Play & Learn: Designing Engaging Educational Games for Children

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The use of computer games as common vehicles for education, as opposed to pure entertainment, has gained immense popularity in recent years. In this paper, we investigate the appealing characteristics of engaging computer games for children, and whether embedding these characteristics into an educational tool enhances children's learning. We present the results of an evaluation study done with 120 primary school children over a period of two weeks. The study used an educational tool to teach children numeracy and embedded the characteristics we discovered in the first part of the research. The effectiveness of the educational tool was measured using a pre-test and a post-test, as well as other indicators such as the frequency and duration of time interacting with the tool. The results showed that the modified version of the tool with our features embedded was more effective in enhancing children's learning.

Keywords: Designing Educational tools, Games, Children, Learning, Engagement.

INTRODUCTION

The use of computer games as common vehicles for education, as opposed to pure entertainment, has gained popularity in recent years. Computer games can generate two extremes of reactions, one being their negative impact on society and another being their benefits, especially for enhancing the users' learning. Several studies such as Anderson & Dill (2000) and Walsh et al. (2004) have investigated the negative effects of computer games on children as well as generally on society, especially the effects of the violent themes contained in a large proportion of games. Some of these studies have also looked at the effect of extended periods of game playing on children. Other studies such as Mitchell & Saville-Smith (2004) and Prensky (2001) have looked at the positive outcomes of games when they are used as a source of information. Computer games have intrigued a lot of researchers because of their potential to entice and engage the player's attention for extended periods of time as well as the increased involvement in such games by children.

There are a wide range of computer games available today. A lot of attention has recently been diverted towards the effect of playing games on children's learning. Studies carried out by Fisch (2005) and Chen et al (2011) are two out of the many such studies which have focused on how to achieve positive results for learning by playing games. A key factor which has generated a lot of interest is the capacity of such games to engage the players for extended periods of time.

There are certain attributes of computer games which contribute to how well they are received by the players. Designers of educational tools can integrate these attributes to maximise the tool's effectiveness in increasing learning outcomes, level of engagement and motivation. According to Prensky (2001) a prerequisite of successful learning is motivation. He argues that a lot of what is in the curriculum is not motivating for students these days. Yet the same children are motivated and excited to play video games for long duration. What is notable according to Prensky (2001) is that some children's attitude towards video games is the opposite of the attitude they have towards learning in schools. One way of getting children motivated is to design educational tools which are as engaging and motivating as popular commercial games. These tools can be integrated with the curriculum to enhance children's learning.

The aim of this research project is to extract the dynamics of popular commercial games which are able to engage and motivate players, and utilise those characteristics to create engaging educational tools. Our main research question is "*what are the main characteristics of effective computer games that engage a player for such long periods?*" This paper seeks to explore and examine those characteristics and to design engaging educational tools, based on those characteristics. The proposed educational tools aim to be used in primary school curriculum.

We begin by examining the relevant literature on the characteristics of engaging computer games and collecting opinions of 120 children enrolled in an Auckland primary school, aged between 9-10 years old. We then apply our findings to design an educational tool that addresses those characteristics. We believe our research paves the way for the systematic design and development of full-fledged engaging educational tools.

The remainder of this paper is organized as follows. Section 2 reports on the current literature. Section 3 outlines the research questions followed by methodology in Section 4. The modified game is presented in Section 5. We then describe the evaluation study and the results, followed by conclusions and future work.

RELATED WORK

The use of technology, such as computer games, to enhance student achievement in the classroom is a timely topic that permeates a lot of educational literature today. Video and computer game design have been studied by various researchers interested in finding out how different aspects of the game design could be utilised in developing educational games (e.g., Malone, 1981; Rieber, 1996; Amory, Naicker, Vincent, & Adams,1999; Squire, 2003; Claypool and Claypool, 2005; Dickey, 2006; Dondlinger, 2007; Pinelle et al 2008). The increase in the popularity of computer games and recent developments in information and computer technologies have attracted researchers to investigate the learning benefits of computer games. Van Eck (2006) points out that over the past 25 years there has been a lot of research on how games can be properly utilized for learning. Researchers have been interested in figuring out not just about game functions but what features in games make them work.

