THE POTENTIAL USE OF GAMING PEDAGOGY TO TEACH MATHEMATICS: CASE STUDIES IN MIRI, SARAWAK, MALAYSIA

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Abstract

This research explores how mathematics pedagogy can be improved by looking at how children are engaged in computer games. Two approaches were considered: (a) the use of computer games, either educational or commercial off-the-shelf (COTS) games, and (b) the use of embodied learning principles of computer games. The feasibility of these approaches was explored by examining the perceptions of students, mathematics teachers and parents along four major themes - mathematics education, technological experience, gaming experience and the use of computer games to learn mathematics. A mixed methods approach was employed in which qualitative interviews [six teachers, eight students and eight parents] and quantitative surveys [total students, n=175] were administered concurrently at two government secondary schools in Miri, Sarawak, Malaysia. Both quantitative and qualitative data were analysed independently and combined in the final interpretation to provide a holistic and consolidated finding.

Data collected from teachers revealed that they gave most attention to the exams, syllabus completion, practice, and would only consider using educational computer games built on drill-and-practice. However, the students described the games as being monotonous and lack complexities. The students claimed that they enjoyed playing COTS games and reported learning of metacognitive skills through the games. Unfortunately, most teachers and parents disregarded COTS games as educational. In addition to that, the lack of infrastructural facilities, low level of computer literacy amongst school teachers as well as the time constraint to complete syllabus suggested the use of educational or COTS games to teach mathematics was deemed to be impractical in schools. All the respondents would still prefer to have teachers teaching in a classroom.

Hence, an alternative option was considered - the use of embodied learning principles of computer games. Identification of good practice in computer games could be used in the mathematics classroom for improvement. Mathematics pedagogy can be improved in three major aspects: (1) mathematics problems should be challenging, enable trial and error, work on bottom-up basic skills, provide instant feedback, and enable learning transfer; (2) classroom activities such as story-telling, role-playing, competition, collaboration and the use of visual aids should be fostered; (3) learning attitude should be changed where mistakes should be seen as opportunities to learn. Here, a more practical mathematics pedagogy is drawn out without overcommitting teachers and it fosters active learning. In this study, the benefits of employing embodied learning principles of computer games in mathematics pedagogy have been seen to be more comprehensive and sustainable in the long-term because it eliminates the possible culture shock, resistance, waste of resources and risk to students' examination performance from using an unproven technology.

Related Publications

The following publications were made during the course of this study:

Yong, S. T., Gates, P. and Harrison, I. (2016). Games and Learning Mathematics: Student, Teacher and Parent Perspectives. *International Journal of Serious Games*, 3 (4). Available at: doi: 10.17083/ijsg.v3i4.112.

Yong, S. T., Harrison, I. and Gates, P. (2016). Using Digital Games to Learn Mathematics – What students think? *International Journal of Serious Games*, 3 (2). Available at: doi: 10.17083/ijsg.v1i4.47.

Yong, S. T., Gates, P. and Harrison, I. (2016). Digital Native Students - Where is the evidence? *The Online Journal of New Horizons in Education*, 6 (1).

Yong, S. T. and Gates, P. (2014). Born Digital: Are They Really Digital Natives? *International Journal of e-Education, e-business, e-Management and e-Learning,* 4 (2), p.102–105. Available at: doi:10.7763/IJEEEE.2014.V4.311.

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List of Abbreviations

4Cs	Challenge, Control, Complexity and Collaboration
AI	Artificial Intelligence
BM	*Bahasa Malaysia* Or Malay Language
COTS	Commercial Off-The-Shelf
DGBL	Digital Game Based Learning
DNAS	Digital Natives Assessment Scale
DOS	Disk Operating System
EPU	Economic Planning Unit
FB	Facebook
GCE	The General Certificate of Education
GPS	Global Positioning System
GTA	Grand Theft Auto
HCI	Human-Computer Interaction
HOTS	Higher Order Thinking Skill
ICT	Information and Communications Technology
IT	Information Technology
KBAT	*Kemahiran Berfikir Aras Tinggi* or Higher Order Thinking Skill
KO	Knock Out
LOTS	Lower Order Thinking Skill
Maths	Mathematics
MIT	The Massachusetts Institute Of Technology
MMORPG	Massively Multiplayer Online Role-Playing Game
MOE	Ministry of Education
MOHE	Ministry of Higher Education
MTAS	Mathematics and Technology Attitudes Scale
NBA	National Basketball Association
OECD	The Organisation for Economic Co-Operation and Development
PISA	Programme for International Student Assessment
PM	Prime Minister
PPSMI	*Pengajaran dan Pembelajaran Sains dan Matematik dalam Bahasa Inggeris* or Teaching and Learning of Science and Mathematics in English
PT3	*Pentaksiran Tingkatan Tiga* or Form Three Assessment
SDT	Self-Determination Theory
SESCO	Sarawak Electricity Supply Corporation
SMS	Short Message Service
SOE	Sony Online Entertainment
SPM	*Sijil Pelajaran Malaysia* or Malaysian Certificate of Education
TIMSS	Trends in International Mathematics and Science Study
TV	Television
UEC	The Unified Examination Certificate
UK	United Kingdom
UNESCO	United Nations Educational, Scientific and Cultural Organisation

UNMC	University of Nottingham Malaysia Campus
UPSR	*Ujian Pencapaian Sekolah Rendah* or Primary School Achievement Test
vs	versus
Wi-Fi	Wireless Fidelity
WoW	World of Warcraft
WWE	World Wrestling Entertainment

Note: Italic – Malay language

Chapter 1: Introduction

1.0 Introduction

This chapter begins with an explanation of why I have an interest in exploring how children engaged in computer games, and how mathematics pedagogy can be learnt through good computer games. After that, I provide a discussion of the background of this study. Besides, this chapter discusses the Malaysian school education system and highlights the need to improve our mathematics education in schools. Subsequently, the research context is discussed, and the rationale and justification for the study are provided. Accordingly, a research question is stated along with the supplementary operational research questions. This chapter then explains the significance of this study. In the final section, the overall organisation of this thesis is discussed.

1.1 About Myself

1.1.1 My PhD Journey

I am a lecturer teaching in Foundation Engineering at The University of Nottingham Malaysia Campus (UNMC) since 2008. Prior to my current employment, I was a lecturer at two private universities in Malaysia. Throughout my 15 years of teaching career, my major expertise has been in Information Technology (IT) and computer programming.

Although I have loved mathematics and computer games since I was young, I have minimal experience in teaching mathematics. My main research interest is mathematics education and computer games, and this has inspired me to explore the potential of combining computer games and traditional mathematics pedagogy.

In July 2010, I was given an opportunity to further my PhD in Engineering at UNMC. After two years of research, I came to realise that my major interest was educational research. Thus, in 2012, I changed my research direction to mathematics education and computer games. I was fortunate to meet a supportive PhD supervisor, Dr. Peter Gates, who shared the same research interest.

Throughout my ten years of PhD journey (where three years were spent at other universities), I have worked under nine PhD supervisors from various disciplines, e.g., in business, marketing, e-commerce, IT, engineering and education. Each of them has given me an invaluable knowledge, experience and guidance. Nonetheless, Dr. Peter Gates has the greatest influence and impact on my research pathway. He has helped me to discover my personal interest and capability in educational research.

In this study, I position myself as a researcher who is interested in how mathematics pedagogy can be improved by looking at how children play computer games. I am looking at mathematics pedagogy from an outsider's perspective because I am not a mathematics educator myself. My position has given me an advantage to look at mathematics pedagogy from a completely different perspective. In this way, an outsider's objective point-of-view is instrumental. I am not confined to the existing mathematics pedagogy in the more conventional classroom teaching. Mathematics educators may be embedded within the contemporary culture of schools, and may be reluctant to take a step back and consider a different approach. A fresh and novel perspective can shed new light and provide new ideas in mathematics pedagogy. I hope I have done that in this thesis.

As someone who has a background in teaching computer programming in an Engineering Department, I tend to look at and write about mathematics pedagogy differently from someone coming from a pure mathematics education background. My writing is more technical in nature because my thinking is greatly influenced by the subject I teach, i.e. logic programming. Knowing my limitations in educational research, this thesis has posed a great challenge to me. Throughout my PhD study, I have tried my best to improve my writing by giving more critical analysis and view of the findings as part of the learning process – as an engineer, this has not always been easy. Furthermore, language barrier is another great challenge for me. English is not my first language and I always find it hard to convey a message precisely and accurately, especially using the language of educational terminologies. Despite years of hard work and struggle, I can only be simple and straightforward in my writing.

1.1.2 My Teaching and Learning Experience

When I was young, I always thought that mathematics was an easy subject. However in one of the Additional Mathematics examinations during my high school, I had failed mathematics for the first time in my life and it was a wake-up call for me. Other than embarrassment and guilt for the failure, I could not explain why I was not able to apply my knowledge during the examination. I was very fortunate to have an excellent teacher who inspired me to love and learn mathematics. Through her proper guidance and advice, I subsequently excelled in mathematics and pursued mathematics education at University level. Throughout my study in university, I found the teaching and learning experience was very dull and boring. I liked mathematics but I did not like education. Even after I had graduated with an honours degree, I had no clear idea of what education was. I only knew education by theories such as Bloom's Taxonomy, Pavlov's experiments with dogs, Skinner's theory of operant conditioning and Gardner's multiple intelligences. For me, education was very abstract with no connection between the learning theories and teaching philosophies in books, and practices. Owing to this misconception, I pursued a master's degree in IT. After graduating in 2002, I started to teach IT at the tertiary level, in several universities and colleges. Since then, I had become a better teacher through the real classroom teaching and learning experience as well as through interactions with students. I came to realise that I was bored with education when I studied at university level because the teaching and learning were not situated within the actual learning context. Consequently, our formal education was out of context.

I had once talked to a mother of a seven-year-old boy. The boy had failed badly in school. She said that her child could not learn merely through reading and memorisation, which were the techniques used by his school. The child could have understood and remembered if he conducted experiments or observed the real life phenomenon. To help her child to learn science, the mother guided the boy to do many experiments at home. For example, to show the formation of rain, she heated a pan of water to show the process of evaporation. The water vapour at the inner side of the lid showed the process of condensation. In another case, to prove that objects would float or sink in water, she demonstrated experiment in the bathroom with a bucket of water and different objects. These examples have shown that schools have taken away children’s curiosity and killed their interest to learn naturally through exploration. For many children, academic knowledge is abstract and disconnected from the real world or real life contexts. If they are expected to read, listen and memorise, it is possible that the abstract nature of knowledge in schools would indirectly kill the children’s innate nature of curiosity towards things around them.

Throughout my teaching career, I have realised that teaching skills need continuous practice and the pedagogical strategy needs to change because students change, as do computer technologies. When I started my teaching career, there was no Facebook, Twitter and YouTube; smartphones and laptops were hardly affordable. Students rarely possessed any electronic gadget other than a cellular phone. Nevertheless, after the booming of smartphone and Facebook in recent years, most of the students possess at least a smartphone due to its affordable price. Advancement in computer technologies has changed how students learn in the class. Students have short attention span, and will access YouTube, play computer games and get connected to social networks (e.g. Facebook) during the class. Students do pay some attention to the lesson in the class, but they like to do multitask to ensure that the time spent is worthwhile. Although I do not support the students' learning behaviour fully, the trend is getting more and more prominent with the passage of time. Being an educator, it makes me wonder how students learn. For instance, what attracts them to computer games? What could we learn from computer games to improve our classroom teaching strategy?

1.2 Background of the Study

The rapid advancements in science and technology have significantly influenced our lifestyles. Today's students are different, and they have changed to become more technology savvy when compare to those of the past.

> *Our students today are all native speakers of the digital language of computers, video games and the Internet* (Prensky, 2001a, p.1).

These students, designated as *Digital Natives*, were born in the digital age and have spent their entire lives immersed in digital technology (Prensky, 2001a). They are used to various types of digital technologies and live much of their lives online – chatting, watching video clips, playing games, writing blogs, surfing the Internet and participating in social media.

However, in schools, computers are hardly used for teaching and learning. For instance, mathematics is often taught using traditional didactic methods primarily in the form of face-to-face lectures, chalk and talk, drill-and-practice and repetition of instructions (Bragg, 2003; Romberg and Kaput, 1999). Many students find traditional methods of mathematics instruction dull, boring and irrelevant (Chang, 2009; Wilkinson *et al.*, 2001; Sedighian, K., & Sedighian, 1996; Venkateshwar Rao, 2016; Jablonka, 2013). However, these students are easily engaged in playing computer games (Chang, 2009; Offenholley, 2011). Digital native students love to play computer games, and it has become a major part of their lives since young (Anderson *et al.*, 2004; Virvou and Katsionis, 2008; Irvine, 2008; Gee, 2007; Beck and Wade, 2006). Apparently, students prefer playing computer games to formal education in schools.

The use of computer games in education is fast becoming a popular trend (Becker, 2007). Past studies have indicated that computer games have been used in learning mathematics (Ke and Grabowski, 2007; Holzinger *et al.*, 2001; Rosas *et al.*, 2003), language (Rosas *et al.*, 2003), history (Natvig and Line, 2004), management (Chua, 2005), biology (Cai *et al.*, 2006), civil engineering (Ebner and Holzinger, 2007), computer knowledge (Papastergiou, 2009), programming (McInerney, 2010), simulation (Wishart, 1990) and sport (Mokka *et al.*, 2003). The popularity of computer games and the motivation they bring should be exploited by educationists to incorporate them into teaching and learning activities.

However, the biggest problem in today's education is the *Digital Immigrant* teachers, who speak an outdated language and assume that students are the same as they have always been (Prensky, 2001a). Today's students have grown up in a digital world where technology is a part of their lives. Their expectation, thinking and learning pattern are influenced by the early exposure to computer technologies. Many teachers, however, find it hard to understand their students. The generation gap is a crucial factor in the alleged decline in students' interest in traditional classroom teaching and learning (Prensky, 2001a). The changes in society, technology and students' learning attitudes are pushing the educators to reconsider and change of teaching approach. One way of doing it is through the use of gaming pedagogy.

> *The theory of learning in good video games fits better with modern, high-tech, global world today's children and teenagers live in than do the theories of learning that they sometimes see in school* (Gee, 2007, p.5).

Thus, it would be meaningful to explore how children learn from computer games, and how it could influence the change in mathematics pedagogy.

1.3 Malaysian Education System

In Malaysia, the education system is regulated by the Ministry of Education (MOE) and the Ministry of Higher Education (MOHE). The school year starts in January until the third week of November and every child is eligible for 11 years of free formal education (i.e. primary and secondary education). The regular national education is depicted in Figure 1.1. There are other educational pathways such as vocational, arts, religious, sport, private and international schools that are beyond the scope of this study. In Malaysia, children start the primary education (i.e. Primary 1) at the age of seven and complete the secondary school education at the age of 17 after taking the Malaysian Certificate of Education Examination (SPM) at the end of Form 5. Form 5 is equivalent to Year 11 in the England's and Wales's educational system and SPM holders are considered to have equivalent academic qualifications to those with the General Certificate of Education Ordinary Level (GCE O-level).

According to the latest national blueprint (Ministry of Education Malaysia, 2012), Malaysia aspires to attain an *excellent* education system within 15 years as measured by The Trends in International Mathematics and Science Study (TIMSS) and The Programme for International Student Assessment (PISA). In the latest TIMSS (2011), Malaysia's performance in mathematics and science slipped below the international average. In TIMMS, Malaysia's average marks for mathematics subject fell from 519 points (1999) to 508 points (2003), 474 points (2007) and 440 points (2011). In the latest PISA (2012), Malaysia also scored below the average of the Organisation for Economic Co-operation and Development (OECD) countries in mathematics, science and reading. Malaysian students recorded an average score of 421 (2012) in mathematics, a slight improvement from the score of 404 (2009+ edition), but still far below the mean score of 494 for OECD countries. Malaysian students did not perform well in mathematics because they were not proficient in three aspects of cognitive skills - knowledge recall, the application of knowledge in solving problems, and the ability to reason in working through problems (Ministry of Education Malaysia, 2012).

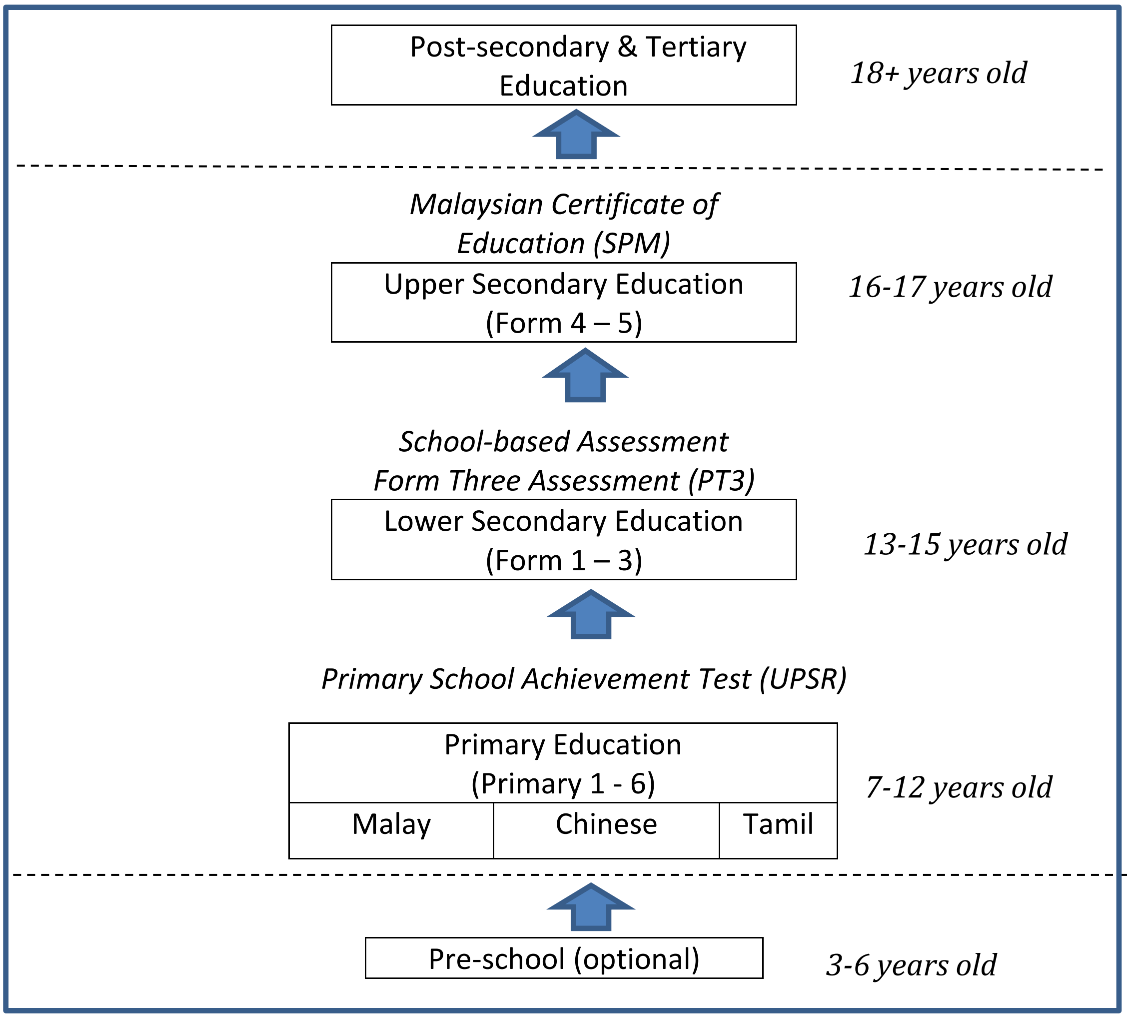

Figure 1.1: Stages of Malaysian Education

The government is very concerned about the students' poor performance in mathematics and is currently investing significantly in this area (Ibrahim, 2015). From 1999 to 2010, the Malaysian government invested approximately RM6 billion promoting the policy of *Teaching and Learning of Science and Mathematics in English* (PPSMI). Although the policy has been phased out, the Malaysian government continues to place great emphasis in learning of science and mathematics. In the latest national education blueprint from 2013 to 2025, it is stated that every child should be literate and numerate (Ministry of Education Malaysia, 2012). In line with the national aspiration of transforming the country into a developed country, it is worth the attention of this study to explore teaching and learning of mathematics in this country.

1.4 Research Context

In this work, two case studies have been conducted in Miri, Sarawak, Malaysia. Miri is a city located at the northern part of Sarawak state in Malaysia. It is one of the 11 administrative divisions of Sarawak with a population of approximately 234 thousand. Miri was originally a fishing village, but has turned into the first oil town in Malaysia with the discovery of oil at Canada Hill in 1910 and its offshore oil in the 1960s.

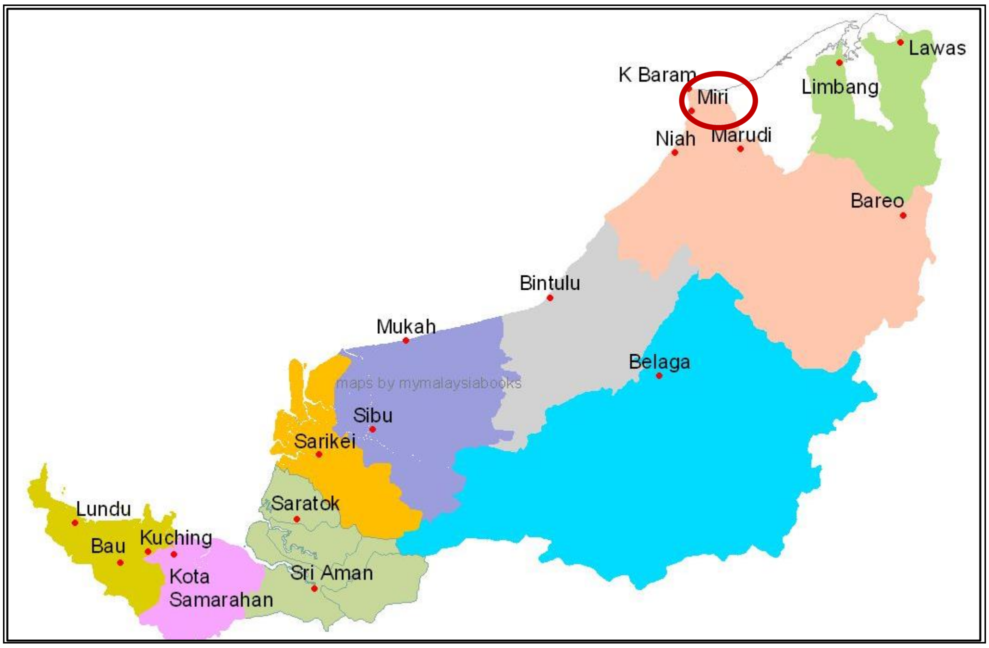

Figure 1.2: Map of Sarawak[1]

Sarawak state is the largest state in Malaysia and located on the island of Borneo. It is a multiracial state with high diversity of languages and cultures as it has more than 40 ethnic groups. Besides the Malay and Chinese, there are numerous indigenous people that include the *Iban, Bidayuh, Baketan, Bisaya, Berawan, Kelabit, Kejaman, Kedayan, Kayan, Kenyah, Lisum, Lun Bawang, Longkiput, Lahanan, Melanau, Punan, Penan, Sekapan, Sihan, Saban, Tagal, Tabun* and *Ukit* (Sarawak Tourism Federation, 2016). Most of the indigenous groups reside in rural areas. Each ethnic group has its own distinct linguistic, lifestyle and cultural background. This makes the Sarawak's demography very dissimilar and unique when compared to the other states in Malaysia.

Sarawak has the largest area of tropical rainforest in comparison to any other state in Malaysia, and it has rich natural resources such as petroleum, natural gas, and timber. However, the state has been reported to be the second poorest state (United Nations, 2011) or the poorest state in Malaysia (Rentap, 2014). The standard of living is causally

[1] Source: http://www.mymalaysiabooks.com/maps/map_of_malaysia.htm

related to the educational attainment and occupation hierarchy. In Sarawak, 31.9% of the labour force has no formal education or only completed primary education, and these people are mostly working as agricultural or elementary workers (Tawie, 2013). According to the MOE (2012), Sarawak is one of the lowest-performing states in the national examinations (i.e. UPSR and SPM). Every year, approximately 8,500 students in the state failed to complete their secondary school education and so add to the number of lowly-educated members of Sarawak workforce (Ong, 2016). Worse still, 25.6% of indigenous children live in poverty (United Nations, 2011) and most likely drop out of formal education. In the latest statistics released by Malaysian Department of Statistics (2013), Sarawak has the lowest literacy rate in the country. Poverty is the cause and effect of insufficient access to quality education. Apparently, education is one way to fight and prevent the transmission of poverty between generations (UNESCO, 2016).

Consequently, it is meaningful to explore how the education in the state can be improved. Two secondary schools in Miri, Sarawak have been chosen for my case studies. Miri is the first city in Sarawak moving towards the digital age. Miri was declared as a Wi-Fi City on January 10, 2008, in an effort to enhance connectivity in Sarawak (Borneo Post Online, 2010; Mohd Yassin, 2010). Technology has profoundly changed education in many ways and connectivity can expand the access to education, social network, and the Internet as well as computer games. Thus, to explore the potential use of gaming pedagogy in teaching mathematics, it is important to explore the feasibility of the pedagogy in these schools. If the finding of this study indicates a negative outcome, then it is unlikely that the idea of using gaming pedagogy to teach mathematics is appropriate for other schools in Sarawak and further afield in Malaysia.

In Sarawak, students are classified as boarders and day scholars since some students live too far away from schools and they are unable to travel to schools every day. The first selected school (M1) has a combination of boarders and day scholars; the second school (M2) has only school boarders. The names of the schools are kept anonymous due to ethical consideration. Pseudonyms are used to protect the confidentiality and privacy of the schools and research participants.

1.4.1 M1 School

M1 School has 36 classes in operation, 85 teachers, 20 support staff and 876 students ranging from 13 to 19 years old. M1 School is a high performing school as it continues to maintain a high ranking for the performance in public examinations (e.g. SPM) in the Sarawak State.

1.4.2 M2 School

M2 School has 47 teachers and 422 students ranging from 13 to 17 years old. The school is a high performing school and is classified as *Smart School*. The *Smart School* policy is the government's aspiration to utilise technology in the teaching and learning activities.

1.5 Research objective and questions

This study aims to explore the potential to improve the quality in teaching and learning that can be brought about by computer games. The main purpose of this study is to explore the potential use of gaming pedagogy to teach mathematics at two secondary schools in Miri, Sarawak, Malaysia. Gaming pedagogy is defined as:

> *An educational philosophy, style and approach to promoting learning in educational contexts through the use of video games, non-digital games, the embodied learning principles and techniques of games, and gamification (IGI Global, 2016; von Gillern, 2016).*

In this study, the gaming pedagogy is confined to the use of computer games, and the use of embodied learning principles of computer games. The research question addressed in this study is:

> *How can mathematics pedagogy be influenced by an understanding of children's engagement with computer games?*

To explore how computer games can influence mathematics pedagogy, two possible pedagogical changes have been studied: (a) the direct or informal learning of mathematics through computer games and (b) the learning of mathematics through the embodied learning principles of computer games. In option (a), educational computer games (i.e. direct learning) and commercial off-the-shelf (COTS) games (i.e. informal learning) have been considered. In option (b), the good theory of learning in computer games has been considered.

This study has employed a mixed methods approach: (1) survey of students, (2) interview with teachers, students and parents. It should be noted that the research question is not meant to be answered by the research participants. In fact, it is my role as a researcher to respond to the research question by asking other questions that provide insights and indicators allowing the answer to be formulated. Operational research questions derived from the research question have been used to govern the research process. These questions are stated below.

1. What are students', parents' and teachers' perceptions towards mathematics education?
2. What are students', parents' and teachers' technological experiences?
3. What are students', parents' and teachers' gaming experiences?
4. What are students', parents' and teachers' perceptions of the use of educational games to learn mathematics?
5. How do children learn through computer games? What transfer issues are there?

The operational or empirical questions have helped to identify the data needed from the research participants. In this study, data about children's engagement in games is drawn from the literature so no experiment has been conducted in this area.

