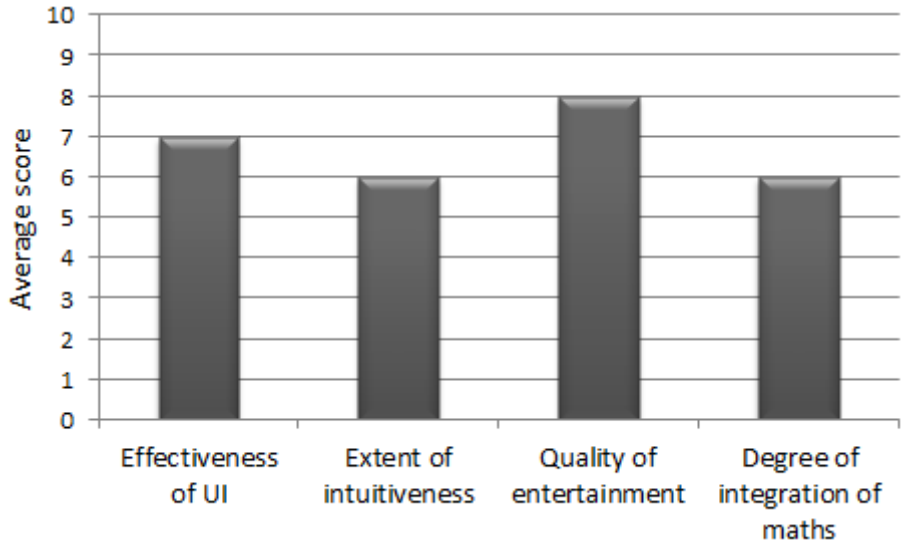

Figure 6: Average score of each focused area (Olivotos, 2019).

In *Phase 2*, the participants tested the upgraded version and were asked to rank their preference for the following game features: maths content, story line, quest sequence, landscape and virtual environment, non-player characters personality, graphics (movement, skill casting, dialogue boxes, etc.), combat and fighting techniques.

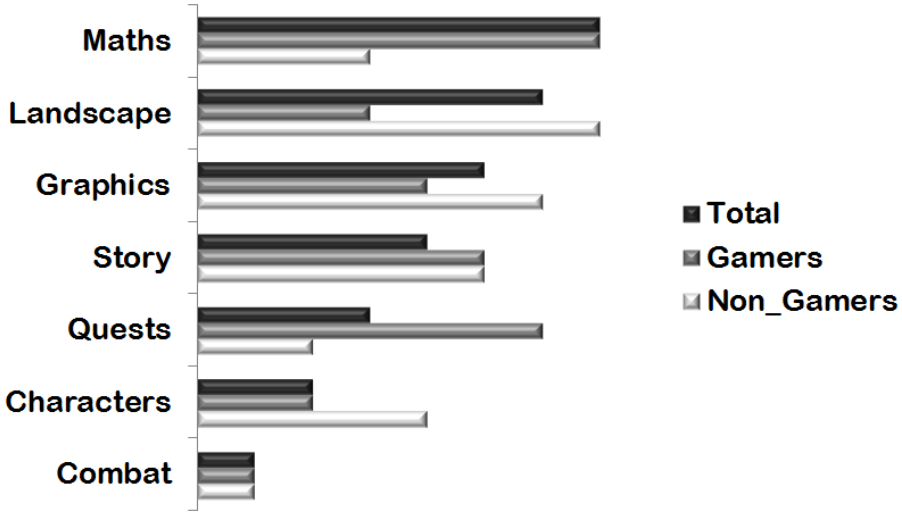

Figure 7: How gamers and non-gamers rank the game features

Fig. 7 ranked the maths content as first, with gamers stating that it is their first preference. Non-gamers picked landscape as their first choice and graphics as their second which verifies that a well-designed virtual environment is engaging and motivates to carry on playing a game (Wagner, 2008).

An interesting result is that the 'combat' feature was ranked last by both gamers and non-gamers. Data from the open questions in the questionnaire revealed that the players found the use the multiple choice wheel too fiddly. They would prefer to have to type the answer rather than choose the correct letter. Gamers also commented that they found the wheel distracting while in combat. Hence, the skill wheel is to be reviewed at a future version of the game.