There have been a number of studies showing that children's learning increased as a result of playing computer games. Research (e.g., Csikszentmihalyi, 1990; Provost, 1990; Rogoff, 1990) has shown that game playing makes up a vital element of a child's cognitive and social development.

These studies assert that children learn more from playing and carrying out "hands-on" activities than by being simply asked to "recite" information from books. According to Vygotsky (1976), children learn by playing with others, creating and improving their zone of proximal development; as they play, they are more involved in carrying out complex activities. Fisch (2005) has noted that children have learnt about diverse subjects such as prehistory and asthma education by playing computer games. The learning aspect of computer games has been further endorsed by Chen et al (2011). In this study, the researchers proposed a set of design guidelines that can be ideally applied to any game to teach children how to manage their diabetes. The preliminary results of their research showed that users enjoyed playing the game and they believed their knowledge of diabetes increased as a result of playing the game. Other examples of educational and health-related games include Consolvo et al., 2006; Fujiki et al., 2008; Alankus et al., 2010; Berkovsky et al., 2010. A lot of games stimulate thinking and curiosity and the outcome, i.e., the desire to win is what attracts players to playing any game. For any game to be successful, it must be able to engage the player and attract their attention.

Based on our experience, most of the educational games available in New Zealand primary schools are not motivating enough for students. These games lack the fun factor. Children are not as motivated to play these games as they are to play popular computer and video games at home. Most of the games that do exist are usually the basic grill and drill practice models. There is a need to develop useful and instructional computer games, which are relevant to the current New Zealand curriculum and can be integrated in the day to day learning.

In a recent study conducted by Brand (2012), it was discovered that parents are progressively accepting of the notion that using computer games as educational tools. Commissioned by the Interactive Games & Entertainment Association (IGEA), the study found that "79 per cent of parents with children under the age of 18 play video games, and a further 90 per cent of this group do so together with their children" (Brand, 2012, p. 13). This report shows an increase from 2010, when these figures were 63 per cent and 59 per cent, respectively (Brand, 2010, p. 34-35). Furthermore, the report also found "92 per cent of parents believe video games are educational, with three-in-four actively using games as an educational tool with their children" (Brand, 2012, p. 13). These findings show an increase from 2010, when 64 per cent of parents used video games as an education tool (Brand, 2010, p. 35). The report showed that video games are increasingly embraced as teaching tools not only by parents but also by teachers at schools and tertiary environments.

RESEARCH QUESTIONS

Our research questions are as follows:

- What are the main characteristics of effective computer games used to engage a player for such long periods?
- Can adding those characteristics to an educational tool enhance children's learning?

As the first step, we decided to explore those characteristics by collecting feedback from primary school children. We then designed an educational tool based on the feedback we collected.

COLLECTING USERS' INPUT

We selected a group of 120 children aged between 9-10 at Glen Eden Primary School in Auckland, NZ. They were given a questionnaire and were asked to choose 3 features (from a given list) of computer games that they found most appealing.

As shown in Figure 1, the following game attributes were most appealing:

- Challenges (**CH**): having different levels in the game
- Feedback (**FB**): knowing how many points were scored
- Graphics (**GH**): having realistic graphics

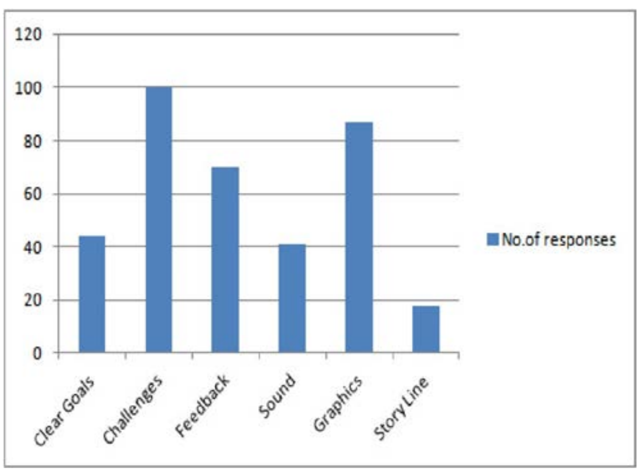


***Figure 1*. Number of responses corresponding to each of the game features surveyed.**

In order to dig deeper into realistic graphics, a further questionnaire was designed and given to children. In this questionnaire children were asked to select three features which stood out for them when describing what realistic graphics were.

