Acquisition of Numeracy Knowledge through a Computer Game

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ABSTRACT

The use of technology in teaching and learning mathematics is not new. The view of how technology should be used in the mathematical classroom is affected, among others, by changes in the community. A form of technological tool that is becoming popular in teaching and learning mathematics is the use of technology-based games. Many educators are interested in developing instructional games in Mathematics to engage today's children in a fun way of learning. However, the process required for developing a game that is both engaging and instructionally effective remains elusive. This study aimed to investigate pupils' level of acquisition of numeracy knowledge in a specially developed computer game called Numeraction. The game supports major components in numeracy, namely mental computation, visual thinking and number sense. The game has a response system for recording and displaying the pupils' scores. Participants of this study were 971 pupils from fifteen primary schools in the state of Selangor in Malaysia. Questionnaires were distributed to the students after they played the Numeraction game. Learners' perception in terms of motivation and engagement and their views of the game design were scrutinized. The relationship between their perception (in terms of motivation and engagement) and the level of acquisition of knowledge was also examined. Results showed that 34.2% variations in the acquisition of knowledge from the game were reliably explained from the independent variables, namely the game design, motivation and engagement.

Keywords: *computer game, numeracy knowledge, mathematics*

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BACKGROUND OF THE STUDY

Learners perceive the nature of mathematics differently. Hence, the way they learn and think about Mathematics differs. Their thinking will divert to dealing with operations of numbers if they perceive mathematics to be all about numbers. On the other hand, they challenge themselves to solve problems if they perceive the nature of mathematics as a challenging subject which involves reasoning or thinking. Their perceptions of the nature of mathematics influence their engagement in learning it (Nardi & Steward, 2003). Nevertheless, the learning environment also plays a very important role for learners to be active in the learning process (Aldridge et al, 2000). The learning environment may significantly contribute to children's numerical competence. If their experiences at home and school are directly related to mathematical knowledge, they are well-exposed to the real practices of mathematics that basically involves number sense. The learning environment ensures children's numerical competence is attained and hence, acquisition of mathematical knowledge is achieved (LeFevre et al., 2009).

The use of technology in teaching and learning mathematics is not a new issue. The view of how technology should be used in the mathematical classroom is affected, among others, by changes in the community. Strong expectations from stakeholders in some ways determine the way mathematics is taught in the classroom. Today, with the support of technology, long and complex mathematical calculations described by mathematical structures can be done using various software available. Computer is seen as an agent of change in supporting teaching and learning of mathematics. Moreover, the integration of mathematical content and technology with the learning environment in a manner that enables pupils to do interesting mathematical discoveries is more effective to engage pupils in their learning (Olkun, Altun & Smith, 2005; Teoh, Toh & Nor Azilah, 2010). Technological tools help to stimulate learners' familiarity of the mathematical contents which lead to engagement in the learning environment. Technological tools also increase learners' opportunities to be exposed to social perspective on numeracy through different illustrations and simulations of everyday problems.

A form of technological tool that is becoming popular in teaching and learning mathematics is the use of technology-based games. Results from various studies reveal that using technology-based games in the classroom is beneficial to learners of all ability levels in learning arithmetic skills (Shin et al., 2012). These research recommend that appropriate games with clear objectives and of appropriate level must be selected for target learners and feedback should be provided too. Technology-based games should also be built in ways that stimulate learners' various abilities, such as creativity, problem solving, logical thinking as well as build a positive attitude toward mathematics (Wentwortha & Monro, 2011). The importance of real life illustrations and simulations of mathematical numeracy was pointed out by Nunes, Bryant and Watson (2009). Sullivan, Youdale and Jorgensen (2010) and Sullivan and Gunningham (2011) also emphasise that carefully supported and targeted interventions are important to raise learners' attainment. The engagement helps shape their ideas about the nature of mathematics with an overview of the potential impact on conceptual understanding of mathematics (Brown, Cooney, & Jones, 1990).

