

Enhancing Children's Numeracy & Te Reo Skills using Computer Games

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Abstract: The use of computer games as common vehicles for education, as opposed to pure entertainment, has gained immense popularity in recent years. In our earlier work, we investigated the appealing characteristics of engaging computer games for children and designed an educational tool based on those characteristics. In this paper, we present the results of a study conducted with 120 primary school children, in which two versions of our proposed educational tool (features enriched vs feature devoid) were used for four weeks to teach primary school curriculum areas of Numeracy and Te Reo Maori language. The effectiveness of the educational tool was measured using a pre-test and a post-test, as well as other indicators such as subjective analysis, the frequency and duration of time on playing the game. We found that the features enriched game enhanced children's learning in both Numeracy and Te Reo curriculum areas more than the feature devoid version. In the case of Numeracy, the increase in scores was twice as much as the feature devoid version and in the case of Te Reo it was five times as much. Finally, the results of the subjective analysis showed that the feature enriched game was more popular with children – the test group indicated that they enjoyed playing the game more than the participants in the control group and are more likely to recommend it to their friends. The results also showed that the sound effects, the visual effects, the level of challenges in the game and the feedback messages contributed more to their engagement.

Keywords: Learning, games, literacy, numeracy, engagement, children

1. Introduction

The success rate of computer games in engaging children has prompted educational researchers to investigate if similar techniques can be used to engage children with 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 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 with the aim of making them as engaging and motivating as popular commercial games. These tools can be integrated with the curriculum to enhance children's learning.

In our earlier work, we investigated the main characteristics of engaging computer games (i.e. graphics, feedback and challenge) and designed an educational tool with those characteristics embedded into it (Nand et al, 2013). This paper seeks to examine the effectiveness of our proposed educational tool in enhancing students' knowledge of Numeracy and Maori Language – two subjects heavily used in New Zealand primary school curriculum

The remainder of this paper is organised as follows. Section 2 reports on the current literature. Section 3 briefly describes our proposed educational tool. We then present the research questions, evaluation study and the results in Section 4, followed by conclusions and future work.

2. 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; Dondlinger, 2007; Pinelle et al 2008). The increase in the popularity of games and recent developments in information and computer technologies have attracted researchers to investigate the learning benefits of computer games.

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; 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 developments. 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.

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 our previous study, we investigated the main characteristics of computer games used to engage player for a long period of time. We then designed an educational tool based on the feedback we collected.

3. Game Design

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. The following game attributes were most appealing (Nand et al., 2013):

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

The participants were also 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 (Māori language). 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"*.

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 (see Fig. 1). It was also identified as one of the games children enjoyed playing; hence modifications were made to incorporate educational features into it.

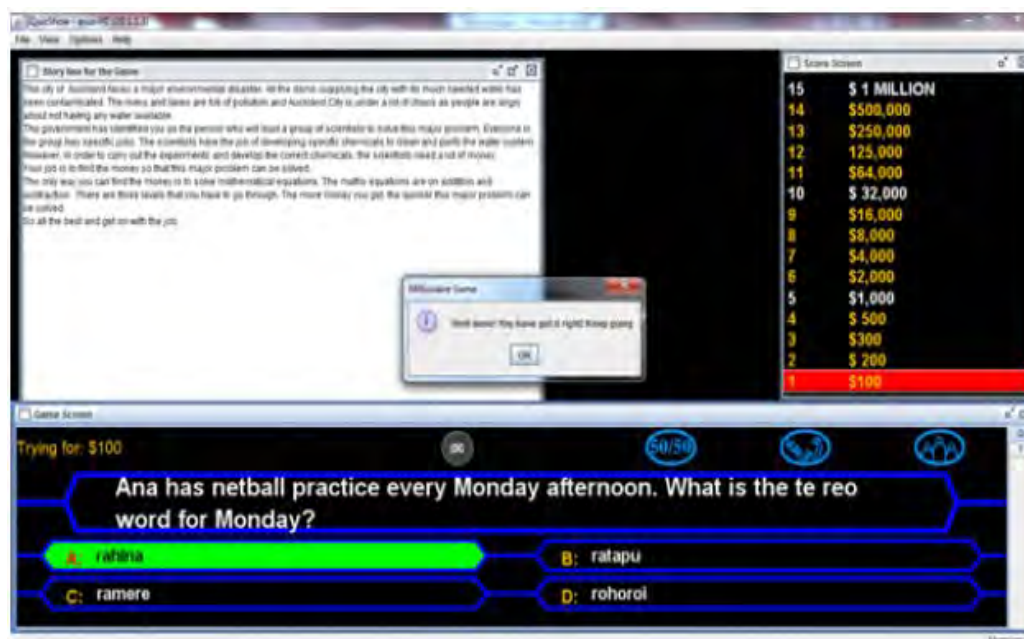


Figure 1. Screenshots from the game “who wants to be a millionaire?”

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 current 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 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 Fig. 1). Once a player passes a level 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.