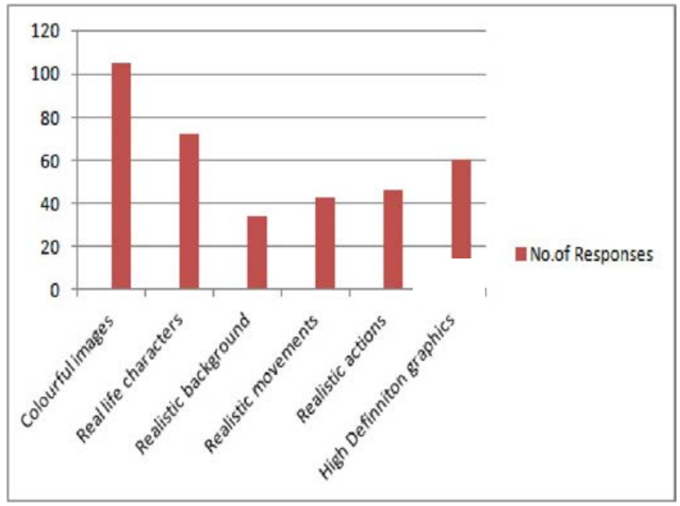


***Figure 2.* Number of responses showing the detailed attributes corresponding to realistic graphics**

As shown in Figure 2, the children identified the following attributes as the three aspects of graphics they liked the most in a game:

- Colorful images
- Real life characters
- High definition

Furthermore, children were asked to select the curriculum area in which they preferred a game to be designed in. The Topics Related part included Science, Social Studies, Technology and Te Reo (Mario language). Results are shown in Figure 3.

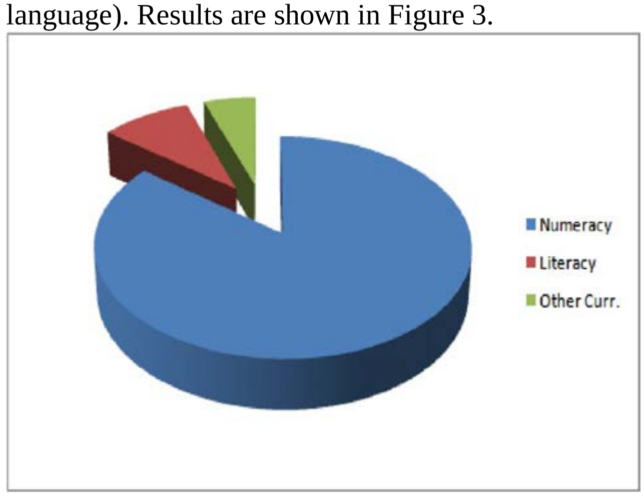


***Figure 3.* Curriculum areas preferred**

As shown above, a vast number of children were interested in playing numeracy games. Some of the reasons given as to why they wanted a numeracy game developed included: *"I want to get better at maths"*, *"I want to learn my multiplication facts"*, *"Learning maths in a game will be a fun way to learn"* and *"I don't like maths so playing a game and learning will be better"*.