1.6 Significance of the Study

The findings of this study will provide a useful understanding of the potential use of gaming pedagogy in learning mathematics in Malaysian secondary schools. By examining the views and perceptions of teachers, students, and parents, this study could provide insights into the concerns and attitudes of different groups of respondents. This study also provides some recommendations and approaches that educators can adopt to meet the challenges and demands of the current generation of students. In other words, this study can help teachers to look at gaming pedagogy from a different lens – the use of embodied learning principles rather than the use of computer games. This study hopes to foster the policy maker's awareness to evaluate, revise and make appropriate changes to their role in promoting a better education system that is on par with the rest of the world.

1.7 Organisation of the Thesis

There are nine chapters in this thesis. The structure of the thesis is explained in brief in the following order.

Chapter 1 gives a general *introduction* to this study. This chapter contains the background to the research with an emphasis on how the current generation of students learn and how the national curriculum may bring impact upon the learning of mathematics. A brief overview of the background of the study, the Malaysian education system, research context, aims and the significance of this study are presented in this chapter.

Chapter 2 is the *literature review*. This chapter presents findings of literature reviews and evaluations of various issues surrounding the topic under investigation. The literature review is used to identify the premise and concepts of mathematics learning, motivation, digital game-based learning (DGBL), educational gaming model, playful learning and learning theories in computer games. Some research articles and journals have been reviewed to direct the development of this study.

Chapter 3 is the *methodology.* This chapter first reviews the existing definitions of mixed methods research that are used as a guideline to design this research methodology. Also included in this section is the rationale for adopting a mixed methods approach. Then, the paradigm worldview guiding the research is discussed before considering the theoretical lens, methodological approach and data collection methods. After that, a discussion of the plan to collect quantitative and qualitative data is provided that includes details of the various data gathering tools and sampling used for the research.

Chapter 4 is the *data collection.* This chapter highlights the three stages of data collection - before, during and after the data collection. This chapter first discusses the preparation for data collection, mainly regarding the development of data gathering tools, access to the schools and ethical concerns pertaining to the research participants and the overall research practice. Thereafter, a discussion of the data collection is provided, which details the collection of quantitative and qualitative data in two schools. Finally, the chapter explains the process of transcription and translation of data collected, and how the data will be analysed.

Chapters 5 and 7 are the *analysis of teachers' and parents' interviews.* These chapters direct a focus on the findings and analysis of the various issues and themes brought forward by mathematics teachers and parents on the potential use of computer games in learning mathematics. The findings generated from this qualitative aspect of the study are compared in relation to existing literature on how children learn from computer games. Issues about mathematics education, teachers' and parents' proficiency in computer technologies and computer games are also discussed.

Chapter 6 is the *analysis of students' surveys and interviews.* This chapter presents views and perceptions that have been highlighted by individual students during interviews on the potential use of computer games in learning mathematics. The survey provides a general opinion on this issue. The findings generated from these qualitative and quantitative aspects of the study are also compared to existing literature on how children learn from computer games. Issues about mathematics learning and students' proficiency in computer technologies and computer games are also discussed and addressed.

Chapter 8 is the *A-Chronological Findings: Gaming in Mathematics Learning.* This chapter extends the discussion further and explores three viewpoints of gaming pedagogy – practice in educational computer games, learning of implicit skills through COTS games and a theoretical model of gaming pedagogy that emerged from the data analysis. Finally, the chapter gives recommendations on how to push the gaming pedagogy into mathematics classroom learning.

Chapter 9 is the *Conclusion and Future Research*. This chapter contains the discussion of the key findings and predominant themes generated from the data analysis pertaining to the research questions. The theoretical implications, limitations of this study, suggestions for future research and final thoughts are reflected in this final chapter.

Chapter 2: Literature Review

2.0 Introduction

Mathematics is exciting and challenging. However, children tend to be negative, less motivated towards mathematics and not confident in solving complex and complicated mathematical problems (Kislenko, 2006; Awanta, 2009; Fan *et al.*, 2005). Despite this, children are drawn to and able to solve sophisticated problems in computer games (Papert, 1998; Prensky, 2001c). It would be interesting and meaningful to look at how these games *engage* players in addressing various problems in games. This study investigates how mathematics pedagogy can be influenced by an understanding of children's engagement with computer games. It is important to look at the essential skills required in mathematics problem-solving.

This chapter focuses on mathematics learning and what computer games can teach us about learning. The chapter is organised into seven sections. Section 1 discusses mathematics learning from different domains needed in problem-solving. Section 2 explains why computer games should be used in today's classroom teaching and justifies how the technological advancements have changed the current young generation who is also labelled as the game generation. Section 3 focuses on different approaches to DGBL. Section 4 explains the benefits of play and playful learning. Section 5 discusses how digital games are embraced in different well-established learning theories. Section 6 discusses what motivates children to engage in computer games, and how these motivation elements may be useful for a potential change in mathematics pedagogy in future. Finally, the last section discusses the different generations of educational computer games.

2.1 Mathematics Learning

For centuries, mathematics has been a highly respected discipline in education and is crucial in many fields of study including engineering, science, business and computer science.

> *Proficiency in mathematics is a strong predictor of positive outcomes for young adults, influencing their ability to participate in post-secondary education and their expected future earnings* (PISA, 2012, p.6).

Problem-solving plays a significant role in mathematics education since it requires a proper understanding and manipulation of various complex thinking skills. For example, considering the case of a student attempting to learn *Pythagoras' Theorem*, the theorem can be applied to find the hypotenuse of a right-angled triangle given the length of the other two sides. In a right-angled triangle, the square of the hypotenuse is equal to the sum of the squares of the other two sides. A student who is good at memorisation could compute the hypotenuse of a new right-angled triangle if he or she has sufficient routine practice of the past examples. However, Pythagoras' Theorem is not just about computing the hypotenuse of a right-angled triangle. The theorem specifies the fundamental geometrical relation between the three sides of a right-angled triangle. A student who learns to compute the hypotenuse of a right-angled triangle through a routine practice may not understand the significance of this geometrical relation in Pythagoras' Theorem. The student could be unable to apply the theorem and answer whether a triangle has a right angle when the three sides (length) are given.

Mathematics problem-solving is not simply the application of formula and model answer. It requires associated thinking, strategies and motivation. Given a mathematics question, if someone can simply retrieve an immediate answer from memory, then there is no problem (Sternberg *et al.*, 2012). Problem-solving skill is required when we need to overcome obstacles to achieve a goal (Sternberg *et al.*, 2012). Problem-solving in mathematics depends on three broad domains: (1) cognitive, (2) metacognitive or metacognition, and (3) affective or motivation (Ke, 2008a, 2009). Similarly, these three domains can be defined as skill, metaskill and will (Mayer, 1998).

> *Skill is domain-specific knowledge relevant to the problem-solving task; metaskill is strategies for how to use the knowledge in problem-solving; and will is feelings and beliefs about one's interest and ability to solve the problems* (Mayer, 1998, p.61).

Skill, metaskill and will play significant roles in the success of problem-solving in academic settings (Mayer, 1998). Despite many different terms that have been used in the literature, cognitive, metacognition and affective will be used in the following sections.

2.1.1 Cognitive

Cognitive is mental cognition on content (Moghadam and Fard, 2012) and cognitive psychology is

> *the study of how people perceive, learn, remember, and think about information* (Sternberg *et al.*, 2012, p.3).

Cognitive psychology is a huge area of study, and one of the foci is problem-solving (Sternberg *et al.*, 2012). Problem-solving is one of the fundamental human cognitive or thinking processes. One way to improve cognitive skills is to teach each basic skill in problem-solving to mastery (Mayer, 1998). Cognitive skills required for mathematics problem-solving include: (1) *instructional objectives* – large task is broken down into a collection of *instructional objectives* and each objective is a single skill; (2) *learning hierarchies* – task analysis that yields a hierarchy of subtasks whereby students carry out the simpler computational procedures before moving to the more difficult ones; (3) *components analysis* – a reasoning task is broken down into basic cognitive processes (Mayer, 1998).

There are a few approaches to mathematics problem-solving (Yimer and Ellerton, 2006; Mayer, 1998; Sternberg *et al.*, 2012; Lazakidou and Retalis, 2010; Schoenfeld, 1985) and all the approaches are fundamentally built on the four-stage model of Polya (1945) - (1) understand the problem, (2) devise a plan, (3) carry out the plan and (4) look back.

a. Stage 1 - Understand the Problem

At this stage, a problem solver has to understand clearly what is required (Polya, 1945). The approach to problem-solving depends on how people understand the problem (Sternberg *et al.*, 2012). Students' interest to solve a problem is important, and the question should be natural, interesting and not too difficult or too easy (Polya, 1945). According to Mayer (1998), a boring task cannot be made interesting by adding a few interesting details to increase emotional interest (e.g. arousal and excitement). Instead, motivation should be based on intellectual interest (e.g. make sense out of the task).

b. Stage 2 - Devising a Plan

At this stage, a problem solver has to plan at least in outline, which calculations, computation or constructions to be performed in order to obtain the unknown (Polya, 1945). A plan is how various items are connected and how the unknown is linked to the data to obtain the idea towards the solution. Problem solvers should try to think and relate a familiar problem having the same or similar unknown that they have solved before (Polya, 1945). This is a metacognitive skill, also known as *intellectual behaviour* (Schoenfeld, 1987).

c. Stage 3 - Carrying out the Plan

A plan is a general outline and the problem solver has to be convinced that the details fit into the outline (Polya, 1945). A problem solver should control and self-regulate to keep track and carry out the plan. These metacognitive skills are also classified as *metacognitive control* (Kleitman and Stankov, 2007), *regulation of cognition* (Ozsoy and Ataman, 2009) or *metacognitive regulation* (Schraw, 1998).

d. Stage 4 - Looking Back

By reconsidering and re-examining the complete solutions, problem solvers could consolidate their knowledge (Polya, 1945, p.15). Many mistakes in the calculation (e.g. wrong arguments or method) can be avoided by having a detailed plan. However, mistakes are inevitable. In this case, metacognitive skills are required. Poor metacognitive skill may lead to failure in providing accurate reflection and evaluation of effective learning (Yimer and Ellerton, 2006).

Apparently, the use of the four-stage model of Polya's (1945) alone does not automatically lead to a solution of a mathematics problem (Orton, 2004). Problem-solving requires metacognitive skills. Routine problem-solving can be applied by using a drill-and-practice method of instruction. However, students continue to struggle with non-routine problem-solving that requires metacognitive skills (Mayer, 1998).

2.1.2 Metacognition

a. Metacognitive Skill

Metacognition or metacognitive is the second-level mental operation (Moghadam and Fard, 2012). Metacognitive is defined as follows.

> *Knowledge and cognition about cognitive phenomena* (Flavell, 1979, p.906)*;*

Following the original definition given by Flavell (1979), multiple definitions are given in the literature (Biryukov, 2004; Moghadam and Fard, 2012; Kleitman and Stankov, 2007; Sternberg *et al.*, 2012). An overview of these definitions clearly demonstrates that metacognitive is the awareness of one's thinking, and assessment of one's own ability to think and control one's cognitive processes. In brief, metacognitive is *thinking* about *thinking*.

Metacognitive knowledge and metacognitive skill are two of the metacognitive components (Flavell, 1979; Biryukov, 2004; Kleitman and Stankov, 2007; Ozsoy and Ataman, 2009; Schraw, 1998; Schoenfeld, 1987). Metacognitive knowledge is knowledge about one's thought processes, for instance, how accurate are you in describing your thinking? (Schoenfeld, 1987).

> *Metacognitive knowledge is one's knowledge and beliefs in his mental resources and his awareness about what to do* (Ozsoy and Ataman, 2009, p.68).

Other definitions of metacognitive knowledge include awareness about what one knows (Biryukov, 2004) such as strategies, knowledge, processes, techniques and ideas (Ozsoy and Ataman, 2009); or knowledge about one's cognitive processes such as how, when and why certain strategies are used (Kleitman and Stankov, 2007). *Metacognitive skills* are what one can do (Biryukov, 2004) or

> *knowledge of when to use, how to coordinate, and how to monitor various skills in problem-solving* (Mayer, 1998, p.53).

Metacognitive skill includes *control* aspect of learning (Kleitman and Stankov, 2007) and regulation of cognition (Ozsoy and Ataman, 2009). The regulation of cognition involves: (1) *planning* and *prediction* – selection of appropriate strategies and allocation of cognitive resources before the task (e.g. making predictions before reading, strategy sequencing, and allocating time or attention selectively before beginning a task); (2) *monitoring* – awareness of one's understanding and performance during the task (e.g. ability to engage in periodic self-testing while learning); (3) *evaluatin*g – appraising the performance and efficiency after task completion (e.g. re-evaluating one's goals and conclusions) (Schraw, 1998; Ozsoy and Ataman, 2009).

Metacognitive skill will be discussed further in the following section because it is an essential skill in mathematics problem-solving. Metacognitive skill enables a problem solver to analyse the problem, select an appropriate strategy to address the problem from an array of possible alternatives, and monitor the problem-solving process to ensure that it is carried out correctly.

b. Metacognitive skill in problem-solving

Problem-solving involves a strong connection between cognitive and metacognitive skills. The term *cognitive-metacognitive* shows the interdependence of cognitive and metacognitive skills, and indicates the importance of metacognitive behaviour in every phase of mathematics problem-solving to attain a solution (Yimer and Ellerton, 2006). Although cognitive skill is important, a sole focus on cognitive skill is insufficient as the problem solver requires metacognitive thinking (Mayer, 1998; Yimer and Ellerton, 2006; Ozsoy and Ataman, 2009). Efficient use of the cognitive content is possible only through metacognitive skills (Ozsoy and Ataman, 2009). Problem solvers may master the basic cognitive skills, but fail to apply what they have learned to a new situation (failure in problem-solving transfer) as they may not have the ability to organise and control the basic skills in solving a higher-level task (Mayer, 1998). Cognitive and metacognitive strategies work well together in attaining the solution of mathematical problems.

Metacognitive skill plays a significant role in non-routine mathematics problem-solving (Mayer, 1998). Despite the crucial role of domain-specific knowledge, mastering each component of cognitive skill is not sufficient to promote non-routine problem-solving because the problem solver needs to know *when* and *how* to apply specific learning strategies and monitors these cognitive processes (Mayer, 1998). An expert problem solver normally uses more metacognitive strategies than a novice problem solver (Wong, 2002), and spends more time at the initial phase of planning but spends less time at the later stage during the actual implementation (Sternberg *et al.*, 2012). On the other hand, a novice problem solver spends less time at the initial phase of planning and more likely falls prey to all kind of errors (Sternberg *et al.*, 2012). A learner with poor metacognitive skills is not able to provide accurate monitoring, reflection, evaluation, and adjustment of effective learning (Yimer and Ellerton, 2006). Failure in metacognitive skills may lead to failure in mathematical thinking and problem-solving.

2.1.3 Affective

Teaching problem-solving and metacognitive skills are insufficient if a problem solver's feelings and interests are ignored, and the missing component is called *cognitive of motivation, motivation aspect of cognition* or *problem solvers' will* (Mayer, 1998). Despite many different terms used such as *motivation, will, disposition, emotions* or *disbelief*, the most widely used term is *affect* (Chamberlin, 2010).

The affective domain is conceptualised by emotion, attitude and belief (McLeod, 1992) and it plays a central role in mathematics learning. Emotions involve little cognitive appraisal and are short term in nature. There will be frustration at the inability to solve a problem, followed by joy when a solution is found (McLeod, 1992). A long-term positive or negative emotional disposition towards mathematics will affect a student's attitudes towards mathematics (Marchis, 2011). A series of experiences can promote a positive or negative attitude, and this contributes to the development of a more persistent attitude or belief that may influence future behaviour (Pierce *et al.*, 2007). One's beliefs are developed over a relatively long period of time and it is mainly associated with cognitive appraisal (McLeod, 1992). A student having prolonged negative experience at solving mathematical problems will lead eventually to a poor belief in one's own capabilities, whilst a positive experience will produce a more confident belief. In general, belief is developed over long period. It is stable and not easily changed. However, attitude is moderate in duration, intensity and stability, and that it has an emotional content. Thus, beliefs and attitudes are stable, but emotions may change instantly.

For students to become active learners, willing to tackle non-routine problems, their responses in the affective domain need to be higher than students who perform low-level routine mathematical operations (McLeod, 1992). Students are motivated to learn if they are interested in the material which they are learning. Motivational skills include motivation based on: (1) *interest* – students who are interested in the problem work harder and think deeper with higher success rate; (2) *self-efficacy* – students work harder and understand the material better when they judge themselves as capable; (3) *attributions/acknowledgements* – when a teacher gives help or a solution to a problem, students may infer that their teacher has a low opinion of their ability (Mayer, 1998). Another important motivation factor is (4) *usefulness,* in which students' attitudes towards mathematics are also influenced by their thoughts on how useful mathematics is in their daily lives (Marchis, 2011). Unfortunately, students rarely see the significance in learning mathematics.

> *We often erroneously presuppose that we have engaged the student's learning commitment. But the student rarely sees significance in the learning… The learning is meant to deal not with the student's problem…. but with someone else's* (Pea, 1987, p.101).

The mathematics examples and exercises given in the class are usually not relevant to the students. They could not see how the knowledge can be used to solve their problems.

2.1.4 Summary

Mathematics problem-solving requires cognitive and metacognitive skills with the support of affective domain. Cognitive skills needed for mathematics problem-solving include instructional objectives, components analysis and learning hierarchies. The mathematical task should be broken down into a collection of instructional objectives, fundamental cognitive processes and a hierarchy of subtasks. However, efficient use of these cognitive skills is only possible through metacognitive skills. Metacognitive skill is the knowledge of how to use, how to plan, how to coordinate, how to monitor and how to evaluate various skills in problem-solving. Cognitive involves *doing* of domain-specific knowledge relevant to problem-solving, and metacognition involves *strategies* for planning what to do and monitoring what has done. Affective domain is another element that plays an essential role in problem-solving. Students will not attempt a question in mathematics if they have no interest and purpose within them. Affective domain includes interest, self-efficacy, attributions and usefulness.

Mathematics learning is a complex and comprehensive area of study that includes learning of knowledge (cognitive), learning of strategy (metacognitive) and individual interest (affective). In school, knowledge and learning content (cognitive) can be disseminated to the students through classroom teaching, books and various learning platforms. However, metacognitive skills are difficult to teach and acquire. Learning content is tangible but metacognitive skills such as planning, monitoring, coordinating and evaluating are intangible and abstract. The teaching of metacognitive skills requires careful planning of learning activities and it is not easy to control the learning outcome. Metacognitive skill is implicitly learned through a learning experience, and it is subjective and unique to every learner. Moreover, interest is a complex element. If teachers are struggling to teach cognitive and metacognitive skills, they may neglect the students' motivation or interest to learn. In fact, developing students' interest may open the door to learning of cognitive and metacognitive skills.

Essentially, problem-solving skills depend on cognitive, metacognitive and affective domains. Before looking at how gaming pedagogy could support the learning of mathematics in these three domains, it is important to explore students' existing problem-solving skills. To obtain a more comprehensive overview of students' competency in mathematics problem-solving, it would be useful to seek the views and opinions of their teachers and parents in addition to the students themselves. Understanding how mathematics is actually learned would uncover the potential use of gaming pedagogy in supporting a new approach to mathematics pedagogy in these three aspects – cognitive (practice), metacognitive (implicit learning) and affective (motivation). It is difficult to suggest for a pedagogy improvement without knowing the existing limitations in mathematics education.

2.2 Computer Games in the Classroom

Advances in science and technology have gradually transformed our lives and how our society operates. As a result, students in the modern world are not the same as those in the past. They have been born into a digital age where technology forms an integral part of their lives. Digital technologies have surrounded them and they spend a lot of their time watching television, surfing the internet, playing digital games, using mobile phones and other digital technologies. When students come into the classroom - instead of copying down notes, they are more likely take a snapshot of the notes using their smartphone or tablet PC; instead of having face-to-face conversations in the class, they post their updates and messages to Facebook; they use *Google* to search the Internet for information rather than going to the library for relevant books. The communication and learning approaches of students have radically changed in the past 20-30 years. Technology is changing rapidly; the Internet is emerging; social networking is expanding, and computers are running faster and faster.

However, our education system is moving on slow and seems to be left behind by most of the current technologies. While many educators are aware of the problems, many find it easier to ignore the problems and assuming that students are the same as they have always been, and consequently, the same teaching methods will continue to work for the current generation of students (Prensky, 2001a, 2001b). It has always been argued that if learning is not interesting, dry and technical, it would fail to motivate students to learn. Even though motivation is the most important component in effective learning (Gee, 2003; Denis and Jouvelot, 2005; Prensky, 2003), schools are claimed to be boring, dull and not attractive (Mann, 2016; Toppo, 2015; Bryner, 2007). Moreover, the content and teaching style remain unchanged for the past 10 to 20 years. Teachers normally do not provide useful feedback to students and teachers control the learning process (Denis and Jouvelot, 2005). Today's students are not excited to go to the schools.

> *Today's game-playing kids enter the first grade able to do and understand so many complex things… the curriculum they are fed in school often feels to them like a depressant… so uselessly irrelevant - they no longer understand their teachers' outdated language (e.g., dial a telephone, play a record) and the teachers no longer speak theirs (e.g., blog, avatar or MMORPG)* (Prensky, 2003, pp.2–3).

The generation gap between teachers and students is obvious. The teachers continue to blame the students for being passive, lazy, not paying attention and not motivated in their study (Barish, 2012; Alderman, 2008). As a matter of fact, digital technology has changed how students think and learn.

2.2.1 Digital Native

The terms *digital native* and *digital immigrant* were introduced by Prensky (2001a). *Digital native* refers to those students who were born after 1980 and are native speakers of the digital language of computers, video games and the Internet (Prensky, 2001a). Students at schools, colleges and universities have grown up and spent their entire lives surrounded by computers, video games, cell phones and all other digital technologies, which have become almost seamlessly integrated into their daily lives. Digital native is defined as

> *someone who comes from a media rich household, who uses the Internet as a first port of call for information, multi-tasks using ICTs and uses the Internet to carry out a range of activities particularly those with a focus on learning* (Helsper and Eynon, 2010, p.516).

Besides the term digital native, they are also claimed to be the *net generation*, the *Google generation*, the *millennials* (Helsper and Eynon, 2010) or the *Facebook generation* (Ahuja, 2013). Despite different expressions used in the literature, the term *digital native* will be used in this study.

The term *digital immigrant* is used by Prensky to refer to those who were born before 1980 but have adapted and learned new technologies at some later point in their lives (Prensky, 2001a). Most of the teachers and parents are classified as digital immigrants.

> *The single biggest problem facing education today is that our digital immigrant instructors, who speak an outdated language, are struggling to*

> *teach a population that speaks an entirely new language* (Prensky, 2001a, p.2).

There is a gap or *digital disconnection* between the educators and the students. Digital immigrant educators are left behind in the latest technological developments. Many educators teach in the same manner as they were taught in the past.

2.2.2 Characteristics of Digital Native

A study has revealed that generation (i.e. age) alone does not define adequately whether or not someone is a digital native (Helsper and Eynon, 2010). It is argued that other factors such as gender, education, experience and breadth of use, play a part in explaining how a person is classified (Helsper and Eynon, 2010). We should not assume that all digital natives are proficient in *information and communication technology* (ICT). Likewise, educators drawn from the previous generations could be as competent as or even better than some of the students of younger generation in terms of ICT usage even though this is likely to be geographically influenced. There is a difference between *being* the digital natives based on their age (i.e. born after 1980) and *doing* the digital native activities in everyday practices (e.g. multitasking or thrive on instant gratification) (Helsper and Eynon, 2010).

The characteristics of digital natives are (a) used to receiving information fast, (b) like parallel processing, (c) used to multitasking, (d) thinking of graphics first, (e) comfortable with random access, (f) functioning best when networked, (g) thriving on instant gratification and frequent rewards, (h) preferring games to serious work, and (i) having a high twitch-speed (Prensky, 2001a, 2001b). Other researchers have claimed that the existence of digital natives is based on two assumptions: (1) digital natives have sophisticated knowledge and skills in ICT, and that (2) digital natives have different learning preferences compared to the earlier generations of students (Bennett *et al.*, 2008). For instance, digital native students may like to perform multitasking while using computer technologies. Kids do several things simultaneously - listen to music, talk on the cell phone, and use the computer (Brown, 2000). It is important to highlight that multitasking is not a new phenomenon as many of the older generations may have done their homework while watching television, or listening to the radio. In this study, a digital native is defined as someone who is born after 1980 and possesses sophisticated knowledge and skills in ICT.

2.2.3 Generation Gap

Although the existence of digital native is still under some doubt (Bennett *et al.*, 2008), students nowadays do learn differently from the generations of their teachers and parents. The generation gap between these two generations can be observed through many daily life examples. For instance, digital immigrants always refer to the user manual but digital natives prefer trial and error; digital immigrants like to read on a hardcopy (e.g. story book) but the digital natives prefer reading on a computer screen (e.g. e-book); digital immigrants like to have face-to-face communications but digital natives prefer virtual communication (e.g. emails, Facebook, games and messaging applications).

Many studies investigating digital native students' accessibility and their usage of digital technologies assume that digital natives are technologically savvy. They *think and learn* differently from digital immigrants. However, a few studies have shown this assumption to be wrong. A study conducted in the United Kingdom (UK) found that there was no substantial difference between digital natives as compared to the older generation in technology usage (Helsper and Eynon, 2010). Two studies conducted in Australia and Malaysia revealed that the technological skills of digital native students were overestimated because they were not familiar with several new evolving digital technologies such as office applications, the Internet, email and social networking (Kennedy *et al.*, 2008a; Hew and Leong, 2011). The impact and technology skills of digital natives could be overestimated; conversely, the impact and technical skills of digital immigrants could be underestimated. The digital divide between the digital natives and digital immigrants is not as large as expected.

This could be justified because digital natives and digital immigrants are deemed to be proficient in different technological skills. A study in Hong Kong revealed that digital native students were better at advanced web activity, diverse use of mobile phones, social networking such as *Facebook*, gaming and entertainment whereas the digital immigrant educators were better at digital technologies related to work and simple web functions (McNaught *et al.*, 2009). It is most likely that digital native students and digital immigrant educators use computer technologies for different purposes.

2.2.4 How do Digital Natives Learn?

Technologies do play a significant role in changing the way young people communicate, socialise and learn (Helsper and Eynon, 2010). Digital native students are claimed to learn differently from the way digital immigrants learn that the nature of education itself must change to accommodate the interest, expectations and practices of these students (Prensky, 2001a). It has been argued that digital native students often have short attention spans when they are exposed to conventional teaching approaches, but not for the things that interest them such as computer games (Prensky, 2001b).

According to Prensky (2001b), digital natives receive a considerable amount of digital input while they are growing up. He has argued that some of the functioning of their brains are likely to be modified as they think and process information differently from the previous generation of digital immigrants who tend to shape technological usage around their practices. These natives have grown up with a *hypertext mind*, they *leap around*, and develop parallel cognitive structures (Prensky, 2001b).

Even though digital native students do use more digital technologies compared to digital immigrants, there is no evidence to support different learning preferences adopted by the digital natives (Margaryan *et al.*, 2011). It is contended that digital natives' attitudes to learning are in fact influenced by the educators' teaching approaches (Margaryan *et al.*, 2011). It is also argued that students' learning approaches and preferences are not fixed and could change depending on the context of the task given (Bennett *et al.*, 2008). As such, generalisations of particular learning preferences (e.g. receiving fast information, multitasking, etc.) favoured by the digital natives are questionable (Bennett *et al.*, 2008). Nevertheless, teachers' pedagogical approaches do play a major role in exposing students to a range of learning experiences.

There is a need to understand these digital native students, and consider how the education system needs to change as a result. Helsper and Eynon (2010) asserted that many past research studies focused on young people's usage of new technologies, but arguments regarding ways of supporting the digital native students tended to be minimal. This may be an implication that many educators resist changing their existing teaching approach. Students nowadays *think* and *learn* differently and perform many functions in quite distinct ways. Teachers should understand and communicate in the language of their students and adapt their teaching approaches to one that best fits the students' learning strategies.