Basically, a learning environment that is meaning-focused will elicit learners' motivation. If the effort to develop children into being literate requires semantic and sensory input to support literacy learning process, the effort to develop children into being numeracy literate requires mathematical senses. Developing mathematical senses involves creating mental objects in the mind or the learners' eyes which can be manipulated flexibly. The flexibility of the manipulation develop learners' own understanding of concepts; hence, the environment creates confidence level in the acquisition of the knowledge (Jonassen & Duffy, 1992). The advancement of technology has encouraged pupils' ability in learning. Hence, the development of mathematical knowledge in numeracy is propagated from the technological perspective. Nevertheless, the success of the use of technology to enhance learning depends on the effort to develop well-designed and encouraging learning environment (Lawrenz, Gravely, & Ooms, 2006). This study aimed to investigate pupils' level of engagement and motivation in experiencing the practice of mathematical thinking towards acquisition of the numeracy knowledge through a specially developed computer-based mathematical game. Additionally, the design and usability of the learning environment are pertinent; thus, the research questions are:

1. How do pupils perceive the learning environment design of the technology-based game of numeracy?

2. To what extent can the acquisition of numeracy knowledge be explained by pupils' engagement level, motivation level and perception of the learning environment design?

METHODOLOGY

The purpose of educating pupils to be numerate is focused on their ability and inclination to use mathematics effectively in daily lives (Hogan, Van Wyke & Murcia, 2004; Stoessiger, 2002). Pupils need to identify and use appropriate contextual knowledge to link mathematics to life experiences from different types of mathematical ideas such as number, space, chance and data, algebra and measurement (Hogan, 2000). Thus, the game in this study was designed in the context of daily life situations.

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The goals for the design of the game include enhancement of the development of mental images associated with numbers and developing mental computation process in basic computation involving the four basic operations (addition, subtraction, multiplication and division) among children. It also aims to enhance children's sense of number use in daily life applications. Specifically, Numeraction was specially developed to support the major knowledge components in numeracy, namely mental computation, visual thinking and number sense.

The design of the game emphasizes pupils' speed and precision of getting the answers right. The features of the game were developed from an initial survey among the pupils on their perception of the design of the gaming environment. The game has a response system for recording and displaying the pupils' scores while they were playing the game. In addition, their time spent in the game was recorded. The environment was designed to engage the pupils in practicing and exploring numeracy knowledge.

This study involved a total of 971 pupils from fifteen primary schools in the state of Selangor in Malaysia. The pupils answered a questionnaire distributed after playing Numeraction. Their perceptions of the design of the game, their engagement and motivation as well as acquisition of knowledge were investigated. The main limitation of this study was the measure of perceived acquisition of skills and knowledge rather than testing the users with a separate assessment.

RESULTS

Results of the study provide an insight into pupils' perspectives on the effectiveness of the numeracy gaming software. It explored various constructs such as design of the game, motivation aspect in playing the game, engagement in playing and the acquisition of skills and competence in playing the game. The respondents were asked to rate the constructs based on a five point scale ranging from 1 for Strongly Disagree to 5 for Strongly Agree. Table 1 shows that pupils in this study generally agree about the design of the game. The pupils indicated a high level of agreement that colours and pictures (mean=4.45), the game's beginning and introduction (mean=4.30) and the sound of the music (mean=4.02) used in the Numeraction game were quite interesting. The pupils disagreed with the statements that parts of the game were boring (mean = 2.17) and that the amount of repetitive tasks made the game boring (mean = 1.89).

Table 1: Design of Game

Question	Mean	SD
Q7. I like the colours and the pictures used in the game.	4.45	0.85
Q8. There is something interesting at the beginning of this game that got my attention.	4.30	0.91
Q9. *I thought some parts of this game are boring.	2.17	0.44
Q10.*The amount of repetition of tasks in the game caused me to get bored sometimes.	1.89	0.19
Q11.I like the sound and music in the game.	4.02	0.98

*negative items

Table 2, on the other hand, illustrates motivational aspect in playing the game. Pupils indicated a high level of agreement that the scores on the screen helped them to strive harder (mean = 4.35), they were satisfied with their performance (mean = 4.18), they tried hard (mean = 4.28) and they put in effort as they played the game (mean = 4.11). They somewhat disagreed with the statement that they felt like giving up when they got the wrong or incorrect answers (mean = 2.56). However, the pupils moderately agreed with the statements that their competency level had increased after playing the game (mean = 3.80) and that they felt that it was important for them to do well in the game (mean = 3.82). Finally, this game posed some challenge as they were somewhat unsure if they did better than others (mean = 3.26).