Comparing feedback between gamers and non-gamers, in terms of the aspects presented in fig. 8, the results showed that both categories found the game innovative and worth of recommendation. The quest line was clear to follow and all could easily navigate through the map irrespective on whether they have any prior game experience. A worthy comment here has to do with the dialogue content during questing. Non-gamers found that there was a good amount of dialogue, whereas gamers thought that it was a bit much. Through observation while playing, they were noted to skip dialogue lines in order to advance in the quest line. This is a very important result, as it is the case for most RPGs, and needs addressing.

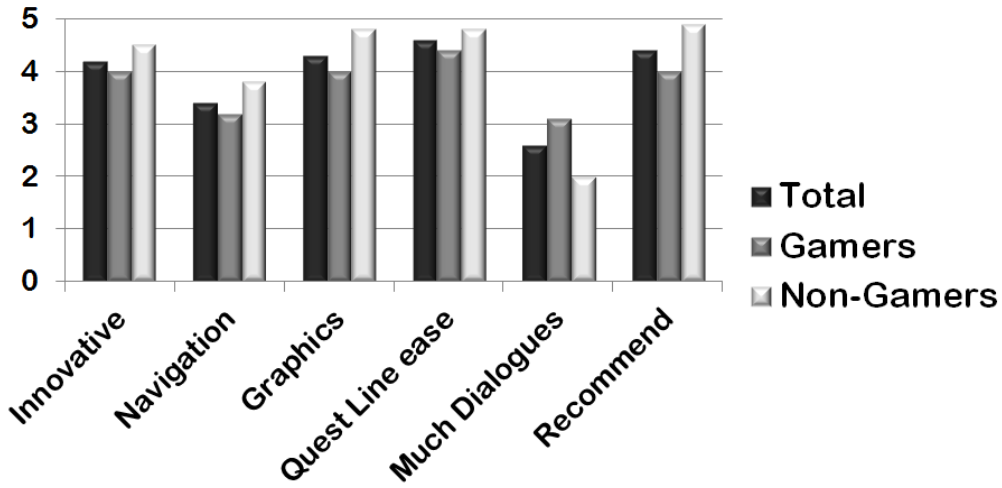

Figure 8: Comparison between gamers and non-gamers feedback

Overall, the participants were satisfied with the game and showed eagerness to play it. In most cases, they used calculator and notebook to solve the problems. Either they had a good mathematical background or little maths knowledge, they were all engaged with the questions and tried to find the right answers in a variety of ways. Fig. 9 shows an example of ways used to solve a particular question, using any method convenient and adjusted to their level of knowledge.