The two subject areas chosen for this study were Numeracy and Te Reo (Maori language). Numeracy was chosen because a large number of students had identified numeracy in the questionnaire as one of the areas they wanted to play games in. 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. Te Reo (Maori Language) was chosen to be the second subject to teach, since this was an area of learning in which there were very limited educational games. Te Reo is a component of the NZ Primary School curriculum. The teachers of the selected group of students were again consulted to find out what competency level the students were in Te Reo. The questions designed for the Te Reo game were then compiled in line with the children’s competence. The questions were based around identifying everyday items, recalling numbers, naming the colour range, as well as naming the days of the week. The children in the study group were expected to have prior knowledge on these topics. 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. To learn more about the proposed features and how they were integrated into FEG version of the game, refer to our earlier work (Nand et al, 2013).

4. Evaluation Study

Our research questions in this study are as follows: 1) How will the domain of the game (Literacy vs

Numeracy) affect users' learning outcome? 2) Do children enjoy using the proposed educational tool with the embedded characteristics?

The Evaluation study was conducted with 120 children aged 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 groups were then pre-tested on the Te Reo learning outcome. The test group was given the Te Reo FEG version to play over a period of two weeks and the Control group was given the Te Reo FDG version to play over two weeks. Both groups were given post tests on the Te Reo 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.

4.1 Measuring Children's Learning

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 and their knowledge of Maori language. 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 1a: Statistics for the Pre and Post Scores for the Numeracy experiment

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

Table 1b: Statistics for the Pre and Post Scores for the Te Reo experiment

Statistic	Control Group		Test Group	
	Pre Test	Post Test	Pre Test	Post Test
Count	60	60	60	60
Average	8.35	8.85	10.52	14.18
Std. Dev.	3.47	3.41	3.22	3.42
Relative Std. Dev. (%)	41.6	38.6	30.7	24.1

As we can see, the average scores for both domains have increased after playing both versions of the game. For numeracy domain (Table 1a), 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, implying a significant effect of the FEG. The

corresponding figures for the Te Reo game is 0.5 or 6% increase for the control group compared to 3.66 or 34.8% for the test group. This gives us an approximately 6 fold increase in the learning score for the Te Reo experiment. The results in the case of the Te Reo curriculum also show a similar pattern to the Numeracy curriculum, in that the test group performed better compared with the control group.

In addition, the participants in the Test group (for both Numeracy and Te Reo domains) 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.

4.2 Analysis of Post-Game Questionnaire Responses

After playing the FEG and the FDG versions of the game over a period of four weeks, the students were given a questionnaire to fill out in order to collect information about their perception of the game. Figure 2 shows the participants' responses to whether they would recommend the game to their friends. As it can be seen, the students in the Test group were more likely to recommend the game to their friends (38 definitely and 17 possibly). On the other hand, very few students in the Control group were likely to do so (1 definitely and 9 possibly). A little more than half of the students in the Control group (17 not at all and 24 not really) said they would not recommend the game, as opposed to only 1 student in the Test group.

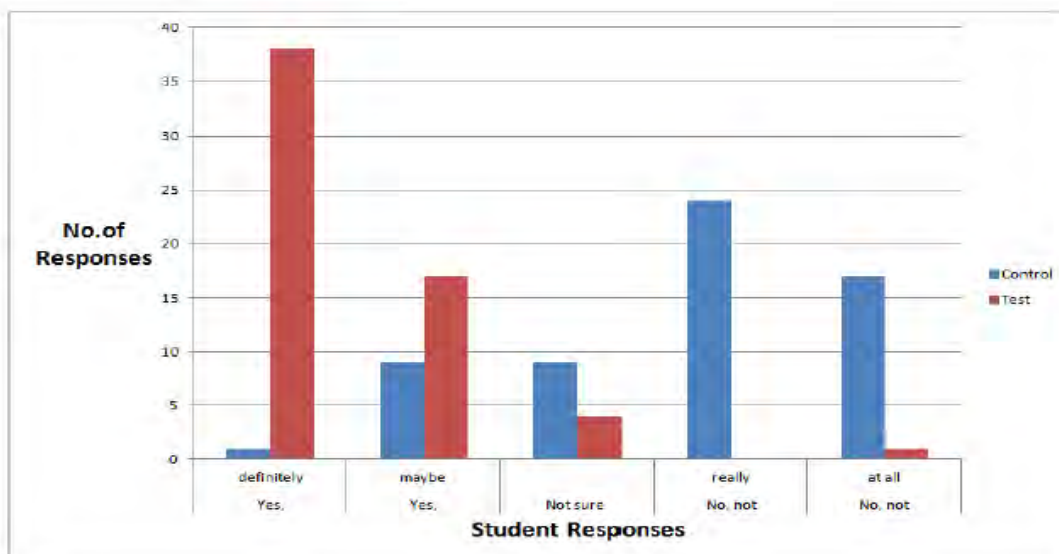


Figure 2. Students' responses to whether they would recommend the game to their friends?