2.2.5 Learning Mathematics with Computer Games

Computer games offer a tremendous opportunity for learning mathematics. Students who are normally uninterested in mathematics would engage in computer games that require tedious computations and problem-solving (Chang, 2009). Although students are generally positive towards learning with computer games, their attitudes could be influenced by their confidence towards the subjects (e.g. mathematics) and the technology (e.g. computer games) (Vale, 2008; Pierce *et al.*, 2007). One of the aims of this study is to explore students' attitudes towards learning mathematics with computer games. Therefore, it is essential to explore students' attitudes towards mathematics learning and computer games.

a. Attitudes towards Mathematics

Students' attitudes towards mathematics have been researched for the past 25 years (Pierce *et al.*, 2007) because affect appears to play a particularly important role in mathematics education (Kislenko, 2006). Student's attitude is claimed to be one of the psychological constructs that has a significant connection with the mathematical learning experience and mathematical achievement (Kislenko, 2006; Yaratan and Kasapoğlu, 2012). Affect is a research interest in mathematics education as the students' attitudes and beliefs towards mathematics learning are strongly related to their success in mathematics (Kislenko, 2006).

Research has indicated that students hold positive views towards mathematics (Fan *et al.*, 2005) and acknowledge the importance and usefulness of mathematics in their daily life (Kislenko, 2006; Sangcap, 2010). Girls are more likely to have a better attitude towards mathematics and better mathematical achievements than boys (Yaratan and Kasapoğlu, 2012) as they tend to value more highly the usefulness of mathematics in their daily lives (Sangcap, 2010). However, girls are more likely than boys to characterise their failures in mathematics to a lack of skill and boys are more likely than girls to characterise their success to skill (McLeod, 1992). This phenomenon is also highlighted in PISA (2012),

> *girls are also more likely than boys to attribute failure in mathematics to themselves rather than to external factors* (PISA, 2012, p.18).

Köğce *et al.* (2009) have argued that students' attitudes towards mathematics are not significantly influenced by gender but rather by their grade level. As students moved to upper levels in the education system, their attitudes toward mathematics learning tend to be more and more negative, and they perceive greater difficulty and abstraction in the topics learned (Kislenko, 2006; Awanta, 2009). Students have confidence in doing simple routine mathematical problems but are not confident in solving challenging mathematical problems (Fan *et al.*, 2005; Awanta, 2009) as they believe that this type of problems is not significant (Sangcap, 2010).

Students' attitudes towards mathematics are also influenced by parents, teachers, teachers' teaching methods, peer groups, society, the level of self-confidence, motivation, previous experience and teachers' evaluation results (Yaratan and Kasapoğlu, 2012). Teachers play a significant role and have great influence on students' development. The support and confidence given by teachers significantly influence students' attitudes towards mathematics (Marchis, 2011). Good teaching may change students' negative attitudes towards mathematics to positive experience (Pierce *et al.*, 2007). Essentially, it is important to understand the qualities of a good mathematics teacher. Furthermore, it is also crucial to understand parents' perceptions of mathematics education and the parental influence on students' attitudes towards mathematics.

b. Attitudes towards learning with computer games

Digital natives are labelled as the *game generation* as gaming has surrounded them since young, and they think that computer games are just another part of the real world (Beck and Wade, 2006). Students normally perceive games to be fun, refreshing and appealing especially for the current young generation, and the use of games in education could easily let the students connect their learning with what they have known in games (Becker, 2001).

Nevertheless, adopting computer games into classrooms may raise as many issues as it would solve (Ke, 2008a), for instance, (1) the game may not be appealing to all students; (2) students may not learn because they are distracted by gameplay; (3) an educational game that enables learning may affect the nature of a game. Furthermore, many reports (The Star, 2014b, 2014a; Stanley, 2013; Hew and Loke, 2013; Yeoh, 2013) have pointed out some negative effects of computer games such as violent, game addiction, suicide, homicide, school dropout and social isolation. Nevertheless, educational computer games are claimed to be not addicting and do not cause social isolation behaviour (Rosas *et al.*, 2003). Despite some academicians perceiving games as something not serious, educators who use games in teaching have produced encouragingly positive results (Becker, 2001).

Many studies reveal that students are positive towards the use of educational games in learning. Students normally describe educational games as fun (Mokka *et al.*, 2003; Ebner and Holzinger, 2007), stimulating (Mokka *et al.*, 2003), enjoyable (Mokka *et al.*, 2003), motivating (Wishart, 1990; Becker, 2001; Rosas *et al.*, 2003; Mokka *et al.*, 2003; Natvig and Line, 2004; Cai *et al.*, 2006; Ke, 2009), informative (Cai *et al.*, 2006), self-efficacy (Ke, 2009) and engaging (Rosas *et al.*, 2003). Educational computer games are claimed to produce an equal or even better learning outcomes than the conventional classroom teaching (Ebner and Holzinger, 2007; Ke and Grabowski, 2007). Students may be motivated if they feel that they could learn more through the educational computer games (Natvig and Line, 2004). The students' positive responses may influence teachers' acceptance of educational computer games (Rosas *et al.*, 2003). Likewise, if students do not enjoy playing educational computer games, the teachers may feel reluctant to try any new teaching innovation related to computer games in the future.

Computer games may help students to associate enjoyable gaming experience to mathematics learning, and this could help students to develop a deeper interest in mathematics (Bragg, 2003; Demirbilek and Tamer, 2010). Mathematics computer games have been developed in many past studies, for instance *Astra Eagle* in (Ke and Grabowski, 2007), *Triangle* in (Holzinger *et al.*, 2001), *Magalu, Hermes, Tiki-Tiki* and *Roli* in (Rosas *et al.*, 2003) and *Proportional Tetris* and *Proportional Clown* in (Çankaya and Karamete, 2009). In Malaysia, there have been several studies on educational games used in mathematics (e.g., Wan Ahmad *et al.*, 2010; Shafie and Wan Ahmad, 2011, 2010b, 2010a; Abdullah *et al.*, 2011; Latif, 2007).

Nevertheless, teachers and students may have a different expectation of DGBL. Teachers may see the importance of learning mathematics through computer games, but students may see it as a tool or even a toy. Most of the teachers having grown up in a technology-poor society focus on mental computation skill, but young students who have grown up in a digital world have developed a different learning attitude toward mathematics (Zevenbergen and Zevenbergen, 2003). Therefore, a combination of interactive computer games and curricular content is an innovative way to make the learning more interesting. However, this requires careful game design and development plan.

2.2.6 Summary

Today's students are digital natives who were born after 1980 and possess sophisticated knowledge and skills in ICT. Digital native students learn differently – want to be fast, perform multitasking, prefer graphics, learn best when networked, like instant gratification and prefer games to serious work. Digital natives have excellent attention span for things that interest them such as computer games. Computer games offer a tremendous opportunity for mathematics learning because students who are normally uninterested in mathematics, surprisingly, stay on complicated tasks in games that require complex problem-solving skills.

Most of the existing studies are looking at how we can change our teaching approaches to fit the current young generation of digital natives. Many researchers are explaining how current students think and learn differently with an assumption that students are on the right learning direction. Indeed, we as educators are trying to change our teaching pedagogies to accommodate the students' needs. Looking from a different perspective, can we urge the students to change their learning styles to match our teaching approaches or the learning objectives? If students have a real intention to learn, they will adjust themselves to different learning environments. For instance, a driving school is not designed in such a way to suit the students' learning preferences but for the purpose of learning how to operate a car and for road safety. Similarly, if the students are not interested in learning basic mathematical computations, should we change it to the use of a calculator to please them? Would it defeat the whole purpose of learning? This is a controversial argument between different views of scholars and educators. This study is done with an assumption that students' ways of learning are in the right direction, and educators should change their teaching approach.

There is a need to explore students' proficiency in ICT by understanding students' technological skills and gaming experience. Despite today's young generation being categorised as digital native, students' exposure to ICT may vary by geographical location, family background and other factors. Students' digital native characters may influence their acceptance of ICT used in education. Students who are characterised to be more digital native and confident in ICT are more likely to have positive attitudes towards the use of computer games in learning mathematics. Conversely, if students are lack of technological or gaming knowledge and experience, they are likely to have a more negative impression of DGBL. Furthermore, there is a need to understand students' attitudes towards mathematics and how they learn. Students' attitudes and learning approaches may reveal the possible change of mathematics pedagogy that motivates students to learn.

2.3 Digital Game-based Learning (DGBL)

The use of computer games for teaching and learning purposes is gaining attention from many educational researchers. A review of the DGBL literature by Van Eck (2006) reveals three techniques to integrate computer games into learning.

1. Educators or game developers develop educational computer games to teach students.
2. COTS games are used for educational purposes.
3. Students are taught how to develop games.

2.3.1 Educational Games

In the first approach, games are designed by educators or game developers to integrate seamlessly learning and gameplay to address educational and entertainment equally (Van Eck, 2006). Some examples of games developed for educational purposes are *Astra Eagle* for learning mathematics (Ke and Grabowski, 2007), *Internal Force Master* for learning civil engineering (Ebner and Holzinger, 2007), *Triangle* for learning mathematics (Holzinger *et al.*, 2001), *Bio-X game* for learning life science (Cai *et al.*, 2006), *Magalu, Hermes, Tiki-Tiki* and *Roli* for learning language, communication and mathematics (Rosas *et al.*, 2003), *Hangman* for learning language and communication (Rosas *et al.*, 2003), *Age of Computer* for learning history of computer (Natvig and Line, 2004), *Proportional Tetris* and *Proportional Clown* for learning mathematics (Çankaya and Karamete, 2009) and *LearnMem1* for learning basic computer memory concept (Papastergiou, 2009). The real challenge for the educators or game developers is developing educational games that are comparable to the quality and functionality of COTS games with persuasive examples and proven track record for being effective in education (Van Eck, 2006). Educational games will be discussed further in Section 2.7.

2.3.2 COTS Games

Van Eck's (2006) second approach involves taking the existing COTS games, not necessarily developed as learning games, and using them in the classroom (Van Eck, 2006). In the short term, Van Eck (2006) claims that this approach is the most cost-effective (i.e. game development cost is not involved) and promising (i.e. flexibility of teachers in choosing the appropriate games and designing their lessons), but the use of COTS games requires careful analysis and a matching of the game content to the study content. Van Eck (2006) further explains that in the long term, game companies should be enticed to develop educational games. This approach is gaining acceptance due to its practicality and effectiveness. For instance, *Tetris* is used to learn mental rotation accuracy (De Lisi and Wolford, 2002), *World of Warcraft* is used to learn game design (Dickey, 2011), *Second Life* is used to learn ecology of the virtual world (Hayes, 2006) and *Angry Birds, The Sims* and *Plants vs. Zombies* are used to learn mathematics (Avraamidou *et al.*, 2015).

2.3.3 Games Development

In the third approach, students take the role as game designers to build the game and study the learning content at the same time (Van Eck, 2006). In this approach, students can learn problem-solving skills and programming languages to develop the game (Van Eck, 2006). Gamers are encouraged to become game designers to evolve sophisticated thinking skills (Papert, 1998). This approach is unlikely to be used widely (except for computer science teaching) due to a few constraints: (1) teachers have no game development skill, (2) teachers have no time to learn/teach game development skill, (3) traditional institutions do not allow for interdisciplinary teaching (e.g. computer science and English), and (4) not all areas allow good content for game development (Van Eck, 2006). For instance, students could develop computer games to learn computer science (Denner *et al.*, 2012; Carbonaro *et al.*, 2010), biology and programming (Yang and Chang, 2013) and language courses (Vos *et al.*, 2011).

2.3.4 Comparison of the three approaches

The use of educational games in classroom teaching may seem to be easy and straightforward because they are specifically designed for educational purposes. However, most of the educational games are not engaging and motivating like COTS games. Educational games are claimed to be lacking in *autonomy, play, affinity* and *space* (Nolan and McBride, 2014). The use of COTS games for educational purposes may seem to be a better option. However, teachers should be knowledgeable and able to choose the appropriate COTS games that can match and fit into the learning curriculum.

The games development approach may seem to be more positive as some studies (Carbonaro *et al.*, 2010; Yang and Chang, 2013; Vos *et al.*, 2011) indicate that students learn more problem-solving skills and become more motivated through game development activities. However, it is not easy to learn programming skills, user interface design, *human-computer interaction* (HCI), *artificial intelligence* (AI) and the associated game development skills. The objective of this approach is not to produce a high-quality game, but to allow students to learn implicit skills through game production. This approach is difficult for the teachers with no computer literacy and programming knowledge. However, many authoring tools require minimal programming skills such as *Adobe Authorware, Adobe Flash, Scratch* and *GameMaker*. *Scratch* is free software developed by *The Massachusetts Institute of Technology* (MIT). It is used by many learning communities to develop games and animations because it is interesting and free to use.

In fact, some gaming companies are looking for gamers to develop games. Recently, *Sony Online Entertainment* (SOE) has published *Landmark*, a free to play *massively multiplayer online role-playing game* (MMORPG) that allows players to design, build and make anything they can imagine (e.g. houses, stores, villages) (SOE, 2014). SOE has hosted a competition and the objects and buildings that the players have constructed in Landmark may be used in the upcoming MMORPG, *EverQuest Next* (SOE, 2014). Nevertheless, most of the past studies in DGBL were built on the first two approaches in which students would play either educational games or COTS games for educational purposes.

2.3.5 Summary

Digital games can be used for learning in numerous ways. There are three approaches to DGBL - use of educational games, use of COTS games for educational purposes and teach the games development skills. Every approach has its pros and cons, and the selection of DGBL approach should be based on the learning objectives.

Every approach to DGBL is unique. The use of educational games is more straightforward and teachers have more control over the flow of learning processes in the games. The games are designed with pre-defined learning objectives, and the learning content is made explicit. It is difficult to justify the claim that COTS games are beneficial for learning. Most of the learning contents or even the metacognitive skills learned through COTS games are embedded in the games and not visible to the players. Players are learning the implicit skills such as multitasking, control, teamwork and other metacognitive skills. Another matter of concern is to what extent these implicit skills are transferable to formal learning and how to assess these transferable implicit skills? Moreover, how can teachers make sure that students learn the desired skills in COTS games (e.g. spatial ability, mental computation and land navigation) and not the others (e.g. cheating, homicide and conflict)? The use of COTS games requires a detailed teaching plan and a teacher who is familiar with the games. The third approach to DGBL - teach the games development skills (e.g. programming, multimedia and graphics design) will not be discussed further because it is not the focus of this study.

There is a need to explore the teachers', students' and parents' understanding of DGBL and COTS games which will provide a guideline for the potential use of DGBL for mathematics learning. For instance, the first approach is not viable if the teachers have no access to mathematics computer games. Furthermore, the second is not feasible if the teachers have no interest and experience of playing COTS. If the teachers' interest and proficiency in gaming are limited, then an alternative approach may be viable – the use of embodied learning principles of computer games.

2.4 Play and Learning

2.4.1 What is Play?

Play in the context of *playing games* is linked with enjoyment (i.e. spending time doing an enjoyable and entertaining activity) and engaging in gameplay (i.e. taking part in a game or competing against an opponent). The words *play* and *game* may seem almost synonymous, but the two terms refer broadly to distinguishable stages of human development. The *play* relates to an earlier stage of child development and *game* to a more mature stage as explained by Bettelheim (1987).

> *Play refers to the young child's activities characterised by freedom from all personally imposed rules, by free-wheeling fantasy involvement, and by the absence of any goals outside the activity itself* (Bettelheim, 1987, p.43).

There are a few factors that merit emphasis in playing. The play is an activity that is: (1) not obligatory (something one chooses to do); (2) not serious (no material interest); (3) unreal (consciously outside of ordinary life); (4) internally motivating (intensely and utterly absorbing); (5) no external goal (creates neither profit nor wealth); (6) uncertain in its outcomes; (7) formed within social groupings; (8) governed by rules; (9) fun and pleasurable (Caillois, 2001; Huizinga, 1955; Corbeil, 1999; Prensky, 2001c; Weisler and McCall, 1976). Children and animals play because they enjoy the freedom of playing (Huizinga, 1955).

The *play* is a relaxing activity without any external goal, but the *game* is governed by a set of objectives. Games are characterised by (1) agreed-upon often externally imposed rules; (2) frequently motivated by a goal or purpose outside the activity; (3) predictable outcome; (4) competitive (Bettelheim, 1987; Berne, 1967). Thus, *playing game* could be referred as an activity governed by a set of rules, not obligatory, but motivated by a goal to win the game. The *play* is directed by internal motivation, but the *game* is directed by external motivation.

2.4.2 Playful Learning

The *play* is a primary socialisation and *learning* mechanism for human and animal species (Van Eck, 2006). Although the satisfaction and purpose of *playing* may not directly relate to *learning*, *playing* is a form of exploration and imitation that enables *learning* to take place almost inadvertently (Corbeil, 1999). *Play* has a deep biological and evolutionary function that has to do with *learning* (Prensky, 2001c). The motivation to *learn* comes through the motivation to *play.*

The focus of *play* and *learning* is termed as *playful learning*. The benefits of *playful learning* go beyond the academic learning content. Playing with dolls helps children to care and role-play; playing with Lego helps children to imagine and build structures. Through their play, the children are learning how to care, role-play, imagine and build, which are the non-academic learning content.

Playful learning is opposed to *edutainment* that focuses on entertainment and education. In *edutainment*, education is viewed as a bitter medicine or suffering that is rewarded by the sugar-coated entertainment to become palatable (Resnick, 2004). The learning is claimed to be fun as learners learn unknowingly through the act of play. In actual fact, it is regarded as the most unpleasant learning experience (Resnick, 2004). The learners may feel cheated to learn.

2.4.3 Resistance to Playful Learning

Despite the clear advantages of playful learning, some problems need to be addressed. Many people are still resisting and being sceptical about playful learning because they see playful learning as just *playing* (Resnick, 2004). Furthermore, many educationists resist making the *learning* fun because they want *learning* to be a painful experience (Prensky, 2002). They believe in the proverb saying *no pain, no gain*, which means suffering is necessary in order to achieve something such as learning. Many people are also influenced by the extreme biblical stance that man's suffering is caused by knowledge, and learning is painful and a form of suffering (Prensky, 2002). Ancient biblical scripts have also revealed that mixing learning (pure and serious) and fun (unholy) is frivolous and sinful (Prensky, 2002).

In fact, there are no theoretical or practical reasons why learning should be painful and one good example is that people are born as babies and they learn without suffering (Prensky, 2002). In this fast changing world, the old reasoning behind the present education system should be changed. The education system should continuously adapt to this fast changing world and abolish the tradition of painful or suffering from learning.

2.4.4 Children's Play

Play is important to the development of children. *Playful learning* has been used in many pre-schools and elementary schools, and research has found that children can learn many things (i.e. counting, story-telling and socializing) through play activities (Resnick, 2004). Through playing, children can express how they see and interpret the world (Bettelheim, 1987). They learn to play and progress in mastering and constructing the relationship between structures of the surrounding world (Annetta, 2008). Playing is the fundamental process that is essential for children's cognitive and social developments (Rosas *et al.*, 2003). As children play, they learn to communicate with others and to solve problems. Furthermore, play helps children to develop language and physical skills such as how to grasp, crawl, run and climb.

When playing games, adults and children need to adhere to the rules of the games but their approaches are different from each other. Children recognise that play is an opportunity for enjoyment but games may involve considerable stress (Bettelheim, 1987). All games have rules and procedures that must be learned and adhered to by the players. Children can understand and follow the rules of the games when they have reached schooling age, but their understanding of the games may change as they grow up (Rosas *et al.*, 2003). Children are looking for the *right* rules in games (Corbeil, 1999). In games, children are not supervised by adults, and they are free to do what they like. When a child starts to play a game, he tries to change the rules to suit him and later found out that the rules are unalterable (Bettelheim, 1987). Later he realises that to win the game, he has to obey the rules and views disobeying the rules as a serious crime (Bettelheim, 1987). For a child, playing a game is analogous to having a task and the child has to discover, learn and adhere to the rules of the game.

2.4.5 Adults' Play

Some people think that adults should not *play* because it is something trivial, unimportant, not serious and a childhood activity (Prensky, 2001c; Corbeil, 1999). In fact, the *play* is an essential component of human development that does not stop at a particular age (Corbeil, 1999). Age does not stop an adult from playing like a child. There is no difference between children's play and adults' play (Corbeil, 1999) and every adult has an inner child in them (Berne, 1967). While young children engage in *play* activity, the *play* is as essential for adults as it is for children. Adults do play; they play with their children and they play games. Adults play football, video game, and chess; collect toys such as car models, robots, teddy bears, Barbie dolls and Gundam; watch cartoons or movies such as Kung Fu Panda, Ice Age, Mickey Mouse, Superman and Ninja Turtle. These are the things they loved when they were children, and they are still in love with them.

Adults' resistance to play games might be because they perceived the games as child's level of interest to play; but if a game is challenging enough to be attempted by adults and they have real feelings of accomplishment and real learning in a virtual situation, they will find it interesting (Corbeil, 1999). When adults play games, they must relearn to act and express themselves as the roles they portray in a game (Annetta, 2008). As mentioned by Huizinga (1955), the play is an activity that stands quite consciously outside of ordinary life as being not serious. Unlike children, adults have a real serious life that is often construed to be in conflict with a play, which is defined as outside of ordinary life and not serious (Prensky, 2001c). Adults make a distinction between real life and game, and they play to move from the usual rules of social interaction in real life to a situation where personal creativity is possible (Corbeil, 1999). Sometimes adults have no interest in practising a new game; unlike children who see it as a challenge (Prensky, 2001c). Adults understand that rules are voluntarily agreed and can be freely altered as long as all participants agree to such changes (Bettelheim, 1987), especially to keep the game going (Corbeil, 1999). This provides a mechanism for adults to manipulate the rules to their advantage.

2.4.6 Summary

Play is defined with a few keywords: freedom, not serious, unreal, engagement, unproductive and pleasurable. Play is important for both children and adults, and it does not stop at a particular age. Intrinsic motivation should drive motivation to play, and play in the form of exploration and imitation enables learning. People may play to learn, or learn to play. In either way, many conservative educators do not recognise the significance of learning through play and perceive learning to be something serious and painful. Adults play and approach computer games differently from children, and they may find children's games to be *childish,* in other words, as more befitting less sophistication. To play games, children try their best to discover the rules governing the games, whereas adults would manipulate the rules as they play the games.

Play is the natural way of learning. Children play with toys to learn how to grab, how to throw and how to operate the toys. Children learn by playing, and they adopt all the significant learning principles - experiential learning, constructivism and situated learning. For instance, children like to play hide-and-seek. Through the game, the children learn from mistakes of where to hide (experiential learning), learn the best strategy to hide and seek based on their prior knowledge (constructivism) and the game is a real context because the children are physically hiding and seeking (situated learning). In some cultures, when adults play, they seemed to be immature and uncommitted to serious work. This prejudice may defy the idea of playful learning. Asian formal education is treated seriously, and not immediately compatible with playful learning.

In this study, there is a need to explore teachers', students' and parents' awareness of playful learning. Their perceptions may be guided by their personal experience of playing computer games or through their observations and readings. It is a very common scene to see children play on their computers continuously for hours. They are most likely to appreciate the benefits of playing computer games. Many adults love to play games too, but they are more conscious about time, responsibility and resources. If both teachers and parents do not play computer games, they may not appreciate the benefits of gameplay. To explore the potential use of DGBL, teachers' and parents' support and understanding are vital.

2.5 Learning Principles of Computer Games

Computer games are embedded with many good learning theories because they are motivating and engaging (Gee, 2007), and their use for educational purposes has been discussed from different perspectives. For instance, Annetta (2008) has viewed them from developmental psychology (play); learning theory (constructivist) and the 21st century skills; Becker (2005) has viewed them from Gardner's (1985) Multiple Intelligences and Gagne's (1985) cognitive constructs.

Before adopting DGBL, school teachers need to be convinced with evidence that a computer game is an effective learning object (Becker, 2005). The use of DGBL receives a considerable amount of resistance from the school teachers. One way to persuade more teachers to adopt DGBL is through pedagogy, and connecting well-established learning theories to existing games design (Becker, 2005). In this section, two major pieces of work (i.e. Kebritchi and Hirumi, 2008; Wu *et al.*, 2012) are explored to understand how the established learning theories apply to DGBL.

In Kebritchi and Hirumi (2008), the pedagogical foundations of modern educational computer games were examined. They reviewed 55 educational games from 50 published literatures between 2000 and 2007. The educational games studies were classified into five basic categories, namely direct instruction, experiential learning, discovery learning, situated learning and constructivist learning. They concluded that most of the educational computer games were based on experiential learning theory, followed by situated learning theory, discovery learning theory, constructivist approach and direct learning (Kebritchi and Hirumi, 2008).

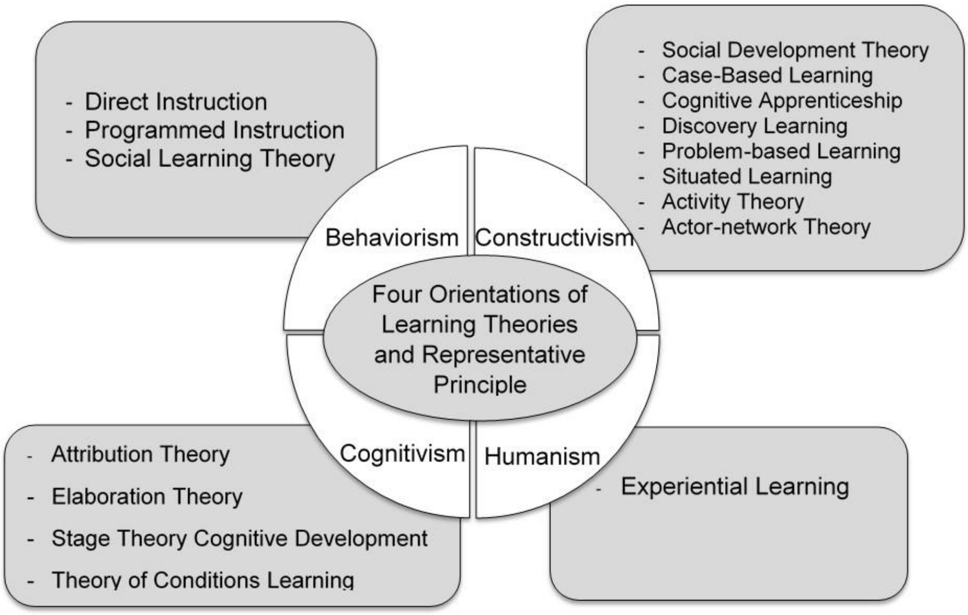

Figure 2.1: Four Orientations of Learning Theories (Wu *et al.*, 2012)

Wu et al. (2012) after reviewing 21 conference proceedings papers, two book chapters, 58 journal articles and ten reports had proposed four classifications of learning theories (see Figure 2.1) applicable to game-assisted learning. They observed that most of the studies were based on experiential learning, followed by situated learning theories, problem-based learning, direct instruction, discovery learning theory and elaboration theory (Wu *et al.*, 2012). This classification generally agrees with Kebritchi and Hirumi (2008) except the constructivist, situated and discovery learning was described as constructivism. In addition to that, Wu et al. (2012) had added a new classification, i.e. cognitivism.

Three predominant learning theories will be discussed in the following sections - experiential learning, situated learning and constructivism. Many game research teams such as the Game-to-Teach group at MIT, the Institute for Creative Technologies at University of South California, and Futurelab, a British instructional game developer, have used these three learning theories to design DGBL (Kebritchi and Hirumi, 2008). Furthermore, the development of DGBL has prompted more studies to focus on constructivism and experiential learning instead of behaviourism and cognitivism (Wu *et al.*, 2012).

2.5.1 Experiential Learning

The primary source of learning and development in experiential learning is *experience*. According to experiential learning theory,

> *learning is the process whereby knowledge is created through the transformation of experience* (Kolb, 1984, p.38)

and

learning is continuously derived from and tested out in the experiences of the learners (Kolb, 1984, p.27).

Experiential learning in adult education typically relates to reflection on concrete experience (Fenwick, 2001). Experiential learning is learning by doing, a combination of grasping experience, understanding and observing the phenomena being studied, and testing and applying them with the intention of achieving the desired result (Dieleman and Huisingh, 2006). Experiential learning theory has been discussed in many past studies of DGBL (Kiili, 2006, 2005b, 2005a; Dieleman and Huisingh, 2006; Hou and Li, 2014; Holzinger *et al.*, 2001).

