Learning mathematics through computer games

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Abstract: *Since the insurgence of computer games in the 1980s, it created an unstoppable wave that invades the lives of many, in particular, pupils. It is undeniable that pupils spend bulk of their out-of-school hours to play computer games. Though computer games are often perceived as unhealthy and detrimental to the young minds, there are also many studies which indicate otherwise. They advocate and highlight the potential of using computer games as a medium of learning. This paper illustrates an attempt by a primary school in Singapore to explore the viability of learning mathematics through playing commercially produced computer games in an internet café constructed within the school premise. Three different types of computer games namely, simulation, role-play and quest or adventure, were selected for the study. Four pupils spent at least two hours a day over a week period to play all three computer games and separate interview sessions were conducted for each pupil at the end of the week. The focus of the study is to examine, through the three selected computer games, how they (1) serve as possible avenues for the acquisition and application of various mathematical skills and (2) motivate pupils to learn mathematics. Interview results revealed that all four pupils applied some form of mathematical skills or processes, such as reasoning, deduction and pattern looking, while playing the computer games. The benefits and problems faced with employing such a strategy are examined. Recommendations for further work include the need to examine collaboration between educators and game designers.*

1. Introduction

In 2003, the Ministry of Education of Singapore initiated the Innovative and Enterprise (I&E) culture among teachers and pupils in schools to promote the spirit of inquiry, originality in thinking and the willingness to do something differently [8]. Armed with this new mandate, a group of teachers from a local government-aided school decided to erect an internet café right in the heart of the school canteen. The internet café opens every recess and after school hours for pupils to patronize. Inside, they can choose to play from an array of computer games produced commercially. The initial idea of this project was to train pupils from Innovative and Enterprising Club to run the café and through it, inculcate important traits of I&E such as business and financial management among these young minds.

Surprisingly, during the course of operating the café, the teachers discovered the vast potential computer games possess on pupils' learning. Pupils who are normally uninterested in mathematics stayed on task in games that required tedious computations and problem solving. They displayed amazing visual intelligence as they maneuvered their planes through series of bullets and obstacles. Yet such problem solving abilities, perseverance as well as visual skills required in the learning of Mathematics, are seldom exhibited or even non-existent in class. It became clear that if we can harness the potential of computer games in schools, pupils' mathematical ability may improve by leaps and bounce.

2. The Study

2.1 Objective

The objective of this study is to find out the viability of using commercially-produced computer games as a tool for learning mathematics. A typical mathematics classroom in Singapore, driven by quarterly summative formal assessment and tight syllabus coverage, predominately consists of chalk and talk as well as drills and practices. Although attempts are made to infuse more pupil-centered and engaging pedagogical ideas, they are reserved mainly for the lower primary pupils (i.e. Grade 1 and 2). As such, pupils from the upper primary (i.e. Grade 3 to 6) often perceive mathematics as boring. Thus the focus of this study is two-fold, to explore (1) how computer games can serve as possible avenues for the acquisition and application of various mathematical skills and (2) how computer games can motivate pupils in the learning of mathematics.

2.2 Preparation

Pupils' Profile

Many pupils have patronized the internet café since its opening. The objective of this study will be examined through a case-study approach. Four pupils who are active members of the Innovative and Enterprising Club were selected by their teacher-in-charge for this exploratory study. The profile of the four pupils selected is shown in table 1 below.

Table 1: Profile of pupils selected for the study

Pupil	Gender	Grade	*Mathemtics Ability
A	Female	5	Low-ability
B	Female	6	High-ability
C	Male	5	High-ability
D	Male	6	Middle-ability

** According to their 2nd Semestral Examination Marks in Oct 2008.*

The pupils were told to spend approximately two hours a day playing all three computer games selected, after school in the café, for a period of one week. They were required to indicate in a log sheet the amount of time spent playing each day, the computer games they played and the stages or level they attained after the end of each session. An interview session was conducted for each pupil after the week. The following are some guided questions posed to the pupils:

(1) Do you think any of the subjects taught in school relate to the computer games played?
(2) Do you 'find' any mathematics in the computer games played?
(3) Did you employ any mathematical skills, concepts or processes while playing the game?
(4) Do they like to play the three computer games? Why?
(5) Do you think you will enjoy a mathematics lesson conducted using computer games?