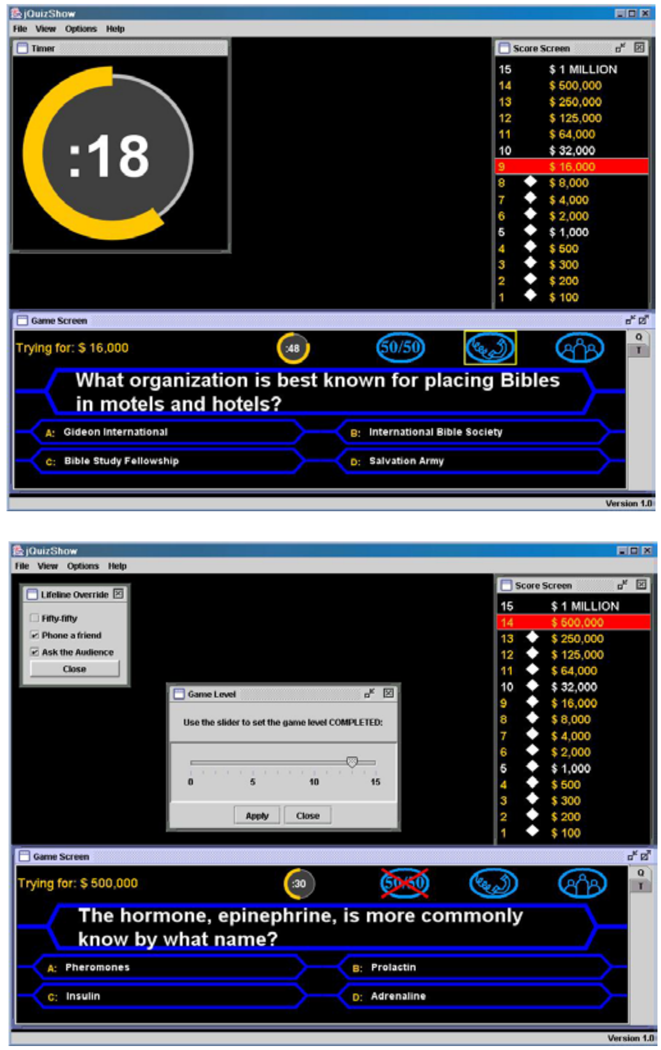
GAME DESIGN

Driven by the three main characteristics identified by the target group and described in the previous section (i.e CH, FB and GH), a variety of open source games were examined. We felt that the Java-based open source game "*Who wants to be a Millionaire*" (http://quizshow.sourceforge.net/download.html) is a suitable option to choose for the preliminary evaluation. It was also identified as one of the games children enjoyed playing, hence modifications were made to incorporate educational features into it.

The game is based on a television game show in which the participants are offered cash prizes for correctly answering a series of multiple-choice questions in the order of increasing difficulty levels. This game can be configured easily to include any content. New content can be added by including the questions at various levels as a text file. Choosing an incorrect answer at any point in the game ends the session, with a feedback message saying the game can be played again from the beginning. Depending on when the incorrect answer is given, the player can leave with either no money or a certain amount. The amount a player can leave with depends on the level reached.

The game designed for this study had three levels indicated by an amount written in white font compared to the rest of the amounts which are written in yellow font (see Figure 4). Once a player passes a level1 indicated by the amounts $1,000, $32,000 and $1 million, the player can leave anytime with the money associated with the highest previous level reached. This applies in both cases: when a player voluntarily chooses to leave the game and/or when the player gets an incorrect answer.

There are five chances for the player to leave with nothing. The first being if he or she were to give a wrong answer before obtaining the first guaranteed amount and the other four being if he/she gets a answer incorrect even before reaching the first level, that is $1000. After reaching $1000, this amount is guaranteed and subsequent questions are played for increasingly large sums (roughly doubling at each turn). The complete sequence of prizes is as follows: $100, $200, $300, $500, $1,000, $2,000, $4,000, $8,000, $16,000, $32,000, $64,000, $125,000, $250,000, $500,000 and $1,000,000. Note that incorrectly answering intermediate level questions, e.g., $4,000, does not enable the player to leave with $4,000, but the last level reached, that is $1,000.



Figures 4a & 4b. **Screenshots from the game "who wants to be a millionaire?"**

For this game, the New Zealand Numeracy Curriculum was used in order to determine the level of question suitable for the children selected for the study. In order for the game to be enjoyable and engaging, it was necessary that the players were given the type of questions of which they had prior knowledge and which were not extremely difficult or "boringly" easy (e.g., a good solution was to provide a progressive level of skills). Their teachers were consulted and the numeracy levels of the children were taken into consideration. It was revealed that the children in the target group were on level 5 according to the New Zealand Numeracy Curriculum. Three levels of questions were therefore developed at level 5 on the following topics:

Level 1: Addition/Subtraction
Level 2: Multiplication/division
Level 3: Combining all the above operations

We developed two versions. The first version was a feature enriched game (**FEG**) which had extensive use of the three identified features (i.e., CH, FB & GH) and the second version, a feature devoid game (**FDG**) had overt absence of these features.