Table 2: Motivation in Playing the Game

Question	Mean	SD
Q12. I am satisfied with my performance in this game.	4.18	0.99
Q13. After playing around with this game for awhile, I felt pretty competent.	3.80	0.93
Q14. The scores on the screen helped me try harder	4.35	0.86
Q15. I tried very hard while playing this game.	4.28	0.89
Q16.* I felt like giving up when I kept getting the answer wrong.	2.56	1.34
Q17. I put a lot of effort into playing this game.	4.11	0.99
Q18. It is important to me to do well in this game.	3.82	1.13
Q19. I think I did pretty well in this game compared to other players.	3.26	1.15
Q20. I would like to play against my friends or classmates.	3.98	1.20

*negative items

Next, Table 3 shows that pupils highly agreed to most of the questions (mean range from 4.07 to 4.49) except for Q24 that this game got them engaged as they played the game (refer to Table 3). They strongly agreed that they enjoyed playing the game (mean = 4.49), found it interesting (mean = 4.39) and put in effort (mean = 4.21) in playing the numeracy game. They also agreed that they would want to play this game over and over again (mean =4.07).

Table 3: Engagement in Playing the Game

Question	Mean	SD
Q21. This game did hold my attention at all time.	4.13	0.94
Q22. I would describe this game as very interesting.	4.39	0.89
Q23. I enjoyed playing this game very much	4.49	0.77
Q24. I lost track of time while playing this game	3.62	1.27
Q25. I put much effort into playing this game.	4.21	.97
Q26. I want to play this game over and over again	4.07	1.08

Table 4 indicates the high level of agreement among the pupils (mean range from 4.20 to 4.59) in terms of acquiring skills and competency by playing the game. They agreed that this game taught them to be quick (mean=4.59) and accurate (mean=4.53) and developed their mathematics skills (mean=4.56). They somewhat disagreed with the statement that they guessed most of the answers (mean=2.82).

Table 4: Acquisition of Skills and Competence in Playing the Game

Question	Mean	SD
Q27.*I guessed most of the answers.	2.82	0.59
Q28. I think the game teaches me to be quick.	4.59	0.79
Q29. I think the game teaches me to be accurate.	4.53	0.74
Q30. I think the game challenges my thinking skills.	4.52	0.79
Q31. I think playing this game could help me develop my Math skills.	4.56	0.76
Q32. I think playing this game could help me with number applications in my daily tasks.	4.20	0.89
Q33. I believe playing this game could be beneficial to me.	4.48	0.83
Q34. I will definitely play this game again.	4.21	0.99

*negative items

A regression analysis was conducted to investigate the relationship between pupils' level of engagement and motivation in experiencing the practice of numeracy mathematical thinking towards their acquisition of the numeracy knowledge. Specifically, the investigation involved a prediction of the percentage of variation in the dependent variable (acquisition of knowledge) from the independent variables (the design, motivation and engagement). The result (Table 5) shows that 34.2% variations in the acquisition of knowledge from the game are reliably explained from the independent variables, namely the design, motivation and engagement.

Table 5: Model Summary for the Regression

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.469[a]	.220	.219	.50549
2	.570[b]	.325	.323	.47046
3	.585[c]	.342	.340	.46451

a. Predictors: (Constant), Motivation

b. Predictors: (Constant), Motivation, Engagement

c. Predictors: (Constant), Motivation, Engagement, Design

The model of the regression is significant since p-value in the testing of the significance of model is less than the level of significance at 0.05 (Table 6). The model is tested significant as further explained by the relationship between the variables.