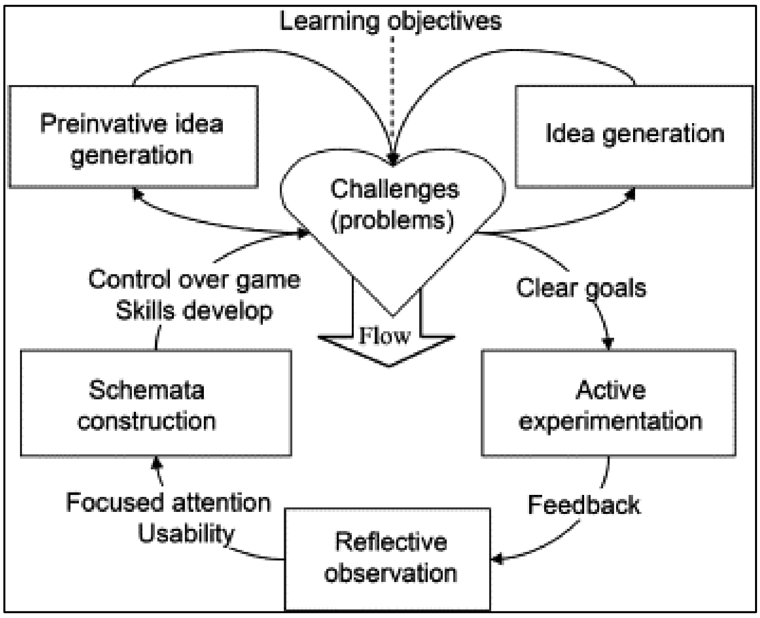

Figure 2.2: Experiential Gaming Model (Kiili, 2005b)

One of the gaming models built on experiential learning is Kiili's (2005b, 2006) experiential gaming model (see Figure 2.2) which was developed from Kolb's (1984) experiential learning theory, flow theory and game design (Kiili, 2005b). Experiential gaming model links gameplay with experiential learning to facilitate flow experience (Kiili, 2005b). According to Kiili (2005b), learning is a cyclic process in which cognitive structures are constructed through action or practice (behavioural) in the game world. The operational principle of experiential gaming model is derived from a human blood-vascular system and it consists of an ideation/solution loop (cycle above the heart), an experience loop (cycle below the heart) and a challenging bank (the heart). Learning is initiated when challenges (the heart) are presented in the games. Once there is a clear goal, users have to overcome the challenges by brainstorming any possible creative solution without considering the constraints (idea generation loop).

Then, the solutions will be experimented and feedback will be observed for reflection. Reflection enables users to focus attention on relevant information, which will lead to schemata construction that in turn can result in the better generation of solutions. Based on these initial solutions, users will regenerate solutions by taking the constraints and resources into consideration. In the experience loop, the users will adopt constructivist and pragmatist learning because knowledge will be constructed through gameplay. In an experiential gaming model, it is prominent that the game provides a meaningful problem-based learning environment that enables the player to set personal goals, gather information, monitor and evaluate problem-solving processes (Kiili, 2005b, 2006).

In brief, experiential learning is learning through experience, and it is the most fundamental and natural way of how humans learn since young. Experiential learning allows children to experience the reality of failure and how to overcome setbacks and challenges. In fact, experiential learning is a complex process with integration of theory and practice. There are many different schools of thought on how experience affects learners, but the dominant understanding of experiential learning is based on constructivism and situated learning (Fenwick, 2001). In the following sections, these two schools of thought will be discussed further.

2.5.2 Constructivism

Piaget's work has laid the foundation for constructivist theory (Lever-Duffy *et al.*, 2004). There are two principles of constructivism:

> *(1) knowledge is not passively received but actively built up by the cognising subject; (2) the function of cognition is adaptive and serves the organisation of the experiential world, not the discovery of ontological reality* (Glasersfeld, 1989, p.162).

According to constructivism, learners should take an active role to reflect on lives experience constructed through activity or social interaction, then interpret and generalise this experience to form mental structures (Fenwick, 2001; Vos *et al.*, 2011). In brief, constructivism focuses on knowledge construction. Learners are not empty vessels waiting to be filled or transmitted with knowledge. On the contrary, learners build and modify their existing mental models through interaction with their environments. For instance, given the same learning content, every learner will generate different learning outcomes because learner constructs meaning, understanding and knowledge from his/her experience.

Constructivists' view of learning can be embraced in DGBL. There are two basic assumptions of constructivism in DGBL: (1) knowledge construction - learners construct their knowledge based on their pre-knowledge and interest, (2) self-regulation - learners manage their learning process (Vos *et al.*, 2011). In computer games, learners can develop logical thinking and problem-solving skills through trial and error, reflection, changing their strategies, and replaying the games (i.e. knowledge construction), and at the same time, they have control over the games' characters (i.e. self-regulation) (Vos *et al.*, 2011). Knowledge construction and self-regulation could lead to a better understanding, remembering and active use of the knowledge (Perkins, 1999). Furthermore, computer games provide learners the opportunity to explore the games' environment, to think critically about the simulation and to experience the situations by role-playing the game characters (Annetta, 2008). Evidently, applying constructivist principles to DGBL yields an approach that puts students in the role of active learners.

Computer games thrive as teaching tools when they assist in knowledge constructions by going through a continuous cycle of cognitive disequilibrium and accommodation to modify the learner's existing mental model (Van Eck, 2006; Obikwelu and Read, 2012; Warren *et al.*, 2012). While playing the games, players go through the virtual world and this experience allows knowledge construction and players can appreciate the knowledge more in comparison to memorising and recalling the content in traditional teaching (Gee, 2003). During gameplay, learners receive immediate feedback and they constantly go through the cycle of hypothesis formulation, testing, and revision (Van Eck, 2006; Warren *et al.*, 2012). The learning is a loop of testing, reflection and refinement, which is similar to the Kiili's (2006) experiential gaming model as discussed earlier. However, constructivism's main idea is that learning is constructed and learners have to build new knowledge upon the foundation of previous knowledge.

2.5.3 Situated Learning

Situated learning is an alternate conceptual interpretation of experiential learning (Fenwick, 2001). According to Lave (1996), situated learning stresses on the relational interdependency of the learner with the world, activity, meaning, cognition, learning, and knowing. Situated learning is defined as

> *learning, thinking and knowing are relations among people engaged in activity in, with, and arising from the socially and culturally structured world* (Lave, 1996, p.67).

Situated learning affirms that cognition and communication in/with the social world are situated in lived-in world with the historical development of ongoing activity (Lave, 1996). Learning is not merely what goes on inside the head of the person, but it is situated in the context, culture or activity in which a person participates (Fenwick, 2001; Brown *et al.*, 1989; Gee, 2007). For instance, learning to *ride* a horse is different from learning to *ride* a bicycle. The term *ride* does not carry the same learning experience. The meaning is clearly tied to the context (situated within). Thus, situated learning is sometimes regarded as socio-constructivism in which learners learn through problem-solving, experiment and reflection in a socio-environment. The key component being that learning takes place in a lived-in world.

Learning in computer games is more effective than most formal learning instructions that normally occur outside of the learning contexts (Van Eck, 2006). Gee (2007) gave an interesting example about the learning of basketball. In school, students will be asked to read a book about basketball because that is what teachers believe about knowledge - learning of content. However, if the students are playing basketball physically or playing basketball computer games, teachers do not regard that as learning because there is no content involved. Reading a book to learn basketball is very abstract and out of context. Conversely, learning basketball physically or through computer games is situated within the actual learning context, whether it is a lived-in world or a virtual game world.

Computer games represent well-established models of learning because the learning is not only meaningful and relevant but can be applied and practised within that context (Van Eck, 2006). Computer games allow learners to explore authentic problems in realistic contexts (Kebritchi and Hirumi, 2008). In computer games, knowledge is not only constructed through understanding of content, but also through problem-solving within the game environments to construct knowledge of skills, attitudes, culture, tools and communities (Egenfeldt-Nielsen, 2007; Warren *et al.*, 2012). Situated learning is active learning of cognitive and metacognitive skills that takes place via one's participation in an authentic setting.

There are a few situated learning models that are applicable to the development of computer games. Three of the major components in these models are: (1) collaboration; (2) learning in an authentic context; (3) support or coaching (Mohd Yasin *et al.*, 2012; McLellan, 1996; Dziorny, 2006; Herrington and Oliver, 2000; Mouaheb *et al.*, 2012). Dziorny (2006) and Mouaheb et al. (2012) have explained how each of these components links to DGBL. The situated learning models are essentially useful for computer games developers.

Nonetheless, some studies (Hayes, 2006; Gee, 2008a) discuss how situated learning is embraced during gameplay: (1) learning to design the property in the virtual world to achieve certain goals (e.g. clothing, avatar skin, building, etc.), and (2) learning of the rules and principles of the game economy (e.g. how to negotiate virtual game currency exchange for real money). In this context, situated learning is formed during gameplay and the learning experience is unique for each player. These studies view learning as relations among people (game characters) engaged in an activity in culturally structured world (game), and this is one of the main features of MMORPG.

> *MMORPG is a persistent, networked, interactive game that allows players to simultaneously play and interact with one another in representations of fantasy 3D spaces* (Dickey, 2011, p.201)

MMORPG (e.g. *EverQuest, EverQuest 2, ToonTown and World of Warcraft*) is one of the most popular game genres (Dickey, 2011). It is argued that MMORPG fits well into situated learning theory (Dziorny, 2006). In an MMORPG, social interaction is the most important component because it requires collaboration between players (Dickey, 2011), and this social interaction is one of the key elements of situated learning.

In a study conducted by Dickey (2011), a MMPRPG was used as a teaching tool to investigate whether positive learning outcomes from playing *World of Warcraft* (WoW) such as fostering peer relationship and community were transferred to the classroom setting. Unfortunately, the games' culture was a conflicted community and this conflict was transferred into the classroom. Other positive learning outcomes such as peer mentoring and role-reversal among the students within the game were not transferred into the classroom setting due to various factors such as gender, age, personality, and even fields of study (Dickey, 2011).

Therefore, commercial games used for classroom teaching should be scrutinised before use. Despite evidence that WoW had a negative effect, Dickey's (2011) study did prove that situated learning took place in MMPROG because the students learn, think and know within the game community and culture. Moreover, there is an affective component of gameplay since there are embodied ethical and moral dilemmas in the game (Becker, 2005).

2.5.4 Multiple Intelligence

Computer games support learning of multiple Intelligences (Gardner, 1985, 1995) and Gagne's five categories of learning (Becker, 2005). However, only cognitive and metacognitive skills will be discussed because these are the skills required for mathematics problem-solving. Cognitive strategy emphasises on the development of thinking skills and processes whereas metacognitive strategy oversees whether a cognitive goal has been met (Livington, 2003). It should be noted that it is difficult to make a clear distinction between cognitive and metacognitive skills. Metacognitive knowledge may not be different from cognitive knowledge (Flavell, 1979) because cognitive and metacognitive strategies may overlap (Livington, 2003).

a. Cognitive Skills

Cognitive skills required to play computer games are very complex. According to Martinovic *et al.* (2014), there are 23 cognitive elements found in computer games - semantic memory, spelling, working memory, colour perception, visual tracking, mental maths, maths concepts, reasoning, matching shapes, problem-solving, planning, visual motor integration, counting and quantity, visual motor speed, spatial perception, selective attention, episodic memory, theory of mind, expressive language, math numerosities, music perception, inhibit and organisation, and so playing the computer games will develop these skills (Becker, 2005).

Nevertheless, these cognitive elements are crucial in developing solutions and engaging players in computer games. For instance, serious and educational games typically require logical thinking, memorisation, critical thinking, discovery and manipulation of virtual objects to enable learning of complex systems (Westera *et al.*, 2008; Annetta, 2008). Furthermore, children like to play computer games because the games require complex learning skills. For instance, to learn how to fly an aeroplane, how to drive fast cars and how to be a warrior; they have to collect information, make decision, plan strategies to overcome the obstacles and even collaborate with others (Prensky, 2001c). It should be noted that complexity is one of the design considerations in developing computer games.

Furthermore, even simple puzzle games require multiple cognitive skills. A study has revealed that playing puzzle games such as *Bejeweled, Solitaire,* and *Minesweeper* involves reasoning and working memory skills (Baniqued *et al.*, 2013). Puzzle games promote logical reasoning and mathematical intelligence (Becker, 2005; Amory *et al.*, 1999; Van Eck and Hung, 2010). Another study has revealed that playing puzzle games can help to improve arithmetic skills, mental calculation speed and motivation to learn (Núñez Castellar *et al.*, 2014). In actual fact, many computer games that look simple require multiple cognitive skills to learn and master.

b. Metacognitive Skills

Playing computer games can help to develop metacognitive skills such as confidence in reasonable risk taking, ability to multitask, leadership, teamwork, visualisation, problem-solving, decision-making skills, self-regulative and monitoring skills (Ke, 2008b; Cherenkova and Alexandrov, 2013). Some of these metacognitive skills are discussed as follows:

1. *Multitask* - Playing computer games involves the integration of touch, voice, music, video, still images, graphics and text (Martinovic *et al.*, 2014). Players have to attend to multiple tasks at the same time.

2. *Land navigation/spatial* - Playing computer games has immediate positive effects on spatial skill (Subrahmanyam *et al.*, 2001; Annetta, 2008; Martinovic *et al.*, 2014). For instance, games that are colourful and presented with two or three-dimensional environment can help in developing spatial intelligence (Becker, 2005). Spatial ability helps players to use their imagination and creativity to learn how to deal with challenges, threats and predators (Corbeil, 1999)
3. *Teamwork* - Playing certain type of computer games can help in developing teamwork (Cherenkova and Alexandrov, 2013). Children like to play computer games because they can collaborate with others to develop social skills (Prensky, 2001c).
4. *Problem-solving* - Problem-solving is the basis of many COTS and educational computer games (Gee, 2003; Holzinger *et al.*, 2001; Becker, 2005; Martinovic *et al.*, 2014). Computer games provide a meaningful problem-based learning environment that enables players to set personal goals, gather information, make decision, plan strategy, monitor and evaluate problem-solving processes (Kiili, 2005b; Prensky, 2001c). Problem-solving skill helps players to think differently to solve complex tasks faster with greater accuracy in the later stage.
5. *Concentration* – Playing computer games has immediate positive effects on attentional skill (Subrahmanyam *et al.*, 2001; Martinovic *et al.*, 2014; Cherenkova and Alexandrov, 2013). Challenging games can be powerful tools to improve attentional skill (Baniqued *et al.*, 2013).

The metacognitive skills as discussed above can be developed or improved by playing a particular type or genre of computer games as denoted in Table 2.1 (Cherenkova and Alexandrov, 2013).

Table 2.1: Game Genres and Metacognitive Skills (Cherenkova and Alexandrov, 2013)

	Metacognitive Skills				
Genre	**Multitask**	**Land Navigation**	**Team Work**	**Problem-solving**	**Concentration**
Strategy	◦	◦		◯	
Simulations		○		○	
Role-Play	◦		◯	○	
Adventure		◯		◯	
Action		◯	◦	◦	○
Driving		◦		○	◦

Note: The size of the circle is proportional to the strength of the metacognitive skills (e.g. smaller size, the less metacognitive skill is developed)

The strongest metacognitive skill in strategy genre is problem-solving skill (Cherenkova and Alexandrov, 2013) because strategy games involve planning, decision-making, and execution and adjustment of actions (Martinovic *et al.*, 2014). Simulation genre requires specific domain knowledge about the system in the game (Martinovic *et al.*, 2014) and the metacognitive skills that could be learned are land navigation and problem-solving skills (Cherenkova and Alexandrov, 2013). Role-play games allow players to get connected to the game characters (Martinovic *et al.*, 2014) and the strongest metacognitive skill learned is teamwork (Cherenkova and Alexandrov, 2013). In adventure games, a player has to overcome a series of obstacles (Martinovic *et al.*, 2014) and strongest metacognitive skills learned are land navigation, visualisation and problem-solving skills (Cherenkova and Alexandrov, 2013; Amory *et al.*, 1999). Action games require eye-hand coordination and fast reaction time (Martinovic *et al.*, 2014) and the strongest metacognitive skill acquired is land navigation (Cherenkova and Alexandrov, 2013). As for driving games, players can learn little problem-solving, concentration and land navigation skills (Cherenkova and Alexandrov, 2013).

In addition to the six game genres presented in Table 2.1, playing puzzle games also help in developing metacognitive skills. For instance, game such as *Tetris* could help to improve spatial ability. In *Tetris*, players have to imagine how a two or three-dimensional object or array would appear after it has been turned around on a specified axis with a given number of degrees (De Lisi and Wolford, 2002).

c. Affective

Playing computer games elicits a positive affective experience. A study has revealed that computer games motivate students to learn, but no effect on cognitive and metacognitive awareness (Ke, 2008b). Learning with computer games is fun because players can choose their own preference of challenging activities and avoid dangerous consequences of the same actions in a real situation (Corbeil, 1999). Motivation in playing computer games is discussed further in Section 2.6.

2.5.5 Summary

Most of the studies on DGBL are developed based on experiential learning, situated learning and constructivism. Experiential learning is a cyclic process of learning through experience. In constructivism, knowledge is actively constructed by modification of existing mental model through interaction with the experiential world. Situated learning is related to the people engaged in the activity and arises from the socially or culturally structured world. Constructivism is user-centred and situated learning focuses on setting, but both learning theories do value user’s learning experience. Computer games also support learning of multiple intelligences in cognitive and metacognitive aspects. Playing puzzle, strategy, simulations, role-play, adventure, action and driving games enable learning of certain cognitive (e.g. mathematical, logical) and metacognitive skills (e.g. multitask, land navigation, teamwork, problem-solving and concentration).

A review of the literature indicates that computer games support many well-established learning theories. The virtual world in games resembles our lived-in world. In lived-in world, we are learning everyday using different learning theories. For instance, we learn how to ride a bicycle after we fall endless times (experiential learning), we construct new knowledge of how to deal with a stranger based on our previous experience (constructivism) and we learn teamwork, planning, leadership, communication and physical skills when playing soccer (multiple intelligence). Our lived-in world is an endless space to learn. The more a computer game simulates the real world, the more learning skills could be learned through the game.

A review of the literature also indicates that there are many good learning theories in games that support effective learning. Most of these theories are limited to a certain group of researchers because school teachers do not read them. This is analogous to a good cookbook - there are fantastic ideas in the recipe book, but the chefs are not reading it. Even if the chefs read the book, they may not know the practicability of the recipes until they start cooking. Education is always about contents, theories, models and principles that are not situated in the lived-in world. Many learning theories are well established but teachers are either not aware of them or do not know how to put them into practice.

There is a need to understand the learning theories guiding the teachers' teaching practices. If the teachers do not see the importance of learning by doing (experiential learning), learning in context (situated learning) and students-centred (constructivism), the teachers may not see the necessity to change their current teaching approach. Moreover, it is also meaningful to investigate the teachers', students' and parents' awareness of cognitive or metacognitive skills learned through computer games. Even if the respondents recognise learning of different cognitive or metacognitive skills through computer games, they may not see the relationship or usefulness of these skills in mathematics learning because there is an issue of transferability.

2.6 Motivation

Motivation has multiple definitions from physiological (i.e. bodily functions and behaviour that are energised by strong external stimuli such as thirst and hunger) to psychological (i.e. cognitive, whereby many aspects of motivation are learned) perspectives (Bixler, 2006). Based on Wlodkowski's definition (as cited in Bixler, 2006, p.1) motivation is defined as

> *processes that can energise and give direction or purpose of behaviour.*

Motivation is the most important component that positively relates to effective learning (Gee, 2003; Prensky, 2003; Denis and Jouvelot, 2005; Bixler, 2006) and high motivation can frame better-learning outcomes (Bixler, 2006). Motivated students' desire to learn will stimulate them to discover the subjects.

2.6.1 Classification of Motivation

Motivation can be classified to intrinsic motivation - pushes us to act freely on our own, for the sake of it; extrinsic motivation - pulls us to act due to factors that are external to activity itself, like reward or threat; and amotivation - absence of motivation (Denis and Jouvelot, 2005). Based on these concepts, Witkin *et al.* (1977) classified learners as either field dependent and field independent learners, whereby field dependent learners are those who rely on external cues for learning (external motivation) and field independent learners are those who can manipulate learning from external cues positively (intrinsic motivation). Learners could also be classified based on achievement goals - performance achievement and mastery achievement oriented (Elliot and Harackiewicz, 1994). Performance achievement oriented learners only do what is asked and only learn what is needed to achieve the performance, whereas mastery achievement oriented learners are interested in mastering the task and learn the task for its sake and understanding (Elliot and Harackiewicz, 1994). Motivation creates a strong participation in learning, but intrinsically motivated students are more likely to spend time and effort to master the learning content for the sake of understanding due to personal interest and curiosity. Intrinsic motivation is an important element in effective learning.

2.6.2 Intrinsic Motivation

Intrinsic motivation is built on inner psychological needs that can prolong the passion for learning effectively. Eventually, learning built on intrinsic motivation tends to be more satisfying. Competence, relatedness, and autonomy are the three innate psychological needs to understand what and why someone pursues a goal (Deci and Ryan, 2000). *Competence* refers to

> *individuals' inherent desire to feel effective in interacting with the environment* (Van den Broeck *et al.*, 2010, p.982).

Relatedness refers to the

> *desire to feel connected to others—to love and care and to be loved and cared for* (Deci and Ryan, 2000, p.231)

Autonomy refers to

> *volition—the organismic desire to self-organise experience and behaviour and to have activity be concordant with one's integrated sense of self* (Deci and Ryan, 2000, p.231).

Competence, relatedness, and *aut*onomy are the essential elements in intrinsic motivation. In the next section, the discussion of motivation will focus on the DGBL.

2.6.3 Intrinsic Motivation in DGBL

Intrinsic motivation is an essential element to retain students' interest and enthusiasm to play computer games for effective learning. If there is no motivation, then there is no game playing and no learning (Gee, 2003). However, learning and instructional design processes are constantly weakly related to motivation (Duchastel, 1997). Effective employment of motivation into instructional design processes must be considered when designing DGBL (Bixler, 2006). Denis and Jouvelot (2005) also describe how DGBL should be designed based on the innate needs: (1) competence - give power to players to test and experience; (2) autonomy/competence - create obstacles so that players have to practise the game; (3) autonomy - provide alternatives that allow creativity, audacity and exploration; (4) relatedness - foster socialisation and communication during the games.

According to Wishart (1990), intrinsic motivation can be fostered through three elements - *complexity* (e.g. simulation with colour graphics), *challenges* (e.g. high score table at the end of simulation) and *control* (e.g. menus of options available to users). These motivational elements can be linked to players' innate psychological needs (i.e. competence, autonomy, relatedness) in *Motivation-driven Educational Game Design* (Denis and Jouvelot, 2005) and game space of educational games (i.e. play, explore, challenge and engage) in *Game Development Model* (Amory *et al.*, 1999). All these ideologies are combined and depicted in Figure 2.3. Collaboration is added to satisfy the need for relatedness.

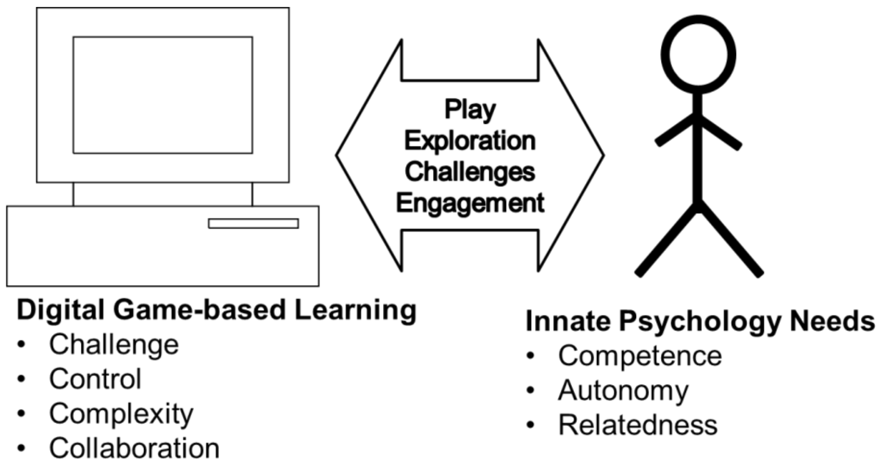

Figure 2.3: Intrinsic Motivation - Gaming and Psychological Perspectives

Based on Figure 2.3, intrinsic motivation can be viewed from two perspectives - psychological and gaming perspectives. From the psychological perspective, users are intrinsically motivated to play, explore, engage and take the challenges in games if their innate psychology is satisfied - competence, autonomy and relatedness. From the gaming perspective, to motivate users to play, explore, engage and take the challenges in games, the games should be designed with challenge, control, complexity and collaboration. When users are intrinsically motivated to play, it will deliver an effective learning outcome.

a. Challenge

The challenge is defined as

> *the degree to which individuals finds it difficult to cope with specific tasks involved* (Shin, 2006, p.3).

Computer games should provide challenges to motivate players to find the appropriate solutions to overcome the challenges (Kiili, 2005b; Amory *et al.*, 1999; Malone, 1981; Wishart, 1990). If the challenges are too easily achievable, the player may get bored; if the challenges are too tough and unachievable, the player may give up and worry (Kiili, 2005b; Malone, 1980; Denis and Jouvelot, 2005). A fun and motivating game should be challenging but achievable (Gee, 2003; Denis and Jouvelot, 2005). Computer games are fun because they are challenging.

Playful learning is driven by intrinsic motivation to engage in challenging activities (Resnick, 2004). Learners are deeply engaged by *hard fun* or *pleasantly frustrating,* which means fun and life-enhancing because it is hard, frustrating, difficult and challenging (Gee, 2007; Papert, 1998). Learning is essentially hard, but learners are having fun engaging in those activities as long as the activities can connect deeply with their personal interest and passion (Papert, 1998). When learners are engaged in enjoyable activities that are meaningful to them, they tend to have the best learning experience.

Fun is the *desire* that comes from challenge, curiosity, problem-solving and competition (Denis and Jouvelot, 2005). Fun can be defined as follows.

> *Both enjoyment and pleasure (good), and amusement and/or ridicule (bad)* (Prensky, 2001c, p.3).

Fun is defined as enjoyment and pleasure when someone has won the games, but fun may be defined as amusement and ridicule when someone has defeated the opponents. Fun in the learning context is to create relaxation and motivation to enable learners to put forth effort without resentment and learn more easily (Prensky, 2001c). Fun is a positive and desirable learning experience. Thus, fun is an important element in computer games design (Baker *et al.*, 2005). For instance, adventure games are rated as the most popular games with a fun element (Amory *et al.*, 1999).

b. Control

Fun in computer games also comes from the pleasure to control (Denis and Jouvelot, 2005). According to De Charms (as cited in Wishart, 1990, p.141),

> *man is motivated primarily by a desire to produce changes in his environment, that is to say to control it.*

The desire to control is a kind of intrinsic motivation (Wishart, 1990; Denis and Jouvelot, 2005). People will feel motivated and empowered if they feel that they are in control because it satisfies their innate psychological need for autonomy. For instance, players are motivated to play games because they have control over the game characters and decision-making in games (Gee, 2003). Games normally provide a certain level of control to the users by giving options and menus (Wishart, 1990). That is why immersive and interactive games are motivating (Cai *et al.*, 2006). Autonomy is an important element of humans' psychology needs. Many people give up in despair for the things that are not controlled. In games, players are in control of their success and failure. This positive feeling comes from being able to effectively compete in game and to exert some control over the game's outcome.

c. Complexity

The third important element in the game design is complexity (Wishart, 1990; Westera *et al.*, 2008). Computer games are fun and appealing because they require a wide variety of skills and significant problem-solving skills (Amory *et al.*, 1999; Prensky, 2001a). Popular computer games such as *FIFA, The Sims* and *Candy Crush* require not only problem-solving skills but also concentration, logical thinking and multitasking skills. The complexity of a stimulus generates perceptual curiosity in people and this high arousal can be relieved by specific exploration of the stimulus (Wishart, 1990). Curiosity leads to the desire to play and this is also an element of fun (Denis and Jouvelot, 2005). Enjoyable games should be designed to stimulate players' curiosity (Malone, 1980). For instance, to draw players' curiosity, the games should provide surprises, and the level and variety should be randomised (Malone, 1980). The appropriate level of complexity in games is desirable to stimulate users' curiosity to play. Users' curiosity to explore complex games requires a certain level of competency and autonomy.