Feedback Feature Implementation (FB)

In order to study the impact of feedback in the game, the feature was used multiple times, almost after every stage in the game. Feedback was implemented using floating dialogue boxes as well as part of the permanent fixture of the game. Apart from the transient feedback, permanent feedback based on the level of question being answered and the amount of money in the bag is provided on the score screen on the top right hand corner of the screen.

The "help" options were in the form of fifty-fifty, phone a friend and ask the audience. These were slightly different to the actual TV game the computer game is based on. The help options were made available using the three icons in figure 4 and their implementation is described as follows:

Fifty-Fifty: The player can choose to have the computer randomly eliminate two of the incorrect answer choices, leaving the player with a choice between the correct answer and an incorrect choice. Based on these two choices, he or she then makes the answer selection.

Phone-A-Friend: Players can ask one out of three pre-arranged friends for an answer. These three friends can be arranged before commencing the game. In the television game, the player can phone one of three pre-arranged friends. Since this not possible in a classroom setting, the player could ask one of three pre-arranged classmates for an answer. The conversation between the friend and the player is timed in the game, with a configurable time, and a value of 60 seconds was used. If the time expires then the game is ended.

Ask the Audience: The player can ask any of their classmates. In the television game, the players get to ask the audience for help. In a classroom setting, we chose to let the players ask any of their classmates. This can involve shouting the question over to a friend in another corner of the room, building up even more excitement in the game.

In the FDG version, feedback was minimal. When a player selects an option, the answer is highlighted with a white box around the answer. If the option selected is correct, then the answer is highlighted again in a basic white colour. A prompt with the dollar amount won is shown next. The player is not given any feedback about what to do next. If a player selects an incorrect answer, then a prompt appears with $0 displayed on it. The player is not informed about what to do next. On the score screen displayed in the top right hand corner of the main screen, the dollar amounts are displayed. There is no indication during the game as to how much the player has won. Also there is no indication of what the guaranteed amounts in the game are. Additionally, the FDG did not have any additional "help" options as in the FEG version, i.e., fifty-fifty, phone a friend or ask the audience.

Challenge Feature Implementation (CH)

In the FEG version, challenge exists in the form of the difficulty level of the questions. The number of levels players can have is configurable and for the purpose of this study three levels were used. Each level contained a set of 5 questions, with level 1 being the easiest set. The game starts with level 1 questions asked 5 times after which $1,000 level is reached in terms of the money earned. At this point $1,000 becomes a guaranteed take-home amount. The next set of 5 questions is then asked from level 2 after which $32,000 becomes a guaranteed take-home amount. Finally, the most difficult set of questions were asked from level 3 after which the player takes home 1 million dollars. The increasing level of difficulty challenges the students to come back and play the game again if they get an answer incorrect in order to achieve a higher level. There is a catalogue of questions stored in the game so that different questions are asked each time a player interacts with the game. New questions can easily be added to the catalogue.

It was difficult to design a version of the game without a challenge feature as the core part of the game is to win increasing amounts of money, which in itself is a challenge feature. However, in the FDG version, the challenge in terms of the difficulty level of the questions was minimised. This was done by randomising the difficulty level of questions instead of a gradual increase. Hence a player could encounter a level 3 (most difficult) question to start with and get a relatively easy question towards the crucial part closer to the end of the game dealing with winning a large sum of money. The randomization of the level of questions was based on the premise that players encountering difficult questions at the start would feel discouraged and abandon the game in the early stages and after a while stop playing altogether. Conversely, players answering a relatively easy question at the point of winning a major prize would not feel the same sense of achievement as they would if they won the same money by answering a difficult question.

Graphics Feature Implementation (GH)

Graphics includes both colour and sound. In terms of colour, the FEG version had a lot of attractive colours in all the parts of the persistent screen as well as the transient dialogues. The main screen has a black background and the questions appear in a blue framed box. The questions are displayed in white font while the optional answers are displayed in yellow font against a black background. When a player selects an answer, this selection gets highlighted in orange. If the option selected is correct, then the correct answer gets highlighted in green. If an option is selected and it is the incorrect option, then the correct answer gets highlighted in green while the incorrect answer remains highlighted in orange. The dollar amounts that appear on the score screen on the top right hand corner of the main screen appear in a yellow font. The guaranteed amounts of $1,000, $32,000 and $1,000,000 appear in a white font. When a player wins an amount of money, this amount is highlighted in bright red. In contrast to the use of the bright colours, the FDG version was done in the two basic colours of black and white.