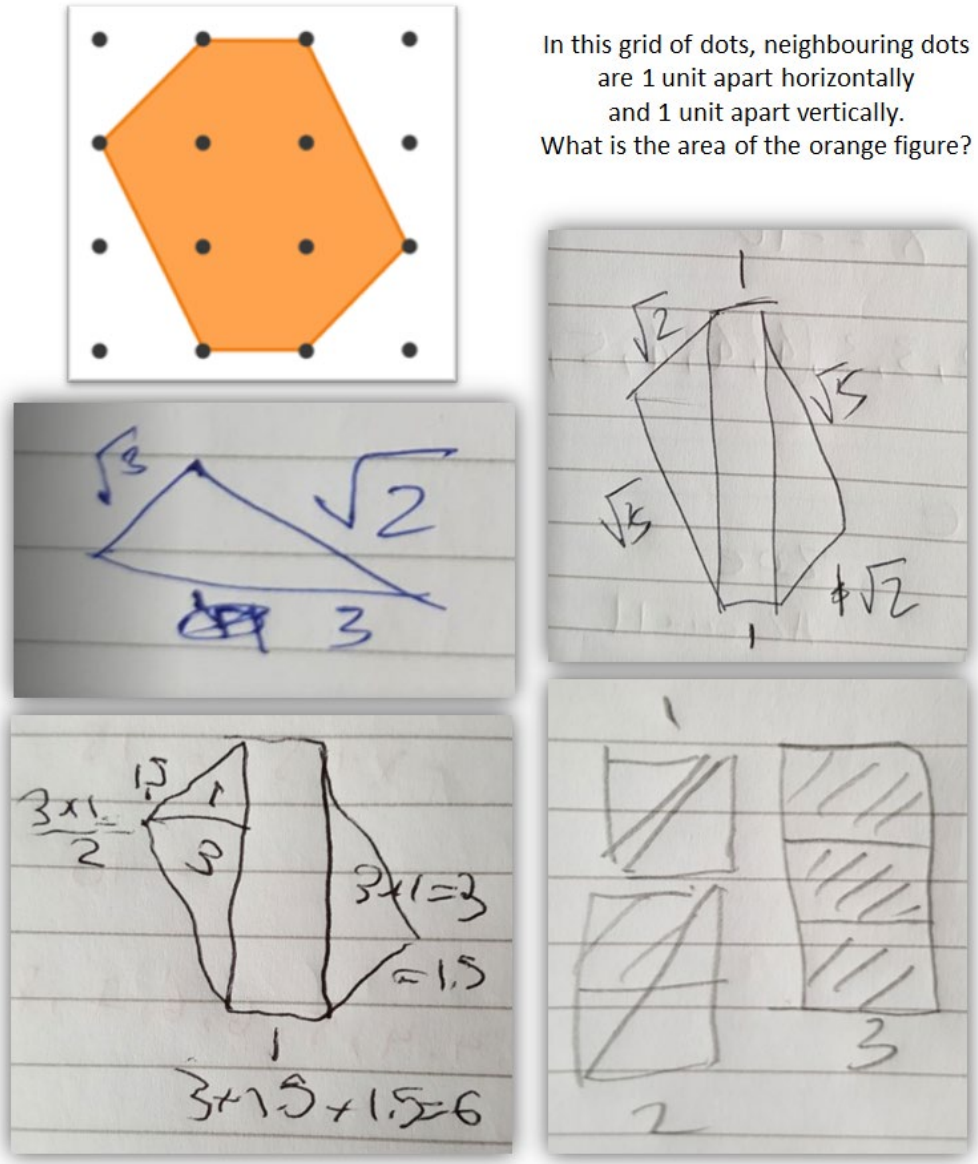

Figure 9: Solving a particular problem using various methods

Remarkably enough, people with a background not relevant to mathematics were particularly eager to understand every maths question. They were using the in-game billboards, google or even asked for explanation. As they stated, the game motivated them to get involved with a field that they were avoiding before.

Conclusion

At the current state, the mathematics integrated into the game are limited. The existing features in the combat and questing systems were simplified in order to test the effectiveness of certain methods. However, the Red Circle demo project provided insights for the built of the wider project in future. Some important outcomes are summarised below:

- The combat mechanics should be revised so that it does not disturb the player's entertainment. If mathematics is to be incorporated into the combat mechanics, it should be in a less complex way which would allow the player to either fight or answer questions, but not both at the same time.

- Mathematics integrated in map exploration and interactive items, like chests, is to be kept and developed further; for example, introducing time constraints and usable rewards following a correct answer.

- The multiple choice wheel function (fig. 5) is to be used but not in combat mechanics. Moreover, the level of the questions could be differentiated as:

    - *Easy*: numeracy and arithmetic questions
      e.g. $2 \times 15 - 8 =$ Possible answers: $A)\ 14, B)\ 22, C)\ 23$
    - *Challenging*: GCSE level algebra
      e.g. $\ln 1 =$ Possible answers: $A)\ 1, B)\ e, C)\ 0$
      $e^0 - 1 =$ Possible answers: $A)\ 0, B)\ e - 1, C)\ -1$

- The quest and story lines can be revised to embed activities and tasks that would indirectly involve the use of mathematics rather than simply ask direct questions. Different landscape areas could be involved with different mathematics topics.

- It was suggested to explore a feature where a teacher, for example, would be given the option to alter the mathematics questions or input new ones to account for their class needs.

Overall, it can be concluded that the Red Circle was an engaging demo game with great potential and could combine mathematics and a virtual fantasy environment into an entertaining experience. Further academic features along with various elements that are essential for fluid gameplay are next in the implementation scope in the future of the game's development.

Developing an online RPG, the future improvements are practically endless and there is plenty of room for creative thinking and innovative ideas. The wider project, however, does not aspire to be yet another commercial mathematics game among the plethora there is in the market. It rather aims to make use of a pre-existing recreational activity and seamlessly embed rigorous academic learning within, such that players are enjoying first and learning simultaneously by default.

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