However, it is argued that educational computer games do not require complexity to support effective learning (Westera *et al.*, 2008). Complexity in educational games should be optimal to stimulate curiosity (Malone, 1980). Simple graphics should be used (Wishart, 1990) and irrelevant multimedia elements should be avoided to optimise cognitive load (Kiili, 2005b). This could be a reason why educational computer games appeared to be less appealing because the games are designed with simplicity in mind.

d. Collaboration

The fourth important element in computer games is collaboration. Collaboration is highlighted because it satisfies the innate psychological need of relatedness. Cooperation in games is important for relatedness (Natvig and Line, 2004) and gameplay improves friendship (Chou and Tsai, 2007). DGBL built on situated learning places a strong emphasis on the social context and knowledge is constructed through participation in the learning communities and gameplay (Egenfeldt-Nielsen, 2007). Although relatedness is claimed to be important in a few studies (Natvig and Line, 2004; Chou and Tsai, 2007; Egenfeldt-Nielsen, 2007), the existence of virtual friends is proven to be ineffective (Holzinger *et al.*, 2001). A boring game cannot be made interesting by adding a few virtual friends to increase companionship. Motivation should be based on relatedness in gaming communities to get connected to other players through competitions or collaborations.

The use of role-play game in learning is also motivating because learners experience the reality of tasks in gaming (Chua, 2005). Role-play serious games such as MMORPGs are addictive owing to strong social reinforcement because other gamers are online at the same time interacting with the character (Charlton and Danforth, 2007). In role-playing games, a player can feel the sense of belonging in virtual world communities and relatedness to other players. The player may also deeply feel connected to the game characters for adoring and respecting their powers and capabilities.

2.6.4 Summary

Motivation is a process that can energise and give the purpose of behaviour. Motivation is classified into intrinsic motivation, extrinsic motivation and amotivation. Intrinsic motivation is the most important element in effective learning. Intrinsically motivated learners are mastery-achievement oriented in which they are interested in learning for its sake and understanding. Intrinsic motivation is directed by three innate psychological needs - competence, relatedness, and autonomy. Users are motivated to play games if their innate psychological needs are satisfied. To motivate users to play educational games, the games should be designed with challenge, control, complexity and collaboration (4Cs).

Human innate psychological needs are very complex and subjective to every individual. It is not a simple and straightforward task to embed 4Cs into educational computer games. The 4Cs are abstract and not tangible – every individual has their own definition of 4Cs. A game that is perceived to be challenging and complex to a teacher may be boring and less sophisticated from the students' points of view. Every individual is motivated and triggered by a different stimulus, and having a different level of expectation in 4Cs. The 4Cs try to make these innate psychological needs more tangible and visible to be implemented. The 4Cs are not only applicable to educational computer games but also other educational activities such as courseware, group discussion, conventional games and a group project. Most importantly, educators should not confine their viewpoint merely on educational computer games but to a broader perspective on how these motivation gaming models benefit their current teaching approaches.

There is a need to understand what motivates or demotivates students to learn mathematics and play games. Based on the literature, students may play games to fulfil their innate psychological needs for competence, relatedness, and autonomy. Once the students' motivational factors to play computer games have been identified, new mathematics pedagogy could be suggested based on the stimulus in games – challenge, control, complexity or collaboration. Students are also not attracted to certain types of games and there is a need to identify what is missing in these games that causes the students not to engage.

2.7 Educational Gaming Model

Educational gaming model can be classified into three generations by using encompassed learning theories (see Figure 2.4).

1st Generation	2nd Generation	3rd Generation
Edutainment	*Educational computer games*	*Educational computer games use* Social-cultural
Behaviourism *(Focus behaviour)*	Cognitivism Constructivism *(Focus learner)*	Situated learning Constructionism *(Focus setting)*

Figure 2.4: Generations of Educational Use of Games (Modified from Egenfeldt-Nielsen, 2007)

2.7.1 First Generation

According to Egenfeldt-Nielsen (2007), the first generation of educational computer games is *edutainment*, which is defined as

> *the combination of educational and entertainment use on a variety of media platforms including computer games* (Egenfeldt-Nielsen, 2007, p.264).

The word *edutainment* was invented by Dr Chris Daniels in 1975 and it embraced the philosophy of *education* through *entertainment* (Daniels, 2010; Cruz Jr., 2012). Edutainment and instructional computer games were once considered as the saviour of education because of their ability to entertain and educate simultaneously (Charsky, 2010). The initial outcome of edutainment was promising (Van Eck, 2006) but it was also littered with *Shavian reversals* attributed by Papert (1998).

> *Shavian reversals is offspring that keep the bad features of each parent and lose the good ones, which are visible in most software products that claim to come from a mating of education and entertainment (Papert 1998, p.88).*

As a result, edutainment is also claimed to be a boring game. Edutainment has a bad reputation for being the worst type of education (drill-and-practice) (Van Eck, 2006; Charsky, 2010) because it *drills-and-kills* learning (Van Eck, 2006). In edutainment, neither the learning nor the game is effective and engaging (Van Eck, 2006).

Edutainment is built on behaviourism learning theory in which learning of skills and content is achieved through reinforcement of training and practice (Egenfeldt-Nielsen, 2007). Edutainment usually starts with an introduction of a new concept and follows by subsequent activities for learners to practise the newly learned concepts. During these activities, feedback will be given. For instance, scores are given for correct answers, and hints are provided for wrong answers. Edutainment is disappointing because it lacks interactivity and it forces the learner through a linear progression without the options for wandering and alternatives that are available in video games (Denis and Jouvelot, 2005). Edutainment encourages learners to practice more to response correctly to the observed action or stimuli (Egenfeldt-Nielsen, 2007). This type of learning method does not encourage creativity and it has long been criticised by many educationists.

This *carrot and stick* approach is useful for fact and rote memorisation learning, but it is insufficient for the development of flexible and sophisticated understanding (Charsky, 2010). Apparently, drill-and-practice with edutainment is more suitable for predetermined content and to train lower thinking skills such as memorisation of facts, concepts and procedures. These surface approaches to learning could not develop the necessary understanding to enable students to apply what they have learned. That is why many students who pass their paper-based exam could not apply their knowledge in practice (Gee, 2008a).

Limitations of edutainment could be summarised as follows, (1) a lack of intrinsic motivation as it uses extrinsic motivation (rewards) to motivate learners to learn; (2) no integrated learning experience or learning from the game as the content is delivered straight forward; (3) drill-and-practice learning principles, which is more to training and not to learning because players just have to memorise the results without understanding the concepts; (4) simple gameplay such as arcade and adventure games (Egenfeldt-Nielsen, 2007). Normally, edutainment development does not require a big budget as it uses simple technology and students are expected to learn on their own using edutainment without the help of a teacher (Egenfeldt-Nielsen, 2007). However, if the deployment of edutainment could only improve students' lower thinking skills and memorisation, it might not be worthwhile to use it to replace the conventional classroom teaching.

2.7.2 Second Generation

The second generation of educational computer games are built on cognitivism and constructivism, and the foci are metacognitive skills, problem-solving, analysing, perceiving and spatial ability (Egenfeldt-Nielsen, 2007). Instructional design has undergone a paradigm shift towards a more student-centred, customised, active learning approach and indirect consideration of motivation in instructional design theories (Reigeluth, 1999). According to cognitivism,

> *memory is given a prominent role in the learning process. Learning results when information is stored in memory in an organised, meaningful manner (Ertmer & Newby, 2013, p.52).*

Cognitive structures are crucial for meaningful learning and people have underlying schemas that represent what they have learned (Egenfeldt-Nielsen, 2007). Thus, the second generation of computer games are built on different approaches (different ways to approach the same topic) to suit different learner (learner focus) because every learner has different learning ability and speed (Egenfeldt-Nielsen, 2007).

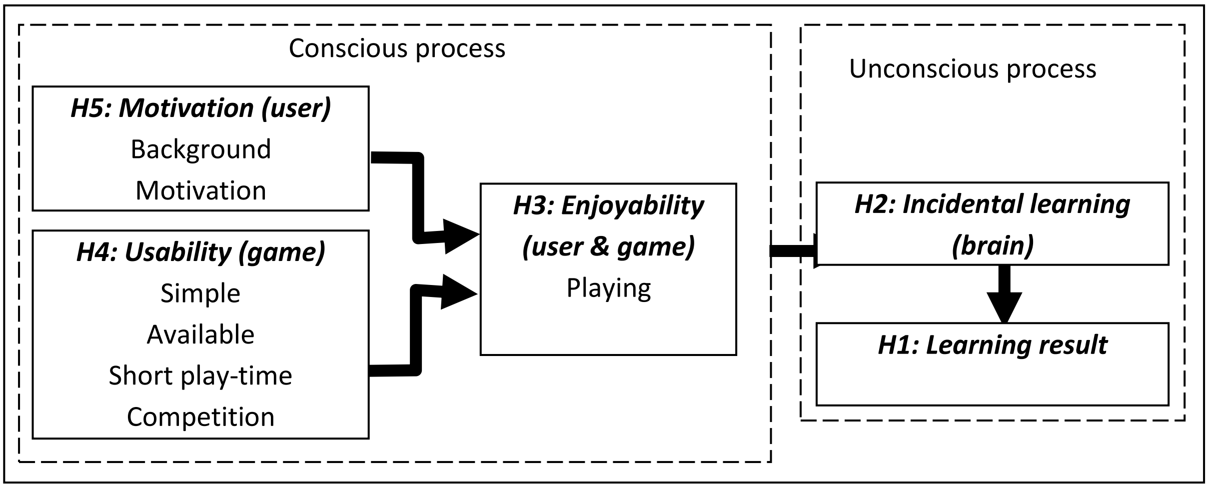

Figure 2.5: User-centred game-based learning (Ebner and Holzinger, 2007)

The user-centred game-based learning model (Figure 2.5) fits the second generation of educational computer games because it focuses on learners and learning of metacognitive skills. In the user-centred game-based learning model, the learning process is divided into conscious and unconscious processes. To generate an enjoyable playing experience, it is essential to understand the user's background and motivational factors (H5) and having a usable game that is simple without endless instructions to read, available at any time anywhere, short play time and featured with competition (H4) (Ebner and Holzinger, 2007). While playing the game, the user unconsciously experiences incidental learning (H2) that generates a learning result (H1) (Ebner and Holzinger, 2007).

Prior to deployment of a computer game, the suitability of the game to fit the users' level of understanding should be considered. For instance, games designed for adults may not be suitable for kids and vice versa. Computer games that failed to take users' motivation and games' usability into design consideration may not generate incidental learning. Incidental learning is also a form of experiential learning (Fenwick, 2001).

2.7.3 Third Generation

The third generation educational computer games place less emphasis on the actual learning content, but focus more on the students' engagement, experience and participation (individually or collaboration) in the social context or learning communities in games (Egenfeldt-Nielsen, 2007). The learning process is mediated in a social context and it stresses on constructionism, situated learning and socio-cultural environment (Egenfeldt-Nielsen, 2007).

Constructionism focuses more on the art of learning, or learning to learn, and on the significance of making things in learning (Ackermann, 2001, p.1).

Constructionism is also more situated and pragmatic than constructivism (Ackermann, 2001). Learning is regarded as a process of subjective and meaning making through engagement and interaction in the gaming communities. Situated learning has been discussed earlier in Section 2.5.3.

2.7.4 Summary

Educational computer games have gone through three generations of transformation and every generation is built on different learning principles. The first generation of educational games or edutainments are built on behaviourism. The games stress on drill-and-practice and memorisation of learning content – more akin to training than learning. The second generation of educational games is built on cognitivism and constructivism. The games stress on metacognitive skills and problem-based learning - learn by doing, learn from experience, learn from mistakes and understanding of the phenomena. The third generation of educational games is built on situated learning and constructionism. The games stress on social-cultural and participation in the learning communities - learning content, skills, attitudes, culture, tools and communities from playing games.

A review of the literature has revealed that the first generation of educational computer games are discouraging. However, the games correspond well to schools' assessment – drill-and-practice of learning content. Schools normally do not assess metacognitive skills. In contrast, the second and the third generations of educational computer games are desirable for learning. These two generations of games are similar in the sense that players are learning through experience and problem-solving. Every player has a unique learning experience subjected to the game's interaction and prior knowledge. The games also support learning of metacognitive skills, as in COTS games.

There is a need to understand the purpose of educational computer games from the teachers', students' and parents' points of view, whether for drill-and-practice, problem-based learning, or learning from social culture in games. If the respondents' understanding is limited to questions and answers as in edutainment, they may not appreciate the use of computer games for learning of higher order thinking skills (HOTS) as in the second and third generations of educational games. Interviews with teachers may also reveal their teaching philosophy of whether these three generations of educational computer games can fit into their teaching approach. For instance, if teachers focus on memorisation of procedures and knowledge, edutainments built on behaviourism may fit the purpose. However, if the focus is

HOTS, teachers may consider using computer games built on cognitivism, constructivism, situated learning and constructionism.

2.8 Conclusion

A review of the literature has revealed that problem-solving in mathematics depends on three broad domains - cognitive, metacognitive and affective. The purpose of this study is to uncover the potential use of gaming pedagogy in supporting these domain areas. For the digital native students who are also labelled as the *game generation,* computer games are fun, fresh, appealing, and they think that computer games are just another part of the real world. Computer games such as educational and COTS games can be used in DGBL. Playing computer games is a form of playful learning. When students are engaged in enjoyable gaming activities that are meaningful to them, they tend to have the best learning experience. Computer games are embedded with many good learning theories such as experiential learning, constructivism and situated learning. When playing computer games, players are going through the cycle of hypothesis formulation, testing, and revision. The learning is not only meaningful and relevant but can be applied and practised within that context. Essentially, computer games support the learning of cognitive and metacognitive skills as well as motivate players to engage in playful learning.

The findings in the literature have revealed a few issues that needed to be addressed during the data collection. Firstly, the existing mathematics education would need to be explored. It is essential to understand whether students are motivated to learn mathematics and equipped with the essential mathematics knowledge and skills. Then, it is important to explore the technology and gaming experience of the research participants. This aims to understand how they learn modern technologies and computer games. Finally, it is essential to explore what the research participants understand about DGBL. This would suggest the possible change of mathematics pedagogy by looking at how students engage in computer games.

Chapter 3: Methodology

3.0 Introduction

This chapter discusses the methods or a set of practices used to collect data. While no research method is known to be superior to any other, it is important to choose the right research questions that can best be answered by an appropriate method or combination of methods (Fraenkel and Wallen, 2006). This study has employed mixed methods approach. The justification for this approach will be discussed in this chapter. Then, the challenges of implementing a mixed methods approach will be presented. After that, the chapter will examine the paradigm worldview, theoretical lens, methodological approach and methods of data collection. Finally, a sample of study and two research instruments (i.e. questionnaire and interview) will be identified to collect the quantitative and qualitative data.

3.1 Mixed Methods Research

There are various definitions of mixed methods research found in the literature. Before embarking on a further discussion about mixed methods research, I would need to clarify the term *mixed methods* research and define its philosophical assumptions and techniques.

> *Mixed method designs as those that include at least one quantitative method (designed to collect numbers) and one qualitative method (designed to collect words)* (Greene *et al.*, 1989, p.256).
>
> *Mixed research is the class of research studies in which a researcher mixes or combines quantitative and qualitative research approaches and techniques into a single research study* (Johnson and Christensen, 2008, p.441).
>
> *Mixed methods here as research in which the investigator collects and analyses data, integrates the findings, and draws inferences using both qualitative and quantitative approaches or methods in a single study or a program of inquiry* (Tashakkori and Creswell, 2007, p.4).

Based on these definitions, a mixed methods research uses quantitative and qualitative approaches, techniques or methods starting from the data collection to the output of the study such as data analysis.

Johnson *et al.* (2007) provide a general definition of mixed methods by analysing 19 different definitions:

Mixed methods research is the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breadth and depth of understanding and corroboration (Johnson *et al.*, 2007, p.123).

Based on this definition, mixed methods research is not only viewed as a type of research that combines methods, but also a methodology that combines both quantitative and qualitative methods, spanning from philosophical assumptions to inference techniques. Furthermore, they have argued that there is no single perfect definition for mixed methods research as the definition would change over a period of time as it continues to develop (Johnson *et al.*, 2007).

Creswell and Plano Clark (2007) gave a more comprehensive definition of mixed methods research that includes both the approach philosophy and method:

Mixed methods research is a research design with philosophical assumptions as well as methods of inquiry. As a methodology, it involves philosophical assumptions that guide the direction of the collection and analysis of data and the mixture of qualitative and quantitative approaches in many phases in the research process. As a method, it focuses on collecting, analysing, and mixing both quantitative and qualitative data in a single study or series of studies. Its central premise is that the use of quantitative and qualitative approaches in combination provides a better understanding of research problems than either approach alone (Creswell and Plano Clark, 2007, p.5).

This definition is used as a guideline in this study as it provides a more comprehensive view of mixed methods. Not all research studies justify the use of mixed methods. Further explanation on the choice of the approach adopted by this study will be discussed in the following sections.

3.2 Justification of Mixed Methods

In general, although it is not practical to use more than one research methods in a single study, there are potential benefits implementing multiple methods that researchers should be aware of (Johnson and Christensen, 2008). Mixed methods research is very practical in a sense where the researcher has the flexibility to use any possible method to answer the research questions (Creswell and Plano Clark, 2011). There are a few reasons justify the use of mixed methods.

3.2.1 One Data Source is Insufficient

Neither quantitative nor qualitative data alone can provide a comprehensive evaluation of how mathematics pedagogy can be influenced by children's engagement in computer games. The combination of quantitative and qualitative data provides a more comprehensive understanding of a research problem because

> *limitations of one method can be offset by the strengths of the other method* (Creswell and Plano Clark, 2011, p.8).

In other words, the resulting mixture or combination has complementary strengths and non-overlapping weaknesses (Johnson and Christensen, 2008).

Quantitative methods are very useful for making statistical generalisations from a sample within a population by investigating a large number of people and evaluating responses to a few variables (Johnson and Christensen, 2008; Creswell and Plano Clark, 2011). The methods provide a general understanding of the population but no detailed understanding of an individual. Quantitative methods are less useful for exploring participants' personal perspectives and personal meanings about phenomena in their lives (Johnson and Christensen, 2008).

To provide a more detailed understanding of a few individuals, qualitative data should be collected. Qualitative research is useful for studying a few individuals by exploring their perspectives in greater depth to obtain rich information about their worldviews and personal meanings (Johnson and Christensen, 2008; Creswell and Plano Clark, 2011). However, the findings from qualitative research cannot be generalised beyond the local research participants because the research is typically based on small non-random sample (Johnson and Christensen, 2008).

The mixed methods research can achieve a triangulation of data.

> *Triangulation is the term given when the researcher seeks convergence and corroboration of results from different methods studying the same phenomenon. When you want to make a statement with confidence, you want your pieces of evidence to lead to the same conclusion or inferences* (Johnson and Christensen, 2008, p.451).

In this study, quantitative and qualitative data were collected simultaneously, analysed individually, and then triangulated to identify points of convergence and divergence. Although the issues covered in both research methods were similar, the conversational nature of the interviews allowed flexible responses from the participants to elaborate on the issues. Through the qualitative interviews, I could understand the participants' matters of concern and any new issue that might not be covered in my interview questions. Moreover, qualitative interviews allowed personal interaction with the research participants and provided rich information through the verbal or non-verbal communications such as their facial expressions, feelings, and attitude. During the quantitative data collection, I did not have the opportunity to get to know any of the students personally because both schools distributed the survey questionnaire through their respective school teachers. Quantitative data alone would not be sufficient for me to get to know the participants personally.

Sometimes, mixed research may yield contradictory findings (Johnson and Christensen, 2008; Creswell and Plano Clark, 2011). For instance in Bragg (2007), the researcher explored students' attitudes towards computer games in learning mathematics using quantitative and qualitative data. The findings from both types of data were reported to be conflicting. The contradictory finding would not be known if only one type of data was collected.

3.2.2 A Need to Explain Initial Results

Other than triangulation, a mixed methods approach could be used to achieve complementary and expansion in this study. Mixed methods approach seeks for

> *elaboration, enhancement, illustration and clarification of the results from one method with results from the other method* (Johnson and Christensen, 2008, p.451)

In this study, quantitative data was an incomplete understanding of my research questions that required further clarification. For instance, quantitative data revealed that one of the female students' favourite game was *Counter-Strike*, a first-person shooter game. However, to better understand the reasons behind this finding, and to gain additional detailed insights, a qualitative interview was necessary. An interview with a female student helped me understand that she liked to play shooting games (i.e. male-targeted genre) because she wanted to spend quality time with her younger brothers.

In another example, quantitative data revealed that students were not very positive towards DGBL. Through an interview with a male student, I speculated that secondary school students might not like to play educational computer games because most of the games were designed for pre-school kids.

Prior to the data collection, I assumed that the quantitative method was the best overall approach to explore my research questions. However, through these interviews, the students' explanations had helped me to understand what the quantitative data actually means. The in-depth interviews were very useful to further explain the quantitative data.

3.3 Challenges in Using Mixed Methods

3.3.1 Complexity

Despite numerous advantages of mixed methods that could enhance the understanding of issues faced in educational research, there were significant challenges raised in this study.

The main difficulty was the skills required to be able to conduct both quantitative and qualitative research. According to Creswell and Plano Clark (2011), to conduct a mixed methods research, researchers should be familiar with both quantitative and qualitative data collection and analysis techniques. Mixed methods research requires expertise in designing and implementing both qualitative and quantitative phases (Johnson and Christensen, 2008; Fraenkel and Wallen, 2006). Thus, a team of specialists is recommended instead of a single researcher (Johnson and Christensen, 2008; Fraenkel and Wallen, 2006). Furthermore, conducting a research involving a sophisticated quantitative study and an in-depth qualitative investigation at the same time is very challenging and may lead to poor qualitative or quantitative work, i.e., it is difficult to excel in both areas (Fraenkel and Wallen, 2006).

I was working alone in this study so I had to learn many different skills in a short period of time. Although I had experience in conducting quantitative research, doing qualitative research was something entirely new in my research pathway. Qualitative research required me to read a lot about mixed methods approach especially with the qualitative interview.

3.3.2 Extensive Time and Efforts

It is noted in the literature (i.e. Johnson and Christensen, 2008; Fraenkel and Wallen, 2006; Creswell and Plano Clark, 2011) that the complex design of mixed methods requires extensive time and efforts. In this study, quantitative data was collected within several days, but qualitative interviews took a few months to complete. Qualitative data collection usually requires more time than that needed for quantitative data (Creswell, 2013).

The application for permission to conduct a research in government schools also requires extensive time and efforts. For Malaysian universities' researchers, approval has to be sought from the MOE. However, UNMC is regarded as a foreign university so the process of application is much more complicated as it involves several government agencies (e.g. MOE, immigration and Prime Minister's department). Furthermore, when the location of the study is in Sarawak, the whole process of application is becoming more complicated because the state has its own immigration controls. Several approvals have to be sought from both the national and state governments.

3.3.3 Disapproval

Some researchers may not be convinced and understand the value of mixed methods design (Johnson and Christensen, 2008; Creswell and Plano Clark, 2011). A review of the literature has revealed that several past studies in DGBL (e.g. Ke, 2008a; Bragg, 2007; Dow *et al.*, 2008; Warren *et al.*, 2012; Reed *et al.*, 2010; Tüzün *et al.*, 2009; Margaryan *et al.*, 2011; Vale and Leder, 2004; Ke, 2014; Lonsdale, 2011) have employed mixed methods approach.

Meta-analysis conducted by Ke (2009) revealed that 15% of the studies on game effects employed mixed methods design, and four out of 17 studies on game design employed mixed methods design too. Other studies supporting the use of mixed methods approach include Ross and Morrison (2004) and Savenye and Robinson (1996) in the area of instructional technology; Fraenkel and Wallen (2006) and Mertens (2010) in educational research. After reviewing the literature, the arguments in favour for the use of the mixed methods approach outweigh those that would caution its use. In particular, the mixed method approach would provide a more comprehensive view of my research findings.

3.4 Designing and Conducting Mixed Methods Research

A research process should include four basic elements: epistemology, theoretical perspective, methodology and method (Crotty, 1998). Crotty's four elements are then adapted by Creswell and Plano Clark (2011) to represent four levels of research developments - paradigm worldview, theoretical lens, methodological approach and methods of data collection (refer to Figure 3.1).

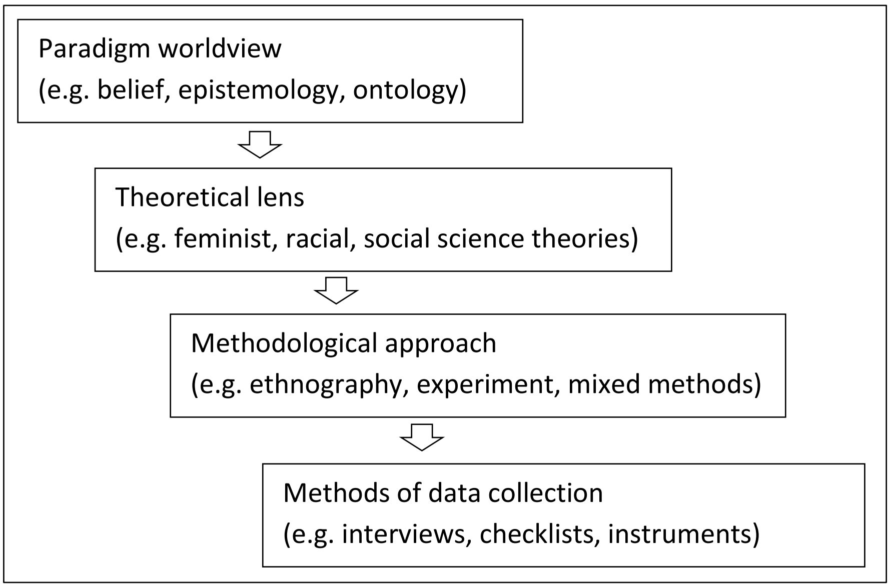

Figure 3.1: Four Levels of Developing a Research Study (Creswell and Plano Clark, 2011)

3.4.1 Paradigm Worldview

The paradigm or worldview is one’s shared beliefs and values (Creswell and Plano Clark, 2011) or philosophical assumptions (Johnson and Christensen, 2008). The paradigm or worldview embraced in this study was *pragmatism*. Other than pragmatism, mixed methods research could employ multiple worldviews such as postpositivism, constructivism and participatory (Creswell and Plano Clark, 2011). However, pragmatism is the most popular paradigm for mixed methods researchers (Tashakkori and Teddlie (eds.), 2003; Johnson and Christensen, 2008). Mixed methods research often adheres to the pragmatist philosophy whereby the researcher mixes research components in any way he or she believes will work for the given research problem, research questions and investigation circumstances (Johnson and Christensen, 2008; Creswell and Plano Clark, 2011). A pragmatist is more concerned with using known working method to answer the research questions instead of classifying the research as quantitative or qualitative. Based on this paradigm, both quantitative and qualitative methods can be used in a single study, and the research question is the main focus of the study (i.e. more important than the method or the philosophical worldview) (Tashakkori and Teddlie (eds.), 2003). This philosophy draws on many ideas, including employing what works by mixing multiple research components and approaches in accordance with a researcher’s belief and practice.

3.4.2 Theoretical Lens

The second stage is to determine the theoretical lens. A theoretical lens in mixed methods is

> *a stance or standpoint taken by the researcher that provides direction for many phases of a mixed methods project* (Creswell and Plano Clark, 2011, p.47).

The theoretical lens of this study has been discussed in Chapter 2 and summarised in Figure 3.2.