In terms of sound, there is a soft, continuous background tune played while the FEG version of the game is being played. When a correct answer is selected, a short, high musical note is played to indicate that this is the correct answer. If an answer selected is incorrect, then a short, low musical note is played to indicate that this is the incorrect answer. At the completion of the game, a clapping sound is played to congratulate the player. In the FDG version all music was muted.

EVALUATION STUDY

The study was conducted with 120 children aged between 9-10 at Glen Eden Primary School in Auckland. The participants were divided into a Control group and a Test group of 60 students each. Both groups were pre-tested firstly on the numeracy learning outcomes. The Test group was given the FEG version to play over a period of two weeks and the Control group was given the FDG version to play over two weeks. Both groups were given post tests on the numeracy learning outcome.

Both FEG and FDG versions of the game were installed on the 12 available computers in the school library and as time permitted, pupils in groups of 12 were given the games to play in a separate room with the computers. Both Control and Test groups played at different times and were not able to see what version of game each group was playing. There was a deliberate attempt to keep the two group's playing times separate. The students were allowed to play the game for about 20 minutes without any interference from the researcher or any of the other teachers. At the end of a maximum of 30 minutes the students were stopped and allowed to go back to their classrooms.

ANALYSIS OF THE RESULTS

Measuring children's learning was our main dependent variable. In order to do that, we used a pre-test, post-test and interaction logs. The pre-test was conducted to measure student knowledge before using the educational tool and the post-test was used to measure the learning outcome after using the educational tool. The questions in the tests were similar to the ones used by teachers in assessing their students in numeracy. The pre-test and the post-test for each of the curriculum areas were done using the same questions. This gave us a direct measurement of the change in the learning outcome. The results are reported in Table 1.

Table 1. ***Statistics for the Pre and Post Scores***

Statistic	Control Group		Test Group	
	Pre Test	Post Test	Pre Test	Post Test
Count	60	60	60	60
Average	12.12	12.97	12.87	14.77
Std. Dev.	4.30	4.21	4.55	3.51
Relative Std. Dev. (%)	35.5	32.5	35.4	23.8

As we can see, the average scores have increased after playing both versions of the game. The average for the control group has increased from 12.12 to 12.97 and for the test group, has gone up from 12.87 to 14.77. In addition, the absolute score for these equate to an increase of 0.85 or 7% for the control group and an increase of 1.9 or 14.8% for the test group. Thus, the percentage increase in the mean score is twice as much for the FEG compared to the FDG game. Comparison of the post-test scores for the control and the test groups (12.97 compared to 14.77) also shows that the FEG was more effective in raising the performance level of the students. The T-Test values are 3.63×10^{-10} for the Control group and 1.31×10^{-31} for the Test group. Both values are orders of magnitude smaller than 0.05, showing that the change in the learning outcome (post-test vs. pre-test) was statistically significant for both groups. Additionally, the T-Test value for the Test group is orders of magnitude smaller than the Control group T-Test value, implying a significant effect of the FEG.
Also, as seen in Table 1, the standard deviation figures show a consistent decrease from pre-test to post-test in both Control and Test groups. The standard deviation for the Control group decreased from 4.30 to 4.21 and for the Test group it decreased from 4.55 to 3.51. This shows

that the scores are more closely clustered near the mean; however, the mean has also increased in value. Hence the decrease in the standard deviation value in combination with the increase in the mean value shows that playing the game in between the pre-test and the post-test had the effect of increasing the scores of the participants. The relative changes in the standard deviation values of the control and test groups show that the effect was comparatively more pronounced for the Test group, indicating the effectiveness of the FEG version of the game.

Table 2 shows the average values of some of the other attributes of the experiments that were extracted from the log files. The participants in the Test group attempted more questions in average, provided more correct answers, spent more time playing the game and reached more levels compared with the Control group—this indicates that the FEG version was better utilised compared with the FDG.