Singapore Mathematical Curriculum

In order to determine the 'kind' of mathematics that pupils can possibly learn through playing computer games, references will be made to the Singapore Mathematical Curriculum [1]. Problem Solving is central to mathematics learning in Singapore. It involves the acquisition and application of mathematics concepts and skills in a wide range of situations such as non-routine, open-ended and real-world problems. The development of mathematical problem solving ability is dependent on concepts, skills, processes, attitudes and metacognition. Figure 1 below summarizes the mathematical framework used in Singapore schools.

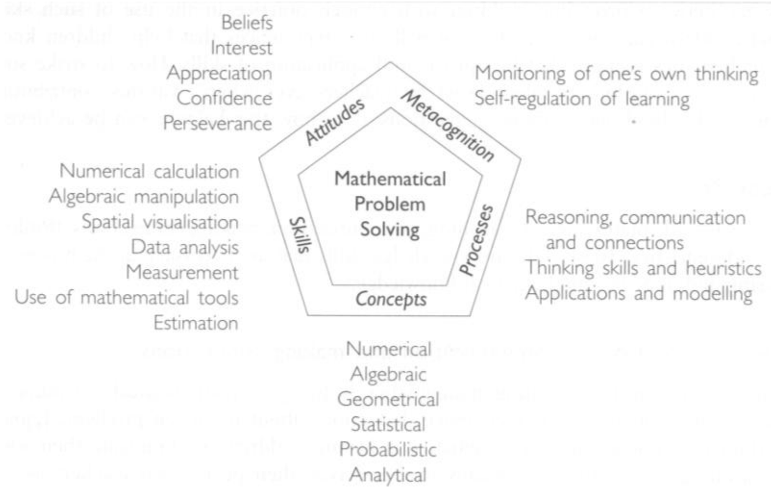


Figure 1 Singapore Mathematics Framework

Part of this study aims to examine if the computer games selected require pupils to apply or acquire, while playing, any of the mathematical skills, concepts, processes as delineated in the framework. If pupils employ any of the above-mentioned, they will deem to have acquired or applied some form of mathematics and thus fulfill the first objective of this study.

3. The computer games

The broad categories of computer games are basically action, adventure/quest, fighting, puzzle, role-play, simulations, sports and strategy games (see [5], [7] and [9]). In this discussion, Pearl Harbour (action, simulation), Zombinis (adventure, quest) and Restaurant Empire (role-play, strategy) were selected because these three computer games cover most of the categories mentioned earlier and are more popular among the pupils. Due to space constraint, only one mathematical learning point from each game will be examined as follows: Restaurant Empire (Skills), Zombinis (Process) and Pearl Harbour (Concept).

3.1 Restaurant Empire (role-play, strategy)

Brief description: The player takes on the role of Armand LeBoeuf who tries to re-establish his uncle's restaurant. He has to set up a restaurant from scratch by renovating the restaurant, hiring staffs, be the main chief and so on. There are different goals and targets at each level of the game e.g. earn a certain amount of money in a month, set up a new branch, participate in a cooking competition etc.

The mathematical skills and concepts identified in Restaurant Empire are shown in table 2 below but only the skill of data analysis under the topic of graph will be examined.

Table 2: Mathematics in Restaurant Empire

Interface in Restaurant Empire	Singapore Mathematics Curriculum		Grade
	Topic	Sub-topic	
Dealing with complains of customer -Price of food too expensive -A particular staff is rude -Food served is cold	• Process – Reasoning • Thinking skills – Identifying patterns and relationships • Heuristics – Guess and check, work backwards		1-6
Profit and Loss statement -Earnings -Expenditure	Percentage	-	5
	Graph	Picture, Bar and Line	1-4
	Measurement	Money	1-4
	Numeracy	Decimal & Four Operations	4-6
Price of each food item	Heuristics – Working backwards		1-6
	Numeracy	Decimal Four Operations	4-6

Responses of pupils

Pupil B relates below, the various representations she saw in the game.