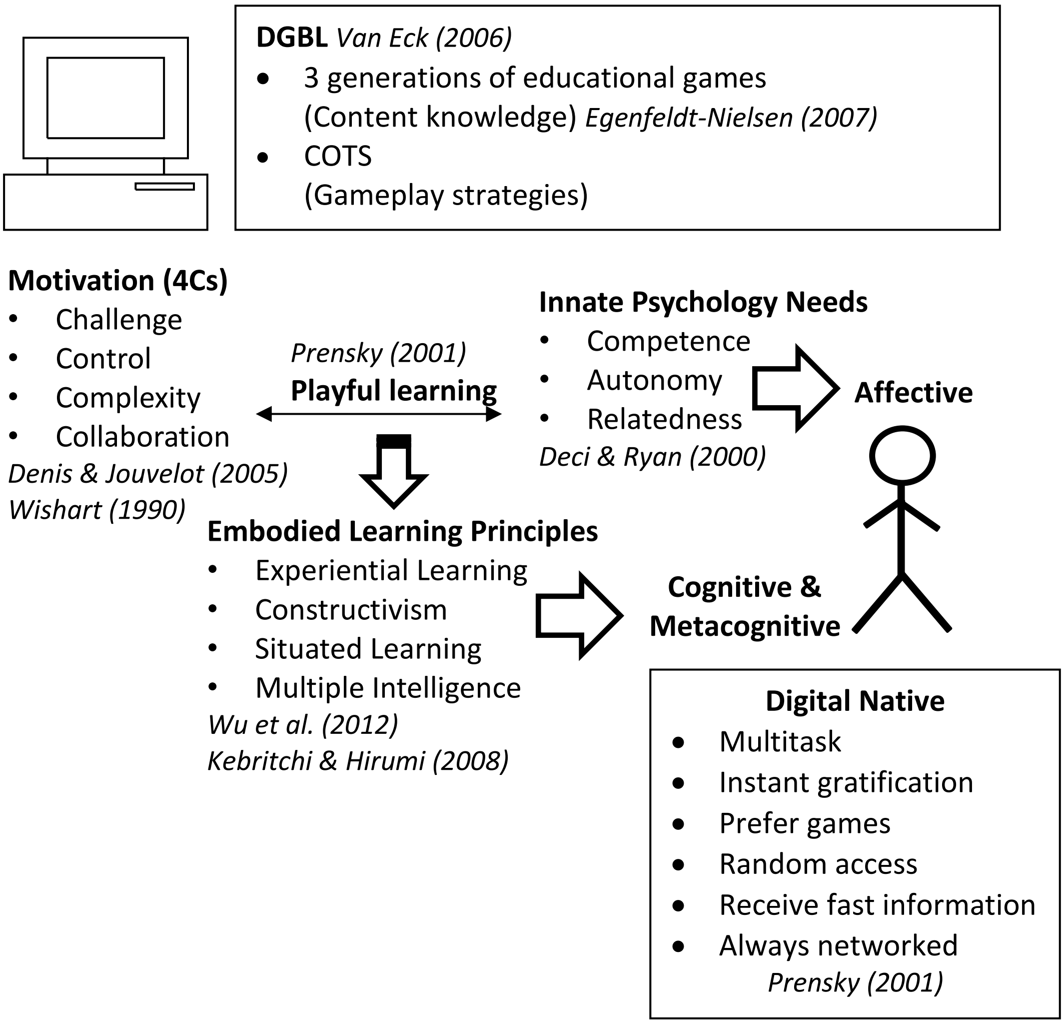

Figure 3.2: Theoretical Lens

Children's engagement with computer games is driven by the motivation elements (4Cs) of DGBL. When children are engaged in playful learning, the innate psychological needs are satisfied and that will create a positive *affective* experience. During the gameplay, they are engaged in experiential learning, situated learning and constructivism to develop multiple intelligence in *cognitive* and *metacognitive* aspects. These *cognitive, metacognitive* and *affective* elements are important in mathematics education.

Once the philosophical foundation and theoretical foundation have been identified, the next step is to choose a methodological approach. In this study, a mixed methods approach was employed.

3.4.3 Methodological approach

There are several key principles for designing a mixed methods study: using a fixed and/or emergent design; identifying a design approach to use; matching design to the study's problem, purpose and questions; and being explicit about the reason for mixing methods (Creswell and Plano Clark, 2011).

In this study, a *fixed mixed methods* design was employed because the use of quantitative and qualitative methods was already determined at the start of the research process. *Fixed mixed methods* design was appropriate for the purpose of my research questions. For instance, one of my research questions is, "what are students' experiences of playing video/computer games?" To answer the question, I needed to adopt both quantitative (i.e. hours spent, types of the game played) and qualitative methods (i.e. what students think about digital games?). Apparently, the research design should always be able to give an answer to the research problem, purpose or question (Watkins and Gioia, 2015). Another reason for the adoption of a fixed mixed methods design was that the sample population of this study had been identified before the data collection. A fixed method should be used if the sample has been identified (Watkins and Gioia, 2015).

Once the *fixed mixed methods design* was determined, a design approach was selected – a *topology-based* approach. Based on this approach, I placed emphasis in selecting an appropriate design from an existing topology.

> *A topology-based approach to mixed methods design emphasises the classification of useful mixed methods designs and the selection and adaptation of a particular design to a study's purpose and questions* (Creswell and Plano Clark, 2011, p.55).

A topology-based approach is highly recommended for researchers who are new to mixed methods studies, and that it is the most widely discussed approach in the mixed methods literature (Creswell and Plano Clark, 2011). It was more appropriate for me as a new researcher to choose an existing research design that matched my research's problem, purpose, and questions.

		Time Order Decision	
		Concurrent	Sequential
Paradigm Emphasis Decision	Equal Status	**QUAL + QUAN**	QUAL → QUAN QUAN → QUAL
	Dominant Status	QUAL + quan QUAN + qual	QUAL → quan qual → QUAN QUAN → qual quan → QUAL

- qual or QUAL stand for qualitative research
- quan or QUAN stand for quantitative research
- Capital letters denote higher priority
- Lower case letters denote lower priority
- (+) represents a concurrent collection of data
- (→) represents a sequential collection of data

Figure 3.3: Mixed methods design matrix (Johnson and Christensen, 2008)

I selected a particular research design from a range of available mixed methods designs. Mixed methods research can be conceptualised as a function of four dimensions - (1) time orientation of the qualitative and quantitative components (i.e. concurrent vs. sequential), (2) paradigm emphasis (i.e. equal status vs. dominant status) that is denoted by a matrix with four cells depicted in Figure 3.3 (Johnson and Christensen, 2008), (3) the level of interaction (i.e. independent or interactive) and (4) the procedures for mixing (i.e. mixing during data collection, data analysis or design) (Creswell and Plano Clark, 2011).

Based on these four dimensions, Creswell and Plano Clark (2011) have presented six prototypical versions of the major mixed methods research designs - convergent parallel, explanatory sequential, exploratory sequential, embedded design, transformative and multiphase. The most popular mixed methods design is *convergent parallel design* (i.e. denoted as QUAL + QUAN) (Creswell and Plano Clark, 2011), and it was employed in this study (see Figure 3.4).

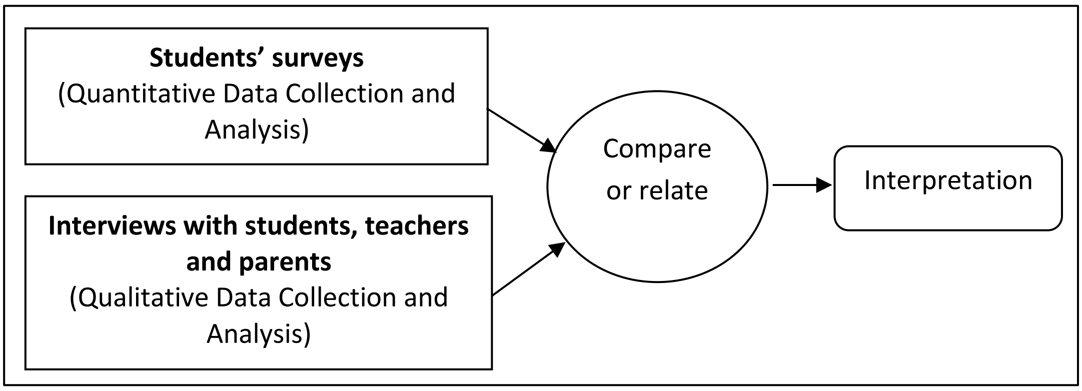

Figure 3.4: Convergent parallel design adapted from Creswell and Plano Clark (2011)

The adapted convergent parallel design of this study used concurrent timing to administer the quantitative survey and qualitative interview components. Both components were prioritised equally, and that they were analysed independently. In the final interpretation, both the quantitative and qualitative results were combined to provide the holistic and consolidated findings of this study. It should be noted that the *convergent parallel design* is in line with the pragmatist paradigm and for a single researcher who can collect a limited amount of quantitative and qualitative data (Creswell and Plano Clark, 2011). The *convergent parallel design* was adopted due to practical considerations. In particular, the time constraints (i.e. approximately four weeks period) for data collection rendered the collection of both types of data must be accomplished within that short period of time.

3.4.4 Methods of data collection

a. Quantitative Questionnaire

There are three main approaches to quantitative research: experimental, causal-comparative and correlational (Johnson and Christensen, 2008). The causal-comparative approach was employed in this study.

> *In causal-comparative research, investigators attempt to determine the cause or consequences of differences that already exist between or among groups of individuals* (Fraenkel and Wallen, 2006, p.370).

In a simple causal-comparative study, there must be one categorical variable (independent) and one quantitative variable (dependent) (Johnson and Christensen, 2008). However, the independent variable is non-manipulative (Cohen *et al.*, 2007). In this study, the quantitative data collected were compared to examine the relationship between the non-manipulative categorical variables (e.g. gender) and the dependent variables (i.e. favourite game genres). I explored the effects (dependent variable) caused by membership in a group (independent variable).

Quantitative data in this study was collected using a survey questionnaire that was adapted from instruments in the literature (i.e. Kennedy *et al.*, 2008b; Teo, 2013; Pierce *et al.*, 2007).

1. The instrument developed by Kennedy et al. (2008b) is widely used[2]. The current study questionnaire used the *technology accessibility* items from Kennedy et al. (2008b).
2. To measure students' perceptions of their degree of digital native-ness, the Digital Natives Assessment Scale (DNAS) developed by Teo (2013) was adopted. Although this instrument was only developed recently, the author (Teo, 2013) has tested its validity and reliability. Furthermore, this tool was

[2] Approximately 900 citations from 2008 to 2016 in the Google Scholar

easily administered, and all the factors used in the instruments were aligned with the definition of the digital native introduced by Prensky (2001a).

3. To measure students' attitudes towards learning mathematics with technology, the Mathematics and Technology Attitudes Score (MTAS) was adapted from Pierce et al. (2007), in which one of the scales (i.e. attitude towards the use of technology for learning mathematics) was tailored to computer games.
4. In addition to developing a questionnaire based on these three instruments (i.e. Kennedy *et al.*, 2008b; Teo, 2013; Pierce *et al.*, 2007), additional questions were added to assist in answering the research problem.

To validate and complement the quantitative data, qualitative interviews were conducted. It is less likely that researchers will make a mistake if they combine two or more research methods (Johnson and Christensen, 2008).

b. Qualitative Interview

There are five main approaches to qualitative research - biography, phenomenology, grounded theory, case studies and ethnography (Fraenkel and Wallen, 2006). In this study, phenomenology was adopted. A phenomenological study,

> *describes the meaning for several individuals of their lived experiences of a concept or a phenomenon. Phenomenologists focus on describing what all participants have in common as they experience a phenomenon* (Creswell, 2006, pp.57–58).

A phenomenological study also hopes to gain some insight into the world of the participants, and to describe their perceptions and reactions (Fraenkel and Wallen, 2006). Phenomenology study is suitable for research that requires an understanding of several individuals' common or shared experiences of a phenomenon (Creswell, 2006). In this study, data was collected from students, teachers and parents who had experienced the same phenomenon (e.g. gaming). A composite description of the essence of the experience for all the individuals was developed.

In-depth interview or qualitative interview is the most commonly used method in phenomenology study or qualitative research (Johnson and Christensen, 2008) because it can be used to obtain detailed information about what is in the participants' mind - thoughts, beliefs, knowledge, reasoning, motivations, and feelings about something (Fraenkel and Wallen, 2006; Johnson and Christensen, 2008). According to Patton (1987) (as cited in Johnson and Christensen, 2008, p.207),

> *the qualitative interview allows a researcher to enter into the inner world of another person and to gain understanding of that person's perspective.*

For instance, I wanted to know a student's thoughts, beliefs and feelings about the use of computer games to learn mathematics. Some of the questions asked during the interview include:

> *Imagine that one day your mathematics teacher is using a computer game to teach in the classroom, how would you feel? Could you explain the reason behind this?*

The interviews were very useful in understanding what the students were thinking and why they thought what they did.

There are four types of interviews: (1) the closed quantitative interview, (2) the standardised open-ended interview, (3) the interview guide approach and (4) the informal, conversational interview (Johnson and Christensen, 2008; Fraenkel and Wallen, 2006). In this study, a combination of closed quantitative and standardised open-ended interview was employed whereby the exact wording and sequence of questions were determined in advance. All participants were asked identical research issues in the same order. This particular type of interview was used so that all respondents would answer the same questions and go through the same interview protocol. It would allow a more consistent comparison of responses because data was exhaustive for each person on the topics addressed in the interview. Furthermore, this could reduce bias due to gender, ethnicity and other demographic or stratified differences.

The interview was voice recorded. The purpose of the audio recording was to assist the process of transcription and ensure that what the participants said were captured completely. The audio recording was sufficient as I was seeking for views and perceptions. No video was captured because I did not conduct any experiment to see how children played computer games. Classroom observation was not used in this study because looking at teachers' current practices were not going to help me to understand the teachers' views and perceptions.

In this study two sets of findings were merged and consolidated for the final overall interpretation of data. The *convergent parallel design* allowed comparison of quantitative statistical results with qualitative interviews for the purpose of validation, complementary for a complete understanding of a phenomenon and illustration of quantitative results with qualitative findings (Creswell and Plano Clark, 2011).

3.5 Sampling

In mixed methods research, sampling is complicated since the quantitative and qualitative issues have to be solved simultaneously (Mertens, 2010). Moreover, a different type of mixed methods design has different sampling consideration (Creswell and Plano Clark, 2011). Data in mixed methods research designs can be collected on the same or different samples using various ways to select samples in quantitative and qualitative research (Johnson and Christensen, 2008). The *convergent parallel design* employed in this study took into consideration the four sampling decisions recommended by Creswell and Plano Clark (2011).

(i) Will the two samples include different or the same individuals?

In the mixed methods research framework, one of the ways to classify the sampling design is based on the relationship between the quantitative and qualitative samples: (1) identical – the same people participate in both the quantitative and qualitative studies; (2) parallel – samples for quantitative and qualitative components are different but drawn from the same population; (3) nested – participants selected for one phase of study represent a subset of those participants who were chosen for the other phase of study; (4) multilevel – use of quantitative and qualitative samples that are obtained from different levels of population under the study (Onwuegbuzie and Collins, 2007; Mertens, 2010; Johnson and Christensen, 2008).

For a mixed methods research that adopts a *convergent parallel design*, the samples can include the same or different individuals and that they depend on the purpose of the study (Creswell and Plano Clark, 2011). In this study, I attempted to synthesise information on my research purpose from different levels of participants (i.e. students, teachers, and parents). Furthermore, two sets of findings from students' surveys and students' interviews were analysed by investigating their corroboration, comparison, and relationship. I used both *multilevel* and *nested* samplings. The quantitative data was collected through students' surveys, and the qualitative interview data was collected from a sub-sample of the same group of students (nested sampling). Moreover, the qualitative interview data was also gathered from teachers and parents (multilevel sampling).

(ii) Will the samples be of the same size?

In a mixed methods research, a good practice is to have the size of the qualitative sample that is much smaller than the quantitative sample (Creswell and Plano Clark, 2011). In the quantitative data collection, a large sample size is better than a smaller one for greater reliability and that it enables more sophisticated statistical tools to be used (Cohen *et al.*, 2007). However, in a qualitative data collection (i.e. interview), small sample size is more favourable than the large sample size for a more in-depth investigation (Cohen *et al.*, 2007). In fact, there is no clear cut answer to what constitutes an adequate or sufficient size for a sample (Fraenkel and Wallen, 2006; Cohen *et al.*, 2007) as it depends on the purpose of the study and the nature of the population (Cohen *et al.*, 2007).

For instance, two past studies (Bikos *et al.*, 2007a, 2007b) used a sample size of 32 for both quantitative and qualitative data collection. In their conclusion, Bikos et al. mentioned that a sample size of 32 was too small for quantitative data analysis and resulted in low statistical power in their study. However, a sample size of 32 was too large for qualitative analysis in finding individual differences.

In this study, the sample size for quantitative and qualitative data was different. If the sample size was too small, statistical analysis could not be conducted on quantitative data, while if the sample size was too big, the richness of qualitative data could not be obtained. This, however, raised another question of how the comparison of quantitative and qualitative data could be done if both samples were different in size. According to Creswell and Plano Clark (2011), some researchers do not perceive the size difference as a problem because the intention of collecting quantitative data is to make a generalisation about a population while the intention of collecting qualitative data is to seek an in-depth understanding of a few people. Both methods serve different purpose. Therefore, the decision of using a different sample size for quantitative and qualitative data was the best option in this study.

(iii) Will the same concept be assessed qualitatively and quantitatively?

In this study, the same concepts were addressed in both the quantitative and qualitative data collection. For instance, the quantitative survey addressed the concepts of mathematics learning, computer, technology skills, computer games and the use of computer games in learning mathematics. Similarly, the qualitative interviews were also assessing the same concepts.

(iv) Will the data be collected from two independent sources or a single source?

Quantitative and qualitative data in this study were obtained from two separate sources (i.e. the survey was independent of the interview). Quantitative data was collected using a survey and qualitative data was collected using an interview. This approach is recommended in a convergent design (Creswell and Plano Clark, 2011).

Other than the four sampling decisions as stated above, some authors (Onwuegbuzie and Collins, 2007; Mertens, 2010; Johnson and Christensen, 2008) classified sampling design based on time-orientation, i.e., whether concurrent or sequential. Since the *convergent parallel design* was employed in this study, *concurrent nested sampling* and *concurrent multilevel sampling* strategies were adopted. The sampling approach used in this study was similar to a past study (i.e. Mertens, D.M., Holmes, H., Harris, R., & Brandt, 2007) cited in Mertens (2010) whereby sequential nested sampling and sequential multilevel sampling strategies were utilised.

3.5.1 Sample for Quantitative Questionnaire

In this study, quantitative data was collected from all Form 4 students (i.e. 196 students) in M1 and M2 schools. To minimise disruption to students' learning activities in the schools, Form 4 students were selected because they were not in examination classes (e.g. Form 3 and Form 5) and they could still offer ample information to this study. MOE and the school principals would not allow the students of examination classes to participate in any study. Form 4 students (i.e. 16 years old) were also deemed to be appropriate because they were more mature as compared to the lower forms students, and had a better English proficiency. Although the cognitive capabilities of children develop at different rates, children older than the age of 14 can think like adults (Leikin, 1993).

Quantitative data in this study was collected using convenience sampling.

> *A convenience sampling is a group of individuals who (conveniently) are available for study* (Fraenkel and Wallen, 2006, p.100).

Given the permissive access to schools, the geography of the state and the timeframes set by MOE, it was not possible to have a meaningful random sample. Though convenience sampling cannot be considered representative of any population, information on demographic and other characteristics of the sample studied has been included so that this study could be replicated with a similar sample in future to verify that the results obtained were not a one-time occurrence.

In this study, the minimum sample size was determined to be 30 students per group (i.e. independent variable). The recommended sample size for causal-comparative study is a minimum of 30 individuals per group for statistical analysis (Fraenkel and Wallen, 2006; Cohen *et al.*, 2007). Since only Form 4 students were involved in this study due to practical constraints, this study did not attempt to generalise the results beyond the population pool.

3.5.2 Sample for Qualitative Interview

In qualitative research, sample size also does not follow any specific rule, and there is no exact sample size that is considered as appropriate or representative (Gall *et al.*, 1996; Papalouka, 2011; Patton, 1980; Cohen *et al.*, 2007) because the sample size depends on the purpose of a research, what is useful and what can be done given the available resources (Patton, 1980; Cohen *et al.*, 2007). Mertens (2010) has mentioned that sample size in qualitative research is dynamic, and the number of observations is not determined before data collection. Instead, a researcher would make a decision as to the adequacy of the observation by identifying the salient issues, such as by repeating instead of extending (Mertens, 2010). Moreover, the sample size is integrally related to the length of time in the field. In other words, qualitative observation is sufficient when data gathering no longer sparks new insights or reveal new properties.

Qualitative interviewing in this study used purposive sampling. Purposive sampling is different from convenience sampling in which researchers do not merely consider whoever is available but rather use their judgment to select a sample that they believe will provide the data that they need (Fraenkel and Wallen, 2006). Though the decision could be wrong, almost all qualitative researchers use purposive sampling because random sampling normally is not feasible (Fraenkel and Wallen, 2006). In purposive sampling,

> *the researcher specifies the characteristics of the population of interest and locates individuals with those characteristics* (Johnson and Christensen, 2008, p.239)

and

> *select a sample they feel will yield the best understanding of what they are studying* (Fraenkel and Wallen, 2006, p.439).

In a phenomenology research, the recommended sample size is approximately six participants (Mertens, 2010; Morse, 1994). Some doctoral qualitative researchers (e.g. Amoah, 2011; Minott, 2006) use four sample size. In brief, sampling size in qualitative research should not be too small to make it difficult to obtain saturation in findings and should not be too large to make it difficult to conduct a broad, case-oriented analysis (Sandelowski, 1995).

There are different types of purposive sampling and the *maximum variation sampling* has been used in this study. In this sampling method, individuals are selected based on the criterion of maximising variation within the sample to represent a diversity of perspectives or characteristics so that all types of cases are included (Johnson and Christensen, 2008; Mertens, 2010; Fraenkel and Wallen, 2006). I have selected an equal number of male and female students, their teachers and parents to represent data from both schools. The number of participants is shown in Table 3.1.

Table 3.1: Sample Study for 22 qualitative interviews

Schools	Students		Mathematics Teacher	Parents
	Male	Female		
M1	2	2	3	**4**
M2	2	2	3	**4**
TOTAL	**8**		**6**	**8**

Due to ethical consideration, I did not select the students based on their ethnicity or ability in mathematics. A researcher should be aware of the complexities of subdividing the sample by gender, race or ethnic origin, disability or ability level because it might not be ethical and educationally sound (Mertens, 2010). In this study, I classified the students based on their gender to get a fair opinion of both male and female students. The students were selected based on a voluntary basis, and the sample of students had a mix of ethnicities (i.e. Malay and Sarawak indigenous groups) with different abilities in mathematics. Cases for this study were selected because they were information rich and they offered useful manifestation of the phenomenon of interest. Further discussion on how I approached the research participants would be discussed in Chapter 4.

3.6 Conclusion

This study employed a mixed-methods approach in accordance with the *pragmatism* paradigm. Based on this philosophy, I employed what worked to answer my research questions by mixing multiple research components in accordance with my belief. To answer the research questions, quantitative and qualitative data were collected using a survey and a set of interviews, respectively. A mixed methods approach was used so that findings from both types of data could be validated and that they complemented each other. Due to practicability and time constraints, the *convergent parallel design* was employed, and the sample of the study was drawn from two schools in Miri, Sarawak. I had no control of the schools selections and the duration of data collection, and this would be further discussed in Chapter 4. Selection of the sample would have an effect on the final findings. This study was meant for an understanding of a context, and it could not be generalised to all secondary schools. Hence, future studies could be conducted in other types of secondary schools, such as regular secondary school, international school, Chinese independent school and many more.

Chapter 4: Data Collection

4.0 Introduction

The process of data collection might appear to be easy to implement but the whole process took more than two years (i.e. Jan 2013 to June 2015) in order to complete the task. The preparation for data collection is essential since poor data that are gathered would affect the results of my analysis and findings. Furthermore, to redo the data collection is not possible because of various constraints. Although I have no control over the quality or outcome of the data collected, a proper planning could minimise any potential negative impact. At the beginning of the process, I focused on constructing the research questionnaire and interview questions. Then, a pilot test was conducted to examine the feasibility of these two research instruments. Data collection could only occur after ethical approval and permission of the MOE, both of these applications required the submission of final research instruments. Actual data collection started in April 2015 and ended in June 2015 (the maximum time granted). Subsequently the interviews were transcribed and where necessary translated (see Chapter 5 to 7).

4.1 Preparation of Questionnaire

4.1.1 Introduction

A questionnaire can be used to collect data with quantitative, qualitative or mixed methods (Johnson and Christensen, 2008). The questionnaire used to address the following issues – (1) technology accessibility and usage; (2) digital native characteristics; (3) computer games; (4) mathematics learning and (5) the use of computer games to learn mathematics. The questionnaire was further verified through a pilot test.

4.1.2 Pilot test of the questionnaire

The purpose of a pilot test is to gain feedback from a limited number of respondents (Cohen *et al.*, 2007). The fundamental rule to conduct a pilot test is to use a minimum of five to ten people to find out whether it operates properly before using it in a research study (Johnson and Christensen, 2008; Mertens, 2010).

In 2013, I conducted a pilot study at UNMC with 209 foundation students who had similar learning experience (i.e. gone through Malaysian primary and secondary education) as the actual sample of study. The students were given one hour to complete the questionnaire. They were encouraged to verbalise their thoughts and perceptions about the questionnaire. This technique is called *think-aloud*, and it is useful to determine if the respondents are interpreting the questionnaire the way it is intended (Johnson and Christensen, 2008). However, most of the students were quite reserved and did not share their thoughts and opinions. In view of that, their feedbacks were obtained through informal conversations during and after the pilot test. The majority of the students mentioned that the questionnaire was too long. Short and medium length questionnaires have better quality of responses than long questionnaires (Johnson and Christensen, 2008). Besides that, there were terms used in the questionnaire that some of them could not understand, for instance, the meaning of MMORPG and arcade. Overall, students took approximately 20 to 50 minutes to complete answering the questionnaire. The students' responses to the questionnaire were also examined. Too many not *sure* answers indicated that some questions could be either unclear or not applicable.

4.1.3 Finalise the Questionnaire

The questionnaire was amended based on the students' feedback obtained through the pilot test. Furthermore, statistical analysis was conducted on the pilot data (e.g. Yong *et al.*, 2016; Yong and Gates, 2014). In view of that, the questionnaire was further revised to improve the reliability of the instrument in answering the research questions. The final questionnaire was divided into five sections.

1. *Demographic information* – students' demographics such as gender, age, field of study, type of students, ethnic group, hometown and place of residence.
2. *Technology accessibility and usage* – students' accessibility to various digital technologies and daily activities. Technology accessibility and usage survey (Kennedy *et al.*, 2008b) was used as a reference.
3. *Digital native characteristics* – to measure whether the students were characterised as digital natives, the DNAS (Teo, 2013) was used. DNAS comprises of 21 items with four subscales: grow up with technology [TEC], comfortable with multitasking [MUL], reliant on graphics for communication [GRA] and thrive on instant gratifications and rewards [INS].
4. *Digital gameplay* – students' gaming experience, information about students' gaming behaviour, favourite games' genre, favourite games played and perceptions towards gaming.
5. *Mathematics learning and the use of a digital game to learn mathematics* – to assess the role of affective domain in learning mathematics with computer games, MTAS (Pierce *et al.*, 2007) was adapted. The instrument consisted of 20 questions, which measured the following attributes:
    - Mathematics confidence [MC]: students' perceptions of their abilities to attain good results and their assurance that they could handle difficulties in mathematics.

- Affective engagement [AE]: how students felt about mathematics.
- Behavioural engagement [BE]: how students behaved in learning mathematics.
- Confidence with technology [TC]: students believed that they could master computer procedures and being able to resolve problem themselves (Galbraith and Haines, 1998).
- Attitude to learning mathematics with computer games [MTg]: this subscale was modified to measure the degree to which students perceived the use of computer games in learning mathematics.

4.1.4 Summary of Pilot Test

The pilot study conducted was very useful because it enabled me to refine the questionnaire. The changes made to the questionnaire took two major issues into consideration – clarity of the questions and relatedness to the research's objective. The clarity of the questions could be identified during the pilot test when the students asked for clarification and during the data analysis when missing data was identified. The relatedness to the research's objective could be identified when a statistical analysis was conducted to determine what kind of information could be obtained from the pilot test data.

4.2 Preparation of Interview Questions

4.2.1 Introduction

The interview questions were developed based on the operational research questions discussed in Chapter 1. The students, teachers and parents were interviewed on the following issues.

1. *Demographic information* - respondents' backgrounds (e.g. age and highest level of education completed).
2. *Mathematics learning* - students' attitudes towards mathematics and issues related to teaching and learning of mathematics.
3. *Computer usage* - respondents' computer accessibility and usage.
4. *Cell phone/ smartphone usage* - respondents' smartphone accessibility and usage.
5. *Technology skill* - respondents' technology skills such as the use of word processing, spreadsheet, the Internet and many more.
6. *Digital natives* - respondents' initial exposure to computers and capability of doing multitasking.
7. *Gaming experience* - respondents' experience and perceptions towards computer games.