Table 2. ***Interaction logs for Test and Control Groups***

	Numeracy	
Av. per participant	Control	Test
No. of participants	60	60
No. of questions attempted	9	11.5
No of correct responses	8	10.5
Time spent playing game (mins)	9.19	10.44
Level reached	1.8	2.3

The bar graph in Figure 5 shows the maximum level reached by the participants instead of the average as shown in the last row of Table 2. These results further illustrate that the game features integrated in the learning tool were effective in achieving better learning outcomes in terms of higher levels of questions attempted between the Control and Test groups. The higher levels attained indicate that the students effectively learned more by being at the learning task for longer. Conversely, the participants in the Control group were not able to progress as much, probably because of lack of motivation.

The results show that the FEG version significantly improved learning outcomes for numeracy—however, it can be even further improved by adapting the game for more fact manipulation or cognitive based curricula.

Cognitive learning is defined as "learning that is concerned with acquisition of problem-solving abilities and with intelligence and conscious thought" (Cognitive Learning, 2012). Numeracy learning is based on problem solving and the game used in this research did not give children an opportunity to practice problem solving skills. To learn mathematics, students must be engaged in exploring, estimating, and thinking rather than recall based learning. Numeracy learning involves understanding the concepts and meanings underlying the operations, as opposed to merely applying rules. So the most important premise of numeracy learning is that when students understand the concepts and reasoning underlying a process, they are more likely to be able to correctly apply that process. This game reinforces previously introduced skills and concepts, but it does not teach players new concepts. Constructivist theorists like Piaget (1970), Vygotsky (1978) and Bruner (1960) assert that when students construct personal knowledge derived from meaningful experiences, they are much more likely to retain and use what they have learned. Hence any learning tool, such as the game designed for this study, should be able to suitably support this.

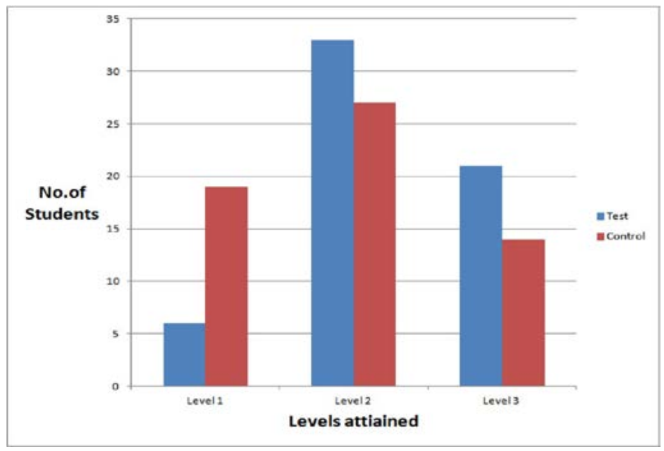


Figure 5. **Maximum Game Levels Attained by Test and Control Group**

CONCLUSION & FUTURE WORK

In this paper we identified the most appealing characteristics of computer games by studying the related literature as well as surveying 120 primary school children. The key features included graphics, feedback and challenge. We then embedded those three characteristics into an educational tool to find out if the modified version could enhance children' learning. A second version with minimal features was used as by the control group.

The results showed that FB, CH and GH features embedded into the learning tool were effective in improving learning outcomes. The main dependent variable used was the amount of learning that took place, measured with the use of pre-test and post-test and user interaction data. The T-Test results on the learning outcome scores also showed that the learning outcome was not achieved by random chance, confirming the effectiveness of the learning tool. The T-Test values for the FEG version were orders of magnitude smaller than the FDG version, although both values were less than the accepted critical value of 0.05, implying that while learning outcomes were influenced by both game versions, the FEG version was more influential.

An immediate future work identified from this study is to adapt the game for more cognitive based learning tasks. Numeracy learning task, for example, involves more fact manipulation operations which involves various intermediate steps in order to arrive at the final answer. The support for such intermediate steps was not fully implemented in the current version used for this study. In addition, a more comprehensive set of questions with intermediate questions can be developed in the game to guide the user to a final answer. It would be interesting to see if the effectiveness of the feature enriched educational tool would also be valid in other scenarios such as for secondary school children and in other curriculum areas. We also plan to conduct a long-term (3-6 months) study to find out if there will be significant increase in learning outcomes and amount of enjoyment as opposed to a two week study.

AUTHOR NOTES

For more information about this research project, please contact Nilufar Baghaei at nbaghaei@unitec.ac.nz

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