> "Everyday, there will be an overall rating of the restaurant using number of stars. More stars the better."

> "Then there is this line graph. Profit is represented by yellow, other coloured lines for expenses and revenue. So we aim to make sure our yellow line is going up which means we are making a profit."

Figure 2 Rating of restaurant

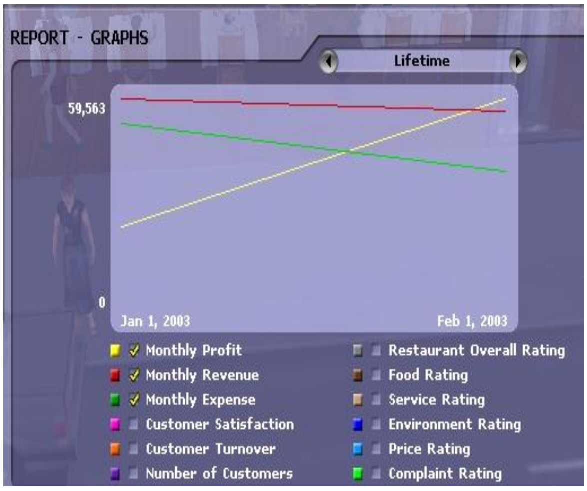


Figure 3 Revenue, expenses and profit line graph

Pupil D identified one more type of graphical representations in the game.

“When I employ someone, I will take a look at their skills. They show using something like a block. The more part of the block is coloured, the higher their skills.”

Figure 4 Skills of potential staff

The three different types of graphical representation illustrated above are basically picture, line and bar graphs that pupils encounter in mathematics lessons. In order to play this game effectively, players are required to read and interpret the data represented and thus apply data analysis skills.

3.2 Pearl Harbour (action, simulation)

Brief description: The player is an allied pilot during WWII. He is supposed to locate enemy strongholds and destroy them while avoiding being shot by enemy warplanes.

The possible concept identified was geometrical (see table 3).

Table 3: Mathematics in Pearl Harbour

Interface in Pearl Harbour	Singapore Mathematics Curriculum		Grade
	Topic	Sub-topic	
Map of the place	Angles	8-point compass	4

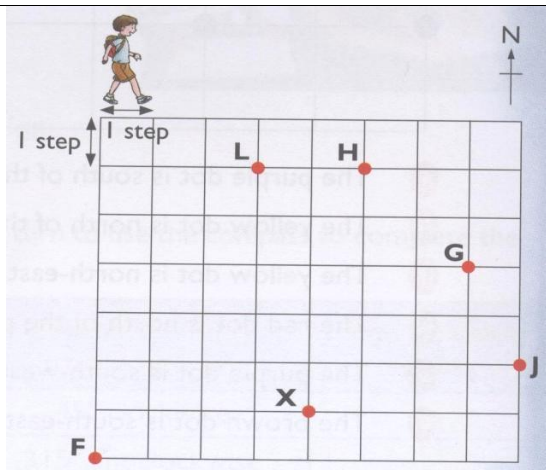
Responses of pupils

Pupil A mentioned that when she heard a siren or when she felt vibrations which are indications that an enemy plane is nearby, she would look at the map provided (see figure 5) to find the location of the enemy in relation to her position.

“the north, south, east, west. They have lines up and down, to tell me where the enemy is.”

In fact, she realised that such map is pretty similar to a particular problem she encountered in mathematics last year (see figure 6).

“like in a graph, a person at a corner and A, B, C, D, she makes a turn and move to this particular place.”

 Figure 5 Map from Pearl Habour	 Figure 6 Problem from My Pals are Here Maths 4A p132

The demands for both the reading of the map in Pearl Harbour and that in the topic of 8-point compass are similar. Pupil has to name and state the four main directions as well as locating or naming a point on a square grid in relation to another point.