8. *Educational computer games* - respondents' perceptions towards the use of computer games to learn mathematics.

To confirm the appropriateness and adequacy of the interview questions, a pilot test was conducted.

4.2.2 Pilot Study for the Interview Questions

The main challenge for employing interview questions as a data collection procedure is the need for instrumentation rigour and bias management (Chenail, 2011). A pilot study is a common practice that is employed to assess and refine the interview questions, and discover any potential researchers' bias to ensure that the questions make sense and interviewees understand the questions being asked (Chenail, 2011; Jacob and Furgerson, 2012; Creswell, 2013). In brief, a pilot study allows the investigator to determine which questions are effective and which are not. Although a pilot study may not promise a successful data collection during the interview, it may increase the success rate of interviews and improve the quality of the data collected.

In social science research, there are two types of pilot study, (1) a test run during planning for the main study and (2) a feasibility study, which is a small scale version (Chenail, 2011). This study has employed the first approach. A pilot study may involve asking the interview questions and having someone to answer them. The study could start up with friends or someone that we know (Jacob and Furgerson, 2012) and then follow up with people who are close to those that will participate in the actual study (Turner, 2010; Jacob and Furgerson, 2012). Pilot cases are typically selected based on convenient access and proximity on a geographic basis (Creswell, 2013). In the event where piloting is not practical, *interviewing the investigator* approach could be adopted in which the investigator undertakes the role as a research participant to be interviewed by someone, but in this event, the investigator may be blinded by their biases and unable to foresee the difficulties during the real interview session (Chenail, 2011). Thus, Chenail (2011) recommended the use of *interviewing the investigator* approach as a pre-piloting technique before conducting a pilot study.

a. Pre-pilot Study

During the pre-pilot study, the *interviewing the investigator* approach was employed. I undertook the role as a research participant (i.e. student) to be interviewed by a friend, and both roles were switched around afterwards. During this process, some questions were found to be too challenging and might be beyond a student's comprehension. Then, we switched position – my friend acted as a teacher or parent to be interviewed by me. Some questions were found to be redundant, similar and not significant. During the interview process, mistakes were discovered while going through each of the interview questions in addition to new issues being raised. This approach was good, but comparatively, more information was acquired for being an interviewer than playing the role of a participant because I could not be a *real* research participant. I knew the questions to be asked and I had my own agenda.

After conducting the pre-pilot study, interview questions had been reduced from an average of 75 questions (i.e. 74 for students; 83 for teachers; 66 for parents) to 48 questions (i.e. 51 for students; 50 for teachers; 43 for parents) without affecting the objective to the study and some questions were rephrased for better understanding and practical reasons. An average time to answer the 75 questions was about 2 hours. Even being an interviewer myself, a large number of questions had also caused exhaustion, loss of concentration and boredom. It exceeded the interview best practice of an hour to 90 minutes of interview (Hatch, 2002).

As a result from the first round of pilot study using *interviewing the investigator* approach, the interview questions were tested again with me being the interviewer and my friend being the interviewee (i.e. acting as a teacher). After practising for more than three times, the time required for completing the 50 interview questions had been reduced to 45 minutes. This was due to my improved familiarity with the questions asked. We did not practise the interview questions for students and parents once again because the questions were 90% similar to the teachers' interview questions.

b. Pilot Study

To conduct a pilot study, participants who were similar to the actual sample of study were recruited - three students, three mathematics teachers, and three parents. They were the people whom I knew personally, including my former teacher, friends, colleagues and their sons or daughters. Although it was a pilot study, all the participants were very helpful in providing constructive feedback, opinions and suggestions to improve the process of the interview. Each conducted interview lasted approximately 1 hour. People are less likely to agree to an interview if it lasts longer than an hour (Jacob and Furgerson, 2012; Mulder and Yaar, 2006).

i. Mathematics Teacher

During the pilot study, each interview took 50 to 60 minutes. The teachers had approximately 11 to 24 years of teaching experience at secondary schools. Feedback obtained from the pilot test had identified five weaknesses which were discussed below. After the pilot test, the interview questions for mathematics teachers were reduced from 49 to 42 questions.

Redundancy

Some questions were found to be redundant. Learning from this, other similar questions were combined into one, with the first question being a general question and the subsequent questions would serve as probes. A general question allows the respondents to answer freely in any direction whilst the probes are used to obtain additional information or to clarify responses (Johnson and Christensen, 2008). One of the examples is shown below.

New question: Tell me about the approaches you used to teach mathematics. Do you use group discussion, games, etc.? [General] Have you ever used computer technologies such as the Internet or any software to teach mathematics in the classroom? [Probe]

There were a few explanations for the mistakes made. When I designed the interview questions, I failed to foresee all possible responses in each interview question. I assumed that all teachers would respond according to what I had anticipated. Apparently, their responses were unpredictable and what was going through the teachers' mind was a matter of conjecture. As mentioned in Jacob and Furgerson (2012), unexpected data and surprises were expected in a qualitative interview. I realised that probe questions were useful to direct the participants to the required path. In addition to that, prompts could be used to allow further justifications of claims and beliefs with appropriate examples and facts. Prompts are useful to get a specific information that respondents did not mention (Jacob and Furgerson, 2012).

Jargons

When all respondents (i.e. students, teachers, and parents) were asked the following questions, they did not understand the meaning of *digital games* and *educational computer games.*

- Have you ever played *digital games*?
- Could you name a few *educational computer games* that you know?

It was important for the research participants to understand the questions asked so that they could generate a rich description and authentic data. Here, I initially made an assumption that all the respondents could understand and be familiar with the technical terminologies. In some cases, technical terminologies could be translated into the every day more easy going language (Cohen *et al.*, 2007). However, translating the terminologies could alter or impair the actual meaning. Furthermore, these terminologies, *digital* and *computer* were rated as common computer terms (PC.NET, 2014). Similarly, the word *computer* was rated as daily used basic term, and *digital* was rated as frequently used basic terminology (TechTerms.com, 2014). Experience gained through piloting phase had supported the needs for providing brief definitions or examples in the new version of interview questions.

Ambiguity

When the following question was asked to all respondents, they elicited undesirable responses because they were confused with the term - *technology skills*.

- What kinds of *technology skills* are you good at? What kinds of *technology skills* are you weak at?

In the new version of interview questions, multiple choices with a list of technology skills were presented. These technological skills were developed based on the literature (GO-Gulf, 2012; Laura, 2005; Donaldson, 2013; Andrade, 2012).

New question: Based on the following technology skills, how you would rate yourself with a rating of 1 to 5 (1 would represent novice, and 5 would represent expert).

- Typing skill
- Word processing (e.g. Ms Word)
- Spreadsheet (e.g. Ms Excel)
- :

One of the important guidelines during the interview is to avoid ambiguity and imprecise questions (Arksey and Knight as cited in Cohen *et al.*, 2007). Sometimes, it is inevitable as many meanings that are clear to one person will be relatively unclear to the others (Cicourel as cited in Cohen *et al.*, 2007).

The teachers responded to abstract and difficult questions in two ways: (1) asked for clarification, (2) answered based on their personal understanding. The first scenario was evident, but the second scenario was very much dependent on my personal justification. I had noticed this problem during the pre-pilot test when my friend did not response accordingly to some interview questions. Suspecting that she could not understand the interview questions, I verified with her after the interview session. She admitted that she did not understand some of the interview questions and chose not to ask. She explained further that she felt embarrassed to ask for clarification. This is the knowledge aspect of the interview, in which interviewee must not feel threatened by the lack of knowledge (Cohen *et al.*, 2007).

Learning from my mistakes, I pre-briefed all pilot test respondents before the interview, and informed them that they should not worry if they encountered any difficulty or confusion during the interview as I would be there to clarify their doubts and they were free to ask for help. It is important to establish the trust and good rapport between the interviewer and interviewees as this would enable the interviewees to provide information about their inner world (Cohen *et al.*, 2007; Fraenkel and Wallen, 2006; Mertens, 2010; Johnson and Christensen, 2008).

Hypothetical

When the teachers were asked the question, "Recently there has been the general opinion that students are falling behind in mathematics. What do you think about this?" all teachers agreed on this statement. However, this question is a hypothetical or speculative question that should be avoided (Asksey and Knight as cited in Cohen *et al.*, 2007). A new question was designed with a proper fact and evident.

Original question: Recently there has been a general opinion that students are falling behind in mathematics. What do you think about this?

New question: Recently, Malaysian students showed poor rankings and average scores in both Trends in International Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA). What do you think about this?

Limitation of Multiple Choices

When all the respondents were asked "What do you normally use a computer for?" a list of activities were given with a multiple choices selection of *yes* or *no*. The responses given might be inaccurate because they were grey areas that existed between *yes* and *no*. For instance, some of them responded *sometimes*, *rarely* and *never*, instead of *yes* or *no*. This indicated that the multiple choices (yes/no) given were inadequate to accommodate all the possible responses. Besides that, when this question was asked, they related it to the utilisation of the Internet. Therefore, instead of asking about computer and the Internet separately, both usages were combined into one question. To rectify this problem, the frequency of usage was added to the list of activities – always, sometimes, rarely or never.

New question: What do you normally use a computer for? Based on the following activities, tell me your frequency of use – always, sometimes, rarely or never.

	always	**sometimes**	**rarely**	**never**
Typing documents	○	○	○	○
Analyse data	○	○	○	○
Prepare presentation slides	○	○	○	○
:				

Interview questions designed with fixed-alternative items confine the respondent to choose their answer from two or more alternatives (Cohen *et al.*, 2007). My intention was to achieve a greater uniformity of measurement so that the responses were coded more easily. The superficiality of multiple choices selection that was thought to be ideal had exposed some weaknesses during the pilot study.

One of the weaknesses of multiple choices selection is

> *the possibility of forcing responses that are inappropriate, either because the alternative chosen conceals ignorance on the part of the respondent or because he or she may choose an alternative that does not accurately represent the true fact* (Kerlinger as cited in Cohen *et al.*, 2007, p.357).

The limited fixed-alternatives may also irritate the respondents who find that none of the alternatives is suitable for them (Kerlinger as cited in Cohen *et al.*, 2007). This problem is more manageable in an interview because an interviewer is more flexible than a survey questionnaire.

ii. Students

The three students interviewed were between 14 to 16 years old. Each interview took 43 to 52 minutes. After the pilot test, I realised that the most challenging aspect of interviewing children was their level of understanding. Two of the students were proficient in English, and yet they had difficulty in understanding some of my questions. After the pilot test, the interview questions were reduced from 51 to 45 questions. The weaknesses found during the pilot test with the students are discussed as follows.

Limited vocabulary

Other than the terms *digital games, educational computer games,* and *technology skills* which were discussed earlier, the students also could not understand the following terminologies - *engineering, simulation, strategy, role-play, land navigation, problem-solving, using search engines, social networking,* and *web browsing*. In the revised interview questions, a brief definition or examples were given. One of the revised questions is shown as follows.

New question: In digital game, do you think you learn _______ skill? • multitasking (i.e. handle more than one task at the same time) • land navigation (i.e. use of compass, map and direction) • team work (i.e. working collaboratively with a group of people) :

The biggest mistake was using the vocabularies that the students could not understand. I initially disregarded the guideline given by Arksey and Knight (as cited in Cohen *et al.*, 2007), in which attention must be paid to the vocabulary to be used and to try to keep it simple. In this case, limited vocabularies prevented students from understanding some of the interview questions. On a few occasions, the questions had to be rephrased with simpler words; some terminologies had to be explained and a few common examples were quoted. Before the pilot study, I thought the students' interviews were similar to adults' interviews.

Although secondary school students are teenagers aged between 13 to 17 years old, they are presumed and associated with children in many past research studies (Punch and Hyde, 2011; Greene and Hogan, 2005; Nordström *et al.*, 2014). Children differ from adults in the cognitive and linguistic development, and it is important to use straightforward language (Arksey and Knight as cited in Cohen *et al.*, 2007).

Complicated question

A complicated question in this context meant that the question could not be fully understood by students at their level of understanding. Some of the interview questions were revised from experience gained in the pilot study. An example of a revised question is shown as follows.

Original question: Would you recommend the use of computer games to learn mathematics in the school? ***New question:*** Imagine that one day your mathematics teacher is using a computer game to teach in the classroom, how would you feel?

The use of role-play (i.e. imagination) question was effective. This approach is also suggested by Mertens (2010). An investigator should ask the same question in different ways to check whether the children understand what the investigator has been saying (Fraenkel and Wallen, 2006). For children's interview, it is important to use child's language (Arksey and Knight as cited in Cohen *et al.*, 2007). Furthermore, I found that complex and compound sentence structure confused the students which confirmed the work of Fraenkel and Wallen (2006) who had suggested to avoid questions which elicited multiple points.

From the pilot study, my rule of thumb for children' interview questions was to keep them short, simple, straightforward and easy to understand. This rule not only helps to obtain rich and valuable information from the children but also to gain their trust and confidence to talk and share their thoughts with ease.

Lack of Probe Question

In the pilot study, two of the students were shy to express themselves and more probe questions were required to lead the students to provide more detailed information.

Original question: Have you ever struggled in a mathematics exam? ***New question:*** Have you ever struggled in a mathematics exam? What do you find most challenging about mathematics? [Probe] In your opinion, what are the most difficult topics in mathematics? [Probe] Do you go to any tuition class? [Probe]

Interviewing teenage students is entirely different from interviewing adults. Students may feel intimidated during the individual interview due to generation gap between the investigator and students, their level of confidence and they may feel threatened by the lack of knowledge. Children differ from adults so it is important to establish trust and to make them feel enjoyable (Arksey and Knight as cited in Cohen *et al.*, 2007).

To encourage them to talk during the interviews, I tried to learn the language which they were using and acted as their friend in order to encourage them to share their views and experience comfortably. Furthermore, projecting a friendly and professional attitude through body language and voice tone were very helpful in boosting their openness and encouraging them to share their thoughts.

iii. Parents

The three parents interviewed were between 38 to 42 years old, of different ethnicities (Malay, Chinese and Indian) – a Ph.D. candidate, a clerk, and a physicist. Each interview took 42 to 71 minutes. The most interesting aspect of interviewing the parents was their diverse perceptions and viewpoints. To refine the interview questions, some probe questions were added as inspired by the parents responses and some unnecessary questions were removed. After the pilot test, the interview questions for the parents were reduced from 43 to 39 questions. The weaknesses found during the pilot study are discussed as follows.

Ambiguity

When the parents were asked “What do you expect the future school should be?” they looked a little puzzled. Nevertheless, they expressed their expectations towards the school and education system. I should not assume that parents were knowledgeable and aware of the schools’ future plans like educators. Instead, I should change the question to ask for their expectations or suggestions of future schools.

New Question: As a parent, what is your expectation from the school education system? Do you have any suggestion for the school?

Mathematics teachers have the similar educational background, working environment, and perceptions towards education. Parents, however, are people coming from various educational backgrounds with different types of occupations and diverse life experiences. Diverse life experiences shape divergent views or perceptions. Being an investigator, it is important to accept that the interview may provoke new insights (Kvale as cited in Cohen *et al.*, 2007).

A pilot test with the parents led me to discover that they did not see and view education through the lens of an educator. They gave me new, interesting and creative ideas which helped me in the design of several new probe questions.

Ill-informed question

When the parents were asked “Recently, there has been the general opinion that students are falling behind in mathematics. What do you think about this?” they seemed to be ill-informed on this subject. Most probably, they had less knowledge of the overall statistics of mathematics examination as compared to the teachers. I made a mistake for asking an ill-informed question because I assumed that the parents knew the answer. Thus, this question was removed. Although the parents did not mention about their doubts explicitly, their body language, facial expression and tone of voice had suggested that it was an ill-informed question.

To get a message across, one’s tone of voice is as important as the word itself. For instance, raised pitch voice (i.e. similar to asking a question) denotes uncertainty (Burke, 2007). In some cases, if the parents are illiterate or they do not have any knowledge about the questions asked, I may need to rephrase the questions. In a worst-case scenario, I might need to skip the question rather than compel the parents to respond to the questions.

c. Summary of pilot study

During the pilot study, every participant gave me a unique interview experience. Being an educator myself, interviewing the teachers did not provide significant findings since most of the issues had been widely discussed in the literature. When interviewing the students, I realised that I had to learn to talk like a child or teenager. Besides that, I could feel the fear and anxiety that they had towards me, in the same way in which they would fill with awe in front of a teacher in the school. Malaysian students are greatly influenced by the Confucian heritage education in which teachers are authoritarian, and students are expected to keep quiet (Hing, 2013). Lastly, parents’ interviews made me to realise that each of them was unique. They had interesting ideas that were very different from my own perspectives.

Every group of respondents provided distinctive feedbacks due to different generational perspectives. Students were expecting questions with simple linguistic building blocks and basic vocabularies. Resolving the linguistic problem was the main concern to ensure that students could comprehend the questions being asked. Adult teachers and parents are more mature, sensible and logical in their interpretations. They tend to seek the rationale behind each of the questions asked. Hence, interview questions should be designed carefully considering the basis, logic and rationality of the questions.

The pilot study acted as a reconnaissance phase, identifying key issues and technical qualities (*technical, linguistic* and *conceptual)* of the interview questions and provided guidance on the actual interview. *Technically*, some interview questions had improper multiple choices selection and follow-up questions. *Linguistic* problems include complicated question structure and the use of unfamiliar terminology or vocabulary. *Conceptually*, some interview questions happened to be ambiguous, hypothetical, and lacked of probe questions, which failed to obtain a better picture of participants' perspectives.

4.2.3 Interview Language

a. Language selection

In Sarawak, there are more than 40 different ethnic groups and each has its own distinct language. Ideally, interviews should be conducted in several languages within a changing cultural context. However, in many cases as with this study, securing native translators with the right command of language and familiarity with the cultural background of the respondents are often difficult. The alternative according to Filep (2009) would be to use a common language that could be foreign to both interviewer and interviewee. In this study, the risk of using the wrong or inappropriate expressions was minimised by using two languages common in Sarawak - English and Bahasa Malaysia (BM), which is the national language. In addition, the cultural misunderstandings are inherently minimised, since I am Sarawakian.

Although the interviews were conducted in these two languages, other languages (e.g. Mandarin and *Sarawak* language) were also used when further clarifications were required as I was reasonably fluent with these two languages and I am a native speaker for these two languages (as a Sarawakian Chinese). Researchers often need to be proficient in several languages and open to the use of multiple languages to clarify any potential misunderstanding (Filep, 2009). In this study, the interview with teachers was conducted in English. However, interviews with parents and students posed a challenge as some of them were not proficient in English. This had raised the issue of translating the interview questions from English to BM.

b. Translation

The purpose of translation is to achieve equivalence of meaning between two distinct languages (Regmi *et al.*, 2010). This study employed Brislin's (1970) *back-translation* model. It is one of the best methods in cross-cultural research (Regmi *et al.*, 2010; Filep, 2009). In this model, the right practice is to employ at least two competent bilingual translators who might be familiar with the research (Regmi *et al.*, 2010). The *back-translation* model is divided into three major steps: (a) the first bilingual person will translate from the source language to the target language, (b) the second bilingual person will translate it back to the source language without seeing the original text and (c) finally, two versions of items in the source language will be compared for accuracy and equivalence (Brislin, 1970; Regmi *et al.*, 2010). If there are ambiguities or discrepancies, both translators should negotiate and discuss (Brislin, 1970).

I translated the interview questions from English to BM. Then, a secondary school teacher who specialised in BM checked for grammatical error and sentence structure. After the verification, another teacher translated it back to English. Finally, the *back-translated* version was compared with the source language version (i.e. English). A discussion was held between two of us to finalise the final version of the interview questions in BM. It is important to ensure that the meanings do not get *lost in translation* (Filep, 2009).

4.3 Access and Acceptance

4.3.1 Courtesy Schools' Visit

In July 2014, I made a courtesy visit to a few secondary schools in Miri prior to the application for research approval from the Malaysian government. To gain access to schools, having a prior discussion with the school principals was thought to be essential and significant. Researchers should not expect access and acceptance by the school communities as a matter of right (Cohen *et al.*, 2007). I sought permission from the school principals because this study had the potential for intrusion and disruption to schools' daily activities. It is important for researchers to gain acceptance from those who could grant the permission and establish the ethical position on their proposed research (Cohen *et al.*, 2007).

At the beginning, I was pessimistic that data collection at national secondary schools would encounter insurmountable roadblocks and obstacles. Preparing for the worst case scenario, I paid a visit to three private secondary schools – two Chinese independent schools and one international school. Regrettably, I was turned down by the two Chinese independent schools. I was informed by one of the school principals that the students and teachers were occupied with classes from morning until evening; hence, they would have no time to spare for any researcher. The international school, however, was in the midst of transition to a new principal. Consequently, I had to revert to my initial plan to collect data at national secondary schools.

I then approached eight national secondary schools - three in rural and five in town area. Unfortunately, I was again rejected by all the school principals or deputy principals. After all the unsuccessful attempts, I reflected on the reasons for their refusal: (i) students were occupied with many classes because they were preparing for various examinations (e.g. both The Unified Examination Certificate or UEC and SPM); (ii) large school population (e.g. few thousands) so the school principals and teachers might be occupied with teaching and administrative work. Even though I was being turned down by 11 schools in total, I had learned a great deal in the process, and it helped me to understand the concerns from the school administrators' perspectives.

After all these unsuccessful attempts, I started to make a hypothesis that school with small student population (i.e. less than 1000) and with students who only sat for national examination (e.g. SPM) might be more positive towards this study. My intuition was right. I got in touch with M2 School principal who was kind enough to accommodate my research. The school's session ended at 1.30pm instead of 4.30pm as in the Chinese independent schools. After having a meeting with the school principal, and explaining to him my intention to collect data in the school, he was very supportive and positive towards my research. He mentioned that data collection could be conducted in the school as long as it did not affect students' learning and preferably not year-end when they were sitting for national examinations. After getting the first consent, I approached M1 School. The school principal was also very friendly, supportive and positive. Having two schools agreeing to participate in this study, my next step was to send in my application for official approval from Malaysian government agencies.

4.3.2 Preparation for Application

Following the advice from fellow researchers, formal approval for the permission to collect data in the Malaysian national secondary schools had to be sought from the MOE. On 1st July 2014, an enquiry was directed to MOE specifically the *Education Planning and Research Division*. After checking with the department, I was informed that the UNMC was classified as a foreign university in Malaysia. Therefore, an application had to be made through the *Prime Minister (PM) Department*. As advised by the department of *Economic Planning Unit (EPU)* under the *PM Department*, I had to make an application, which would assume that I was a foreigner studying in a foreign university in Malaysia. The fact is I am a Malaysian studying at UNMC, which is physically located in Malaysia. It had caused some confusion in the process. Under the *General Circular No. 3 Year 1999* stated in the PM department's website, for an application to EPU, any researcher was defined as a "foreign national or Malaysian from a foreign institution and/or organisation who is scientifically and objectively researching a particular area or problem". Due to this confusion, the correct procedure for this application was unclear. This lack of clarity was also perceived as an issue for the UNMC management.

I referred this matter to the UNMC's Teaching and Learning Provost. With his help, I was granted a copy of the UNMC's licence as the *Malaysian Private Higher Education*

Institution and was presented to MOE. Unfortunately, the response given by the MOE was not positive. The reply given was, “All the foreign universities that have a campus in Malaysia should apply through EPU”. From this statement, it was undeniable that UNMC was categorised as a foreign university in Malaysia. Application through the EPU was more complicated compared to MOE because it would involve getting approval from the PM department, MOE, Malaysia immigration office, Sarawak state government, Sarawak immigration office[3] and Sarawak education office.

4.3.3 Application to Government Agencies

To start the process of application, I consulted the EPU department for the right procedure. After having consulted with the PM department, I was advised to send in another application to the Sarawak state government. After checking with the Sarawak state government, I was informed that application to the PM department was not required because the research was conducted solely in the state. Despite many confusions and grey areas, I submitted my applications to both the PM department and the Sarawak state government on 15th December 2014. The process of application is denoted in Figure 4.1.

The first approval was obtained from MOE on 15th January 2015, but the PM department could not issue an approval letter without first getting approval from the Sarawak state government. Therefore, I followed up with Sarawak Chief Minister’s Office constantly to check on the status of my application and tried to speed up the process. I finally obtained approval from the state government on 30th January 2015. The timeframe given by the state government started on 2nd February 2015, and my data collection must be completed before 2nd August 2015. Because of this limited timeframe, approvals from all the other departments had to be done as soon as possible.

The Sarawak Chief Minister’s Office insisted I must apply for an entry permit to Sarawak even after explaining to them that I am a *Sarawakian*. To conduct a study in Sarawak, all foreigners (i.e. not originated from Sarawak) had to apply for an entry permit from Sarawak immigration office. After consulting the immigration officer in Sarawak, he confirmed that an entry permit was not required. I originated from the state with a Sarawak Identity Card. After the approval letter from Sarawak state government had been received, it was handed over to the PM department immediately. After one week, the paperwork was ready, and the approval letter and research permit were collected from the PM department on 10th February 2015. With all the approval in place (MOE, Sarawak Chief’s Minister Office, and PM department),

[3] Although Sarawak is a part of Malaysia, under the federation treaty, Sarawak retains immigration control and this even for Malaysians.

application to the Sarawak Education office was sent on 13th February 2015. It was approved after four days.

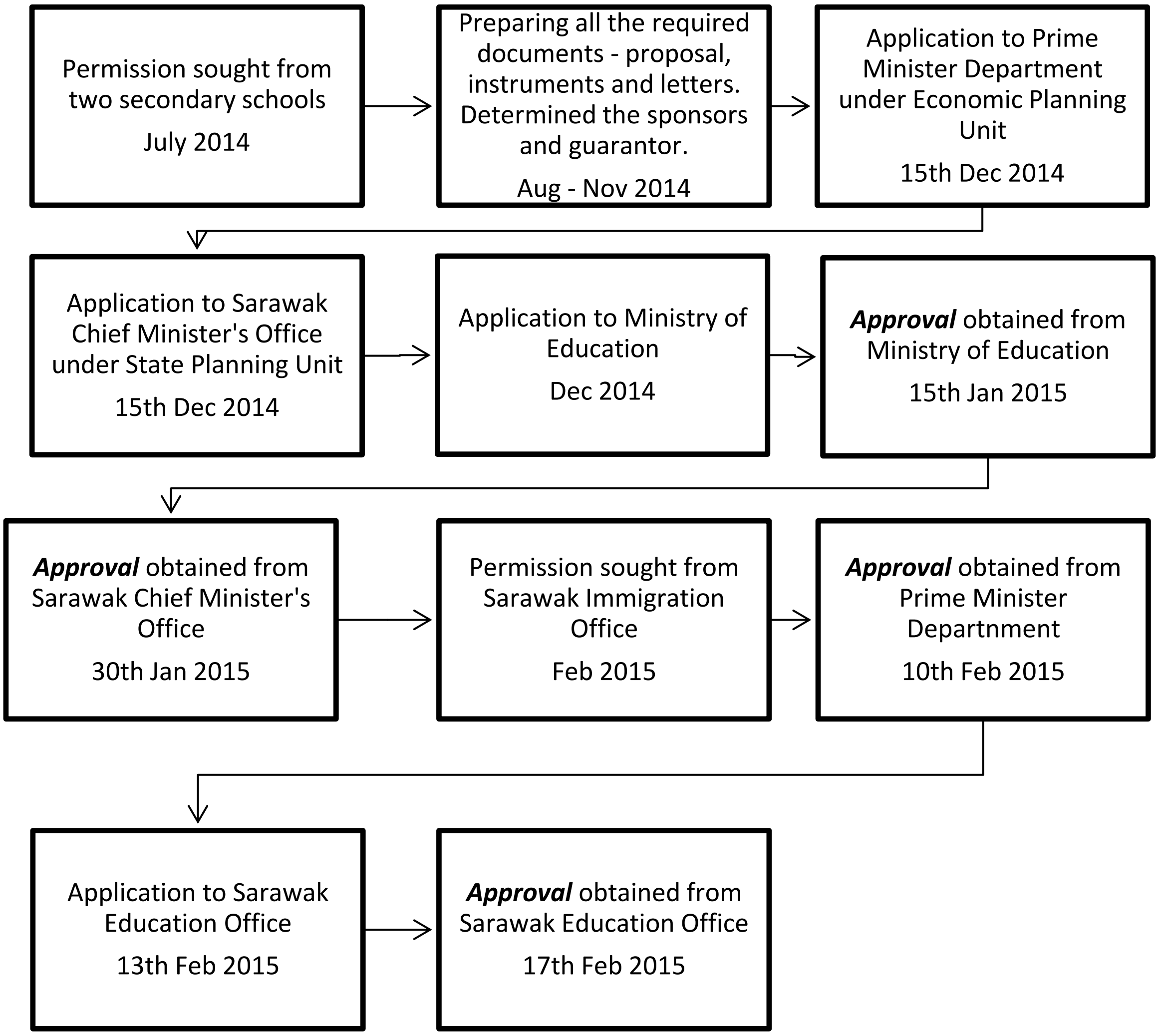

Figure 4.1: Process of Application to Collect Data in the Schools

The process of application was far from being simple and straightforward. There were a lot of confusion, roadblocks and difficulties that required assistance from many people in the government agencies. I truly appreciate the kind understanding and help given by them, as they had followed through my applications in a timely manner after knowing my time constraints. Thanks to all the support from the related government agencies, the process was finally completed without major setback and my application was approved on time due to their efficiency. The whole process of application to all the Malaysian government agencies took approximately two months (15th December 2014 to 18th February 2015) and was much faster than what I initially anticipated. The Malaysian government was very supportive and had encouraged research to be done in Malaysia.