Our results also show that the Test group enjoyed playing the game more than the Control group and was more inclined to want to play the game again. We believe that the presence of the key three features, i.e., the sound & visuals effects, level of challenges in the game and the feedback messages contributed more to their engagement. The FDG version, used by the Control group, was devoid of those features, which resulted in them not wanting to play the game again nor wanting to recommend it to their friends. Moreover, visual observations of students while playing the game showed that the Test group was more engaged and excited with the sound and the graphics compared to the control group. Their expressions and body language demonstrated that they were motivated to keep on playing and they finally had to be stopped at the end of the session. Some of the participants, for example, were shouting in delight when they were given feedback about their answers, smiled and talked to their friend sitting next to them often and shared how they were progressing in the game. On the other hand, the Control group playing the FDG version looked less interested and engaged, and some of them asked if they could leave the session earlier. The game did not seem to hold their attention as they were seen to be fidgeting and their attention seemed to drift from the game to observe what others in the room were doing.

5. Conclusions & Future Work

In this paper, we examined the effectiveness of our educational tool in enhancing students' knowledge of Numeracy and Maori Language, as well as conducting a subjective analysis amongst the participants. The tool is designed based on the characteristics of engaging computer games identified in our previous study, i.e. graphics (GH), feedback (FB) and challenge (CH). We conducted the evaluation study with 120 primary school children aged 9-10, at Glen Eden Primary School in Auckland. 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 results showed that the proposed features embedded into the learning tool were effective in significantly improving learning outcomes. The results of the subject analysis indicated that the Test group enjoyed playing with the game more than the participants in the control group and that the sound effects, the visual effects, the level of challenges and the feedback messages contributed more to their engagement. The test group is also more likely to want to play the game again. We also found that the test group did significantly better when working on the Te Reo questions than Numeracy. The much greater increase in the learning outcome score for Te Reo indicates that the educational tool was especially effective for this curricular. This can be attributed to the difference in the types of learning involved in the two curricula. Te Reo involves fact-based learning where the student is required to learn and recall facts. On the other hand, the Numeracy learning task is based on problem solving; it involves more fact manipulation operations and various intermediate steps in order to arrive at the final answer. The intermediate steps were not fully supported in the current version of the tool designed for this study. In spite of this, the FEG version significantly improved learning outcomes for Numeracy, which can be even further improved by adapting the game for more fact manipulation or cognitive based curricula.

An immediate future work identified from this study is to adapt the game for more cognitive based learning tasks. 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 study to find out if there will be significant increase in learning outcomes and amount of enjoyment as opposed to a two week study. We believe our research paves the way for the systematic design and development of full-fledged engaging educational tools.

References

- Alankus, G., Lazar, A., May, M. and Kelleher, C. Towards Customizable Games for Stroke Rehabilitation. In Proc. Int. Conference on Human Factors in Computing Systems (CHI 2010), ACM Press: Atlanta, GA, USA.
- Chen, G., Baghaei, N., Sarrafzadeh, A., Manford, C., Marshall, S. & Court, G. (2011). Designing games to educate diabetic children. In Proc. Australian Computer-Human Interaction Conference (OZCHI 2011).
- Consolvo, S., Everitt, K., Smith, I., and Landay, J. A. Design Requirements for Technologies that Encourage Physical Activity. In Proc. Int. Conference on Human Factors in Computing Systems (CHI 2006), ACM Press.
- Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal experience*. London: Harper Perennial.
- Dondlinger, M. J. (2007). Educational Video Game Design: A Review of the Literature. *Journal of Applied Educational Technology*, 4(1), 21-31.
- Fisch, S. M. (2005). Making educational computer games "educational". Paper presented at the 2005 Conference on Interaction design and children, Boulder, CO.
- Fujiki, Y., Kazakos, K., Puri, C., Buddharaju, P., Pavlidis, I., and Levine, J. NEAT-o-Games: Blending Physical Activity and Fun in the Daily Routine. *ACM Computers in Entertainment* 6 2(2008).
- Malone, T. W. (1981). Toward a theory of intrinsically motivating instruction. *Cognitive Science*, (4), 333-369.
- Nand, K., Baghaei, N., Casey, J. Play & Learn: Designing Engaging Educational Games for Children. *Int. Journal of Cognitive Technology*, vol. 18, no. 1, 2013.
- Pinelle, D; Wong, N; & Stach, T. (2008) Heuristic Evaluation for Games: Usability Principles for Video Game Design. In M.Czerwinski, A.M. Lund, & D. S. Tan (Eds.): In Proc. Conference on Human Factors in Computing Systems (CHI 2008), ACM: Florence, Italy.
- Premsky, M. (2001). *Digital Game-Based Learning*. McGraw Hill: New York.
- Rogoff, B. (1990). *Apprenticeship in thinking: Cognitive development in social context*. New York, NY: Oxford University Press.
- Vygotsky, L. (1976). Play: It's role in development and evolution, chapter Play and its role in the mental development of the child, pages 537-554. New York, NY: Penguin Books.