3.3 Zoombinis (adventure, quest)

Brief description: The homeland of the Zoombinis was destroyed by dastardly Bloats, leaving only the Zerbles and other wildlife struggling to survive. The player has to create 12 Zoombinis who are responsible of rebuilding their homeland by going through several obstacles.

The mathematical skills and concepts identified in Zoombinis are shown in table 4 below while the respective screen shots are captured in figure 7. The thought processes of the pupils while solving the Secret door shall shed some light on learning in mathematics through this game.

Table 4: Mathematics in Zoombinis

Interface in Zombinis	Singapore Mathematics Curriculum		Grade
	Topic	Sub-topic	
Secret door	Heuristics – Looking for pattern Heuristics – Guess and check		1-6
Pollination	Heuristics – Looking for a pattern Thinking skill - Visualization		1-6
Types of food	Thinking skills – Deduction and comparing		1-6
Producing youngs	Heuristics – Making a list (combinations) Thinking skills – Classifying, Analysing part and whole		1-6

Responses of pupils

Let us take a look at the thought processes of Pupil C when she solved ‘Secret door’.

> "something like reasoning and deduction. For example, one brick at the top with two similar patterns next to each other, you have to find another brick at the bottom with two same shapes side by side."

> "then you make use of what you have found in the first brick to solve another brick, like looking for some patterns e.g. the rectangle represents the eye. Then you use another brick to check to make sure."

Pupil C employed various mathematical processes while playing this stage of Zombinis namely reasoning, deduction and looking for patterns. Mathematical reasoning is a habit of mind that refers to the ability to analyse mathematical situations and construct logical arguments [1]. Many mathematical problems require this process and the example of Pupil C proved that there is a possibility for pupils to apply such processes through computer games as compared to completing mathematical problems in worksheets.

Secret Door

Pollination

Types of Food

Producing youngs

Figure 7 Screen shots of the respective stages in Zombinis

Thus it is not difficult to find non-exhaustive examples in computer games where pupils are required to apply various forms of mathematical skills, concepts or processes. However, it is difficult to assess the other side of the coin, which is the acquisition of mathematics through computer games in this study. The only window that reflected acquisition of mathematics was Pupil C as illustrated below in reference to the Restaurant Empire.

> "I actually learned a hard lesson. I hired the cheapest server. I did not know what the bar beside each hirable staff means and how to read them. And I received a lot of complains from the customers. Then I chose another one with a longer coloured part and it turned out better. So I learnt that the longer the coloured part the better the skill of the server."

Here, Pupil C did not realize that the block is some form of bar graph that shows the level of skill of the staff. But after making a mistake, it dawned upon him the significance of the bar. In a way, he acquired some form of statistical concepts by deciphering the variables (Level of skill and staff) and their relationship.

There are two possible reasons as to why it may appear more difficult to find out the acquisition of learning in mathematics. Firstly, the mathematical skills required in all these three computer games are mostly covered by the time they reach Grade 4 and beyond. And secondly, the subjects selected are from Grade 5 and 6. Perhaps recruiting some pupils from Grade 4 and below may help to give a clearer picture of the acquisition part of this study. Nonetheless, the recommended age for all three games are above 8 years old.

4. Computer games and Motivation

Pupils in the 21st century are not satisfied with just being told about but hunger to learn through questioning, discovery, construction, interaction and fun. Learning through computer games is the timely remedy for them because it engages and interacts.

Engagement refers to the player being put into the game context [9]. Here, the player takes on a new identity where it slowly takes shape and evolves as the player undergoes different events or scenarios depicted in the game which ultimately built on, reify and integrate with the experiences of the player.

Pupil D related it this way:

> "I get to do things I can't do in real-life. Like bombing other people's planes, be a boss of the restaurant, like in World War II, children get to be the commander, they get to see the action, they are the ones who make the action, like you are the one producing a TV show sort of thing."