Table 6: ANOVA[a]

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	104.578	3	34.859	161.561	.000[d]
Residual	200.878	931	.216		
Total	305.456	934			

a. Dependent Variable: Acquisition

b. Predictors: (Constant), Motivation

c. Predictors: (Constant), Motivation, Engagement

d. Predictors: (Constant), Motivation, Engagement, Design

The relationship of the variables is depicted in the regression model. The regression model is illustrated in Table 7. Table 7 shows the regression equation which explains the contribution of different types of variables explicitly known as factors towards the acquisition of numeracy knowledge. The equation is also identified as a model of obtaining the numeracy knowledge in the games with the features of games in terms of design, motivation and engagement. The following is the constructed regression equation or namely, the prescribed model.

The predicted acquisition of knowledge = 1.318+0.322 motivation +0.312 engagement +0.148 design

Table 7: Coefficients[a]

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	Model B	Std. Error	Beta		
(Constant)	1.318	.143		9.221	.000
Motivation	.322	.028	.335	11.690	.000
Engagement	.312	.027	.323	11.606	.000
Design	.148	.030	.140	5.004	.000

a. Dependent Variable: Acquisition

DISCUSSION

Teachers can teach well in mathematics classrooms, but, how effectively teachers can influence learners' motivation in learning is another concern in the teaching and learning of mathematics in classrooms. Kersaint (2007) reveals that learners' perception towards teachers' teaching in classrooms are different when computer games are integrated into the teaching and learning process.

The results of this study showed that the design of the game supported the learners' learning from different perceptions. Among its features were different designs which retained their attention especially when doing the practice in the game even though there was repetition of tasks in the game.

The design of the game motivated learning as illustrated in Table 2. The learners were motivated with the scores they gained in the game and they tried very hard without giving up while playing the game. Even though the learners evaluated a lower scale on the importance of the game (average score of the scale was 3.82) and also being competent (average score of the scale was 3.80), the learners were motivated to try very hard to complete the game because they were competitive to better themselves in their scores. They perceived that the scores offered an evaluation of themselves and that comparison with their friends was less important (average scores of the scales for comparison with their friends and playing against their friends were 3.26 and 3.98 respectively) as compared to their self-satisfaction (average score of their own performance was 4.18).

The pupils' motivation to play the game is shown in the results of their perceptions towards engagement in playing the game (Table 3). The perceived scores were at an average of about 4 points which illustrated positive perceptions of engagement in playing the game. Even though their perception also indicated that they lost track of time while playing, they were well engaged in the learning, as indicated that they enjoyed playing the game (average score of the scale was 4.49) and the game was interesting. Thus, the cause of engagement came from interesting features of the game with its well-designed instructions. The pupils played the game properly as there was low score of agreement that they guessed most of the answers (average score of 2.82). Their competence through the game was shown from their perception that they had learned mathematical skills from the game since the indication of developing mathematical skills was high (average score of the scale was 4.56) and they benefitted from the game (average score of the scale was 4.48). The competence in the skills and knowledge came from the perceptions that they were fast in answering (average score of the scale was 4.59) and in being accurate (average score of the scale was 4.53).

The features of the design as discussed in the results contributed to the cognition enhancement of the learners' acquisition of knowledge in numeracy since the independent variables (design, motivation and engagement) in the regression show significant contribution to the regression equation, namely the model of acquisition of knowledge in mathematics. The results reflect Dede's (1987) findings on the human mind in gaining information and knowledge of the use of non-linear presentations and self-controlled presentations by the user. Dede (1987) reveals that there are three different ways that computer applications assist cognition. The systems are designed in three different ways, namely to simplify related tasks enabling learners to move on building higher level thinking skills, to present information with hypermedia features under the direct control of the learners enabling the information to be portrayed realistically in their mind, and to present artificial realities enabling learners to experience and explore worlds formerly not available in classrooms.

CONCLUSION

This study revealed that a well-thought design of computer-based environment is pertinent to enhance motivation and engage learners in learning. Mathematics is learned through a well-understood and well-practiced environment; hence, more interesting and more features of the game should be included in the design of computer-based learning environment. Learners who are motivated and engaged in their learning in a constructivist computer-based environment always have positive directions in their beliefs and attitudes about knowledge acquisition (Dupagne & Krendl, 1992). Results of this study support the idea that motivation and engagement are the main concerns in a technology-based learning environment. Future research should investigate the suitability of computer-based games in other subject-matter areas.

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