Furthermore, the structured levels with increasing difficulty whet the player's appetite to crave more of the game. The different-tiered challenges shift the equilibrium causing the player to rethink their old mastery, learn something new, and integrate the new mastery with the old one, thus giving the player a sense of control and power (see [4] and [9]). Like Pupil A, the learning task becomes so meaningful and interesting that player is fully engaged for intrinsic reasons.

> "Children like me right, they will just sit there and do it and do it until they are done with it. They don't want to give up. Because they want to see what's in the next stage. Next stage has a different setting. So they have an aim to move on."

Interaction here refers to that between player and the computer game. When the player acts or makes decisions, the game reacts back and gives the player feedback and new problems. In fact, the player becomes a producer as they co-design the game by their actions taken and decisions made [4]. [11] mentioned that learning proceeds most rapidly when learners have frequent opportunities to apply the ideas they are learning and when feedback on the success and failure of an idea comes almost immediately. The feedback in games comes via action or something happened like Pupil C's example in the recruitment of the server. In fact, such interesting and non-intimidating consequences of failures help enhance learning

Learners are a heterogeneous group comprising of visual, auditory, tactile or kinesthetic. Unlike in a classroom setting where interactions consist mainly auditory, computer games allows for multiple representations simultaneously. Pupil A shared her preference here:

> "Children don't like the colour of paper, black and white only. And then when they play the games, there are colours inside. And some don't like to use their hands, tiring and strenuous to keep writing."

[6] noted that multimedia instruction results in better learning than instruction delivered solely in a single medium because information delivered in multiple ways increases available working memory.

5. Discussion

Similar to other studies (see, [7] and [9]), processes such as problem solving and deductive reasoning as well as skills like numerical calculation and monetary skills are most viable avenues for acquisition and application of mathematics in computer games. In fact, [7] reported that mathematics yielded the highest score from parents when asked which subject knowledge computer games can support. Despite its great educational potential, the use of computer games in the learning of mathematics is hardly explored or employed by educators. In this discussion, two forms of inertia are proposed to explain this phenomenon.

The first inertia is the selection and design of computer games that allow specific content to be included. As educators are not directly involved in the design and production of computer games, they can only select games available in the market. Given the complexity and wide array of games, coupled by a short shelf life, it is an uphill task for educators to choose appropriate computer games that relate well to the specific topic, skill, concept and process that is to be developed. On the other hand, if game designers conscientiously design games that mimic closely to specific content, the computer game may become an edutainment that stem from the Behaviourist theory of drill and practice [2]. In fact, the responses of Pupil D below stated the gist of computer games in learning:

> "I just play the game. Naturally the math just comes out like calculating the thing and you are happy! Not like in school when you are doing math, you are always dull (showed a sad face) and bored. This game (Restaurant Empire), they really concealed their maths well. If this is for children to learn maths, I'll give it a thumbs-up. While playing, I do not know that I'm doing maths. I know I'm doing calculations but I don't feel like I'm doing maths."

Thus the challenge for game designers is to embed the learning of mathematics subtly in a fun way so as to bring out the mathematics in a player unknowingly.

The second inertia like [10], is the correlation of computer games and the specific skills, concepts and processes. It is difficult to disentangle which affects the other. The specific skill or process acquired may be a direct result of extensive play, or conversely, the player plays extensively because he or she is good in that skill, concept or process. Without an ideal way to determine the extent to which a given skill, concept or process is influenced by computer games, further research to justify the use of computer games in the learning of mathematics often come to a halt.

6. Conclusion

Indeed, the numerous educational benefits of computer games may be irrefutable as illustrated in this paper but there are many issues to iron out before we can fully harness the potential of such a tool. The greatest impetus is the tussle between commercialism and education. Most commercially-made computer games are based on some inaccurate, badly designed and often violent themes. The gaming industry is more interested in making money and gaining profit than to spend time, effort and money to design suitable and authentic learning tasks for pupils. However designing suitable learning tasks is not a simple feat. Thus it is necessary for both the educators and game designers to collaborate and recognize the importance and potential of learning through computer games before computer games learning can fulfill its purpose.

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