4.3.4 Application to Ethics Committee

The UNMC ethics committee, however, is the major roadblock and setback of this study. Research ethics consideration constitutes an integral part of any research study and it defines the responsibilities of the investigator. Although the distinction between ethical and unethical behaviour is not dichotomous (Johnson and Christensen, 2008; Cohen *et al.*, 2007), ethical principles are usually defined to conform to the standards of conduct of a group of profession (Fraenkel and Wallen, 2006). Educational research normally does not involve any risk that causes physical or psychological harm, and are exempted from ethical approval (Johnson and Christensen, 2008; Fraenkel and Wallen, 2006).

Although no risk was involved in this study, approval had to be sought from the UNMC ethics committee to make sure that it fulfilled the ethical concerns and improved legitimacy of the study, as such UNMC required all its researchers to submit an application to the ethics committee. Two ethics approvals were sought from the ethics committee – pilot test and actual data collection. The first ethics application was made on 4th July 2013 and it was approved after six days on 10th July 2013. The second ethics application was made in parallel with the application to Malaysian government agencies on 10th December 2014. On 27th January 2015, however, my application was claimed to be missing by an administrator. A new application was instantly resubmitted on the same day. One month later on 27th February 2015, the application was rejected as the committee claimed that parents' consent was required for secondary students to participate in this study. For the committee, students at the age of 16 were considered as vulnerable groups. In response to that, I prepared a new application attached with *parental permission* and *consent* forms on the following working day on 2nd March 2015. Due to the limited timeframe given by the Sarawak state government and PM department, I constantly checked with the administrator for the outcome of the review. After three weeks on 23rd March 2015, the feedback given was unsatisfactory on the *parental consent* form. The form was amended and sent in again for approval. It was then cleared to proceed on 24th March 2015.

The second application to the ethics committee took 3½ months to approve. This was in contrast to 2 months' time used to obtain approvals from five Malaysian government agencies. During my application to the ethics committee, no acknowledgement of receipt upon submission and no expected timeframe was given for approval. I had informed the committee about my time constraints, and constantly followed up with the administrator, but no feedback was provided. Slow approval from the ethics committee had caused two months to be lost, so I was only left with four months for data collection. It was the most stressful and difficult part of this study considering these four months include two months of school and UNMC exams; one month of school or public holidays. So practically, I was only left with a month to collect data provided everything went smoothly. Although I would appreciate a faster response from the ethics committee, I still appreciate the thorough inspection and constructive comment provided. In fact, the major concern of the ethics committee was the parental consent form.

4.3.5 Informed Consent

Most social research necessitates giving informed consent before the participants can participate in a study and before a researcher can use individuals' existing records for research purposes (Cohen *et al.*, 2007; Johnson and Christensen, 2008). The principle behind an informed consent was stated as follows.

> *A person, once given the pertinent information, is competent and legally free of the desire of others to make a decision as to whether to participate in a given research study* (Johnson and Christensen, 2008, p.112).

In other words, a researcher should respect the right of any individual to refuse to participate in the study or to withdraw from taking part at any time (Fraenkel and Wallen, 2006; Johnson and Christensen, 2008). It means research participation should be based on a voluntary basis and free from any coercion (UNMC Ethics, 2011). Nevertheless, informed consent can be waived if the collected data is anonymous, and research involves minimal risk (Johnson and Christensen, 2008).

Theoretically, informed consent could be waived in this study because minimal or no risk was involved, and data was anonymous and kept strictly confidential. However, the UNMC ethics committee insisted on parental consent because they presumed that 16 years old students were vulnerable group.

Surprisingly, the UNMC Ethics (2011) defines children or vulnerable group as those *below 16 years old*. Furthermore, the minimum age of consent in Malaysia is 16 years old (Azizan, 2012). The cognitive capabilities of children develop at different rates, but children older than the age of nine have sufficient cognitive ability to decide whether to participate in the research (Leikin, 1993). Though the 16 years old students are obviously *not the vulnerable groups*, it is more ethically acceptable to obtain the parents' consent to enhance the validity of the study. Thus, *Participant Information Sheet* and *Consent Form* have been distributed to the parents prior to data collection from the students.

4.4 Process of Data Collection

Data collection was conducted in three phases mainly due to my personal responsibilities at the UNMC, school exams, and school or public holidays.

4.4.1 Preparation for Data Collection (9th- 13th March, 2015)

On 9-13 March 2015, a second visit to M1 School and M2 School was made. This was the first visit after an official approval was obtained from the Malaysian government. I could not start collecting data prior to the university's ethics approval. Thus, the purpose of this visit was to have a preliminary discussion with the school principals and devise a plan for data collection in April 2015. Upon arrival at the schools, approval letters were presented to the school principals. In this one week trip, I managed to have a short conversation with the school principals and a few teachers. During that time, both schools were having exams. Due to ethical concern, I did not approach any students. However, both schools had different arrangements for me to collect data.

a. M1 School

The school principal was very friendly and helpful, and introduced me to Madam Voon (which was an alias name) and requested her to identify four Form 4 students and three mathematics teachers who subsequently volunteered for the interview. Then, Madam Voon provided me with the contact numbers of the students' parents, and she advised me to talk to the parents personally. I did not instantly contact the parents because I was waiting for the ethics approval. However, I contacted the parents one month later in April after ethics approval had been granted.

b. M2 School

The school principal was also very supportive and helpful who advised me to talk to the mathematics teachers and school counsellors. Firstly, I approached the most senior mathematics teacher in the school whom I knew personally. She agreed for an interview and she then introduced me to two mathematics teachers who were also happy to participate. *Snowball sampling* method had been used here. In this approach, the key informant who was the senior mathematics teacher was approached, and her recommendation led me to other teachers based on her knowledge of who would be the best to help in my research area. Secondly, I approached the school counsellors. They advised me to go to the school on 25th March 2015 to talk to the students' parents personally because they had a meeting with the parents on that day. Unfortunately, I could not make it due to my teaching responsibilities at the UNMC.

Despite a short trip and limited time at both schools, the visit helped me to get an overview of my potential research participants, and to make a proper plan of how I was going to conduct my study – sequence of interview, date, time and venue. For the schools, this visit allowed them to prepare for my next visit in April for actual data collection.

4.4.2 Data Collection Phase 1 (13th – 24th April, 2015)

a. Interview process and survey

After ethical approval was obtained, the first phase of data collection was conducted between 13th and 24th April 2015. I managed to interview 10 research participants (see Figure 4.2) and conducted a survey in both schools. Pseudonym would be used to identify the research participants.

M1 School

Teacher		
A ✓	**B ✓**	**C ✓**

Parent			
H ✓	**P ✓**	**L ✓**	N

Student			
H ✓	**P ✓**	L	N

M2 School

Teacher		
D ✓	**E ✓**	F

Parent			
E	S	Y	A

Student			
E	S	Y	A

✓ - Interviews conducted in April 2015

Figure 4.2: Research Participants for Interview (Phase 1)

On 13th April 2015 (Monday), I went to M1 School and met the school principal and teachers. On the same day, a survey was conducted in the school. The survey questionnaires were distributed to students through their respective form teachers, and 116 out of 126 students responded (92%). Ten students did not respond because their parents refused to grant consent. Research participants were recruited on a voluntary basis so no coercion was used. On the same day, the Teacher A was interviewed (Interview #1). The interview was scheduled with the teacher's agreement and carried out during an hour break in her teaching timetable. The interview took place in the school counselling room. The interview went well and took approximately 52 minutes to conclude.

On 14th April 2015 (Tuesday), a visit to M2 School was made and the survey questionnaires were distributed to students with the help of the counselling teacher. The response rate was 84% in which 59 out of 70 students responded to the survey. 12 students did not respond to the survey as their parents did not approve the participation. On the same day, an interview with Teacher D was conducted (Interview #2) and as requested by the subject at her workstation. The interview lasted 1 hour 5 minutes.

On 15th April 2015 (Wednesday), Interview #3 was conducted with Teacher B from M1 School. Like other teachers, Teacher B had scheduled an hour into his busy teaching schedule. The interview lasted 54 minutes. After the interview, another interview (Interview #4) was conducted at M2 School with Teacher E. The interview was conducted in the staff room as per her request. Interview with Teacher E only lasted for 30 minutes because the teacher did not play any video or computer games, which had led to a shorter interview time. After the two interviews conducted in the morning, Interview #5 was carried out with Parent L in the afternoon. Due to ethical consideration, parental permissions must be obtained before interviewing their children. Thus, it was logical to approach the parents first, before approaching their children. Parent L was contacted earlier, and she agreed to participate. Parent L arrived at the school half an hour earlier than the appointment time and thus we began our interview session 15 minutes earlier than the scheduled time. The interview went smoothly and took 52 minutes to conclude. After the interview, she helped to arrange an interview with her son (Student L) on the following day. Unfortunately, the student did not turn up after I had waited for 1½ hours and he was busy for the rest of the days. Therefore, the interview was postponed and could only be done in the next data collection in June.

On 16th April 2015 (Thursday), Interview #6 and Interview #7 were conducted with Parent P and Parent H. The interview with Parent P was conducted at her house because she could not go to the school. I went to her house in the morning and the interview lasted 1 hour 20 minutes. The parent then provided me with the mobile phone number of her son (Student P) so that the student could be contacted for an interview. After interviewing Parent P, I conducted the Interview #7 with Parent H who was reluctant to meet me in the school since there was no air conditioning in the counselling room. We came to an agreement that the interview would be conducted at a restaurant near Miri beach. We met at the restaurant in the afternoon and the interview took about 54 minutes. The parent then arranged an interview for her daughter on the following day because Student H would be away for a competition on 17th April 2015.

On 17th April 2015 (Friday), Interview #8 was conducted with Teacher C from M1 School. He was using games or software in the classroom. Due to time constraint, the interview session took only 50 minutes. He was kind enough to lend me a few CDs of the games and software used for his teaching. On the same day, Student P was interviewed, which was Interview #9. Appointment with Student P was made through Short Messaging System (SMS) as advised by his mother. The interview with Student P lasted about 1 hour 4 minutes. In the afternoon, Interview #10 was conducted with Student H at the same location as her mother (i.e. at a restaurant near to the beach). After interviewing Student H and P, I sent an SMS to thank the parents.

Four more interviews were scheduled in the following week. However, during my visit to the school on 20th April (Monday), I fell sick and was forced to cancel all my appointments for the whole week. All the four interviewees (Student L, Teacher F, Parent N, and Student N) were informed that I was sick, and they would be contacted again in June for an interview. They were very understanding and had agreed to my request. On 24th April (Friday), the teaching CDs borrowed were returned to Teacher C.

Review for 1st phase of data collection: In my first phase of data collection, ten interviews had been conducted successfully - 5 mathematics teachers, 3 parents and 2 students. Throughout the process, I learned that it was not easy to convince people to spare time for an interview. I had to be skilful in communication and be understanding.

When the research participants were first contacted, a brief introduction was given to inform them that I am a Ph.D. student or a researcher from UNMC. They were then informed that their particulars or contact numbers were obtained from the schools, and an approval had been sought from the Malaysian government to carry out this research. Moreover, they were informed of my research topic and assured that their personal information would be kept anonymous and strictly confidential. They were also being informed that they need not worry about being not able to answer my interview questions because this study was solely for research purpose which was asking for their views and opinions. They were trying their best to help me despite not knowing much on the full detail of my research study.

In this phase of data collection, the three parents interviewed were homemakers. They took time out of their busy household chores to participate in this study. I really appreciated their time and effort. I did contact a few working parents, but appointments with them had to be postponed to my second phase of data collection due to their busy schedule and partly due to my poor health in the second week of my interview period. I really appreciated their effort in trying to accommodate my request for an interview.

My initial thought was that interviews with mathematics teachers would be the easiest because they were physically in school and had agreed to participate for the interview. However, due to their busy teaching schedule and works in the school, my presence had caused more work and stress for them. To minimise the teachers' inconvenience to participate in the interview session, I tried to accommodate their time and request. I really appreciated the help from all the teachers who had tried their best to allocate their precious time for an interview despite their hectic days in school.

b. Teaching and learning innovation

When I was doing data collection at M1 School, I got to know from the school principal and Teacher C that the school was actively involved in many activities that benefited the teachers and students. One that caught my attention was the educational collaboration with *United Nations Educational, Scientific and Cultural Organisation* (UNESCO). The school had a set of educational resources provided by UNESCO.

i. Collection of E-learning tools for leaners age 3-13

This is a collection of E-learning tools recommended for children aged 3 to 13. It is a simple courseware or an educational game designed for children to learn mathematics, language and much more (see Figure 4.3).

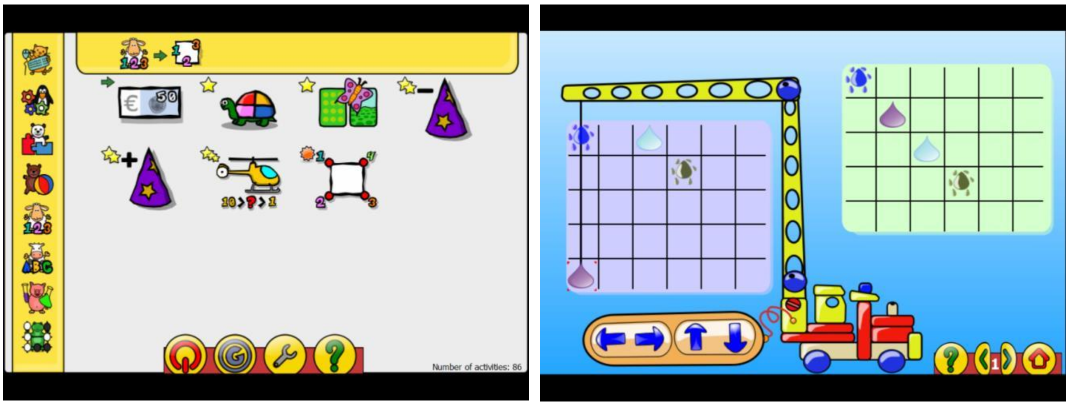

Figure 4.3: Mathematics Games

ii. Courseware for leaners at secondary school level

This is a collection of courseware that can be used for teaching and learning of science, mathematics, and language. The courseware is essentially designed to disseminate the learning content using various multimedia elements. Based on my observation, the courseware is displaying the learning content like a PowerPoint presentation. Only certain parts of the courseware are designed with interactive functions (e.g. Figure 4.4). For example, given a straight line $y = 2x + c$, the learner can change the value of the *y*-intercept (i.e. *c*). However, the option given is limited (e.g. negative integer from -5 to -1).

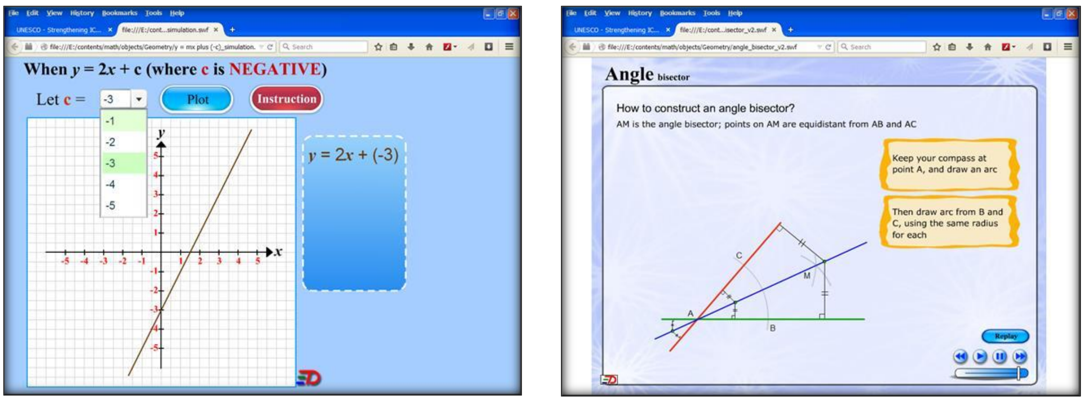

Figure 4.4: Courseware to Learn Mathematics

During the first phase of data collection, the school principal and Teacher C had given me invaluable information about the school's innovation in using computer technologies for teaching.

In my opinion, the success and achievement of M1 School today is inspired by an excellent school principal who always motivate and support her teachers and students to explore new teaching and learning methods. Not to mention the fact that the school also has a group of teachers who are tireless and enthusiastic in their job. I note that any new teaching and learning innovation is in need of support and positive attitudes from the top school management (i.e. school principal) as well as the collaboration and passion from those who would use those tools (i.e. teachers and students).

c. Review for 1st phase of data collection

After having conducted the first phase of data collection, I learned some new lessons that I did not encounter during my initial pilot test. Interviewing the people whom I knew during my initial pilot test was very different from interviewing a complete stranger in my actual data collection, especially the students and parents. In addition to time constraints, cost and more effort are required. I had to obtain their consent, trust, and engagement. Furthermore, I needed to be mindful of cultural and literacy differences.

i. Consent

In some studies (e.g. Bassett *et al.*, 2008), despite consent being obtained from both parents and teenagers, the teenagers may have little or no power to decide over their involvement in the studies because their parents may pressure them. In this study, consent and voluntary participation from the children and parents were crucial. The following statement was stated in the parental consent form.

> *If there is a discrepancy between the wishes of the child and the parent, i.e. the child does not wish to participate but the parent wishes them to, then the choice of the participant (child) has priority.*

To implement this, voluntary participation from the student was first acquired. Once the students had agreed to participate, I would contact their parents to acquire the consent for their children's participation. Based on my experience, once the children agreed to participate, their parents would be very supportive and positive in taking part in the study.

ii. Trust

The trust from research participants is an essential element in any study (Bassett *et al.*, 2008). In my opinion, trust is the most important factor in a qualitative interview. If the participants do not trust the interviewer, they will refuse to participate or may not want to disclose the actual information, which would then make collecting accurate data difficult.

I interviewed the parents before interviewing their children for two main reasons: trust and knowing what to expect. After meeting and interviewing the parents, they would know me personally (i.e. Who am I? Where do I come from? How is my personality?), and in this way I could obtain their trust. Furthermore, after going through the interview session, the parents would have an idea of the types of questions that I would ask to their children. Using this approach, parents would be confident in my credibility as a researcher, and they would give consent for their children's participation. They were very helpful in setting up the interview with their children once they had known me personally. The parents would not allow me to interview their children unless they trusted me, and no interview could be conducted without the trust on the researcher.

iii. Engagement

The third challenge during the interview was engagement. It was not easy to engage the participants to provide me with the information that I would need. Interviewing teenagers were different from interviewing children and adults. Researchers might experience different challenges when interviewing teenagers (Mertens, 2010). In past studies (i.e. Bassett *et al.*, 2008), interviewing teenagers was difficult and frustrating because they were not engaged and only gave a *yes, no* and one-word response. Bassett et al. (2008) found that the teenagers were more likely to open for communication during the interview if the interviewer would get to know about their interests and preferred activities.

I got to know about the students better (i.e. personality, academic achievements and interest) through their parents. For instance, Parent H told me that her daughter loved to play chess and represented Miri Division in a chess competition. Parent L told me that her son was independent, active and loved to play Gundam, Lego, football and hockey. When I met both students (H and P), I tried to relate what I knew about them during the interview sessions. It was really useful for me to get a better picture of the students' interest. To engage the students for the interview, I told them not to worry if they could not answer any of the questions because they were free to ask if they could not understand. Both students seemed to be nervous at the beginning, but they felt more comfortable and relaxed as the session progressed.

iv. Culture

During this phase of data collection, I focused on students or parents from M1 School. When I called the fathers of the four students for consent and interview appointments, they directed me to talk to the mothers. I thought there were two main reasons. In Asian culture, men are designated as the bread-earner and women are designated as the home maker. So, if I were to ask anything about their children, it would be better for me talk to their mothers. Moreover, when I contacted the students' fathers, they were busy and occupied with work. The second reason could be the gender difference. Since I am a female, the fathers might think that it would be more appropriate for me to talk to the mothers as they might find it easier to talk to same-sex people. Culturally, I also found it more comfortable talking to the mothers of the students. However, I was opened to both parents depending on their availability. Most importantly, when the interviewees felt comfortable, they were more likely to engage in the interview session. In a more conservative Asian culture, gender differences do play a significant influence in day-to-day social interaction.

v. Literacy differences

Another important factor that I should not overlook during the interview was the participants' literacy background, especially the parents. In the latest statistics released by the Malaysian Department of Statistics (2013), Sarawak has the lowest literacy rate (92.6%) and lowest computer literacy (47.5%) among all the states in Malaysia. Considering that the parents might be in the disadvantaged group, I did not pursue further if they did not have the knowledge in certain topics. It was important to keep a positive energy and not to let them feel embarrassed, pressured and belittled. From the parents' interviews, I learned a lesson that the interview questions should be applicable to them and at their level of literacy. I overlooked this issue during my pilot study because all the parents recruited for the pilot test were highly educated (i.e. at least graduated with a bachelor degree) and stayed in the Selangor state (i.e. having the highest literacy rate in Malaysia).

After completing ten interviews in this phase, I had become more confident and proficient in conducting an interview. The interview experience had helped me to devise a better plan for the next data collection in June 2015.

4.4.3 Data Collection Phase 2 (3rd - 26th June 2015)

a. Interview Process

After the data collection was undertaken in April, both schools had a mid-year examination in May. Therefore, the data collection during that time was put on hold to avoid interruption to the schools' examinations. After the examinations, school holidays started from 30th May until 14th June 2015.

M1 School

Teacher		
(A)	(B)	(C)

Parent			
(H)	(P)	(L)	N ✓

Student			
(H)	(P)	L ✓	N ✓

M2 School

Teacher		
(D)	(E)	F ✓

Parent			
E ✓	S ✓	Y ✓	A ✓

Student			
E ✓	S ✓	Y ✓	A ✓

( ) - Interviews conducted in April 2015

✓ - Interviews conducted in June 2015

Figure 4.5: Research Participants for Interview (Phase 2)

In this second phase of interviewing, I started to devise a better plan to minimise the distractions that potentially caused inconvenience to the schools and research participants. I made a hypothesis that students and parents might be more agreeable for an interview during the school holidays. My intuition was proven right. During the first week of school holidays, I contacted all the parents and three of them (E, Y and S) agreed to an interview on the second week of the school holidays though without confirmation on the exact date. The other two parents (N and A) were away so I had to follow up with them after the school reopened on 15th June 2015.

During the second week of the school holidays, the three parents (Y, E and S) were contacted. They agreed to have the interviews at their house, which proved to be more convenient and free from public distractions. I went to their houses at 2 pm, and interviewed the parents, which was then followed by the students. Parent Y and Student Y were interviewed on Wednesday (10th June); Parent E and Student E on Thursday (11th June), and Parent S and Student S on Friday (12th June). All the interview sessions (Interview #11 to Interview #16) went smoothly as planned. The research participants were very supportive and positive. I appreciated their help, and I was very thankful to them. Every student's mother was interviewed. During the interview, the father of Student Y and E were away for work. As for Student S, his father was at home during the interview, and he was sitting next to the mother (Parent S) to assist her in the interview.

After the six interviews conducted during the school holidays, I was left with six more participants (Parent A and L; Student A, L and N; Teacher F) to complete my data collection. Making an appointment with Student L, Parent N, Student N and Parent A was a great challenge. I had contacted Student L, Parent N and Student N since my first round of interview in April, but appointments with them had been cancelled several times due to their busy schedule. I was thankful for their patience with me. All the six participants were contacted several times after the schools reopened, but they were very busy during that period. I was grateful that interviews with Parent N and Teacher F on Thursday (18th June) were successfully conducted despite their busy schedule. In the morning, Parent N was interviewed at her office (Interview #17) and in the afternoon, Teacher F at M2 School (Interview #18). On Friday evening (19th June), an appointment was made with Student L after several attempts since April. Interview #19 was conducted at a restaurant at Miri beach. I was thankful to Parent L for arranging the appointment.

To conclude this phase of study as soon as possible, extra flexibility and effort had to be put in to meet the participants' needs and requirements for interview scheduling, regardless of weekend or evening time. Parent A requested an interview on Saturday evening (20th June) at M2 School together with Student A. Unfortunately, Parent A could not make it for the interview on that day. Thus the appointment had to be rescheduled. With the consent given by Parent A, Interview #20 with Student A continued as planned. On Sunday (21st June), I was informed by Parent N that Student N would be unavailable for the next few weeks, and the parent asked me to give up the interview with her daughter. After persuading Parent N for help and explaining the importance of their participation, she finally agreed. I managed to get an hour time for an interview (Interview #21) with Student N at her house on Sunday (21st June) right before her tuition class. I was thankful to Parent N for arranging the appointment for me.

Since Parent A could not make it for the interview on 20th June, my trip in Miri was extended for one more week. Parent A was contacted, but she could not attend to my phone calls, so a few SMSs were sent to her phone. She requested an interview at her working place, which was a school. Since the interview had to be conducted in the school, permission had to be sought from the school principal. I must hold to my ethical conduct to respect every organisation involved in my study. I contacted the school on Monday (22nd June), but the school principal was not available. The school principal was successfully reached on Tuesday (23rd June), and he granted me the permission to enter his school for conducting the interview. On Wednesday morning (24th June), upon arrival at the school, I thanked the school principal for his help. Finally, Interview #22 with Parent A was conducted and with that, my data collection had completed.

The process of data collection concluded one month earlier than I expected. There were three factors that contributed to the success. Firstly, the school principals, teachers, students and parents were kind enough to give me their full cooperation, support and help. Secondly, I altered and devised a better plan to collect data during school holidays, which was proven later to be fruitful. The six interviews conducted during the school holidays had sped up the whole process of data collection. Lastly, the successful data collection not only depended on many external factors, but also my personal determination, hard work and persistence despite continual rejections and negative encounters.

b. Review for the 2nd phase of data collection

During this phase of the interview, I had devised a better strategy and systematic plan that detailed how to overcome obstacles and achieve my goals. The interview strategies are discussed as follows.

i. Appointment in two stages

Appointments for an interview should be made in two stages. The first stage was to get their consent and availability at least two weeks in advance. If they confirmed their participation, a follow-up call would be made one or two days before a confirmed appointment date, time, and venue of the interview. The follow-up call should not be done too early (e.g. one or two weeks in advance) because they might not be able to plan due to many unforeseen circumstances.

ii. Home – the best interview venue

The best interview venue was the participant's house. During the 1st phase of data collection, most of the interviews were conducted at the schools and restaurants. I faced a few problems. In the restaurants, the environment was noisy. I tried to look for a better restaurant, unfortunately, all of the restaurants nearby were even noisier (i.e. playing loud song). When I used the school counselling room, it was noisy due to outside activities (e.g. grass cutting and students' activities) and the room was sometimes locked. Learning from all the experience, I tried to suggest to the parents for the interview to be conducted at their houses to avoid any possible problem. Thus, in this phase of the interview, seven out of the twelve interviews were held at their individual houses, and the interviews went smoothly without any distraction. Initially, I considered conducting the interviews at Miri public library as suggested by some researchers. Unfortunately, the library had no private or discussion room.

iii. Holiday – the best day to interview

Parents and students were more likely to agree to an interview during school holidays. During the 1st phase of data collection, I interviewed the parents and students separately on different days, times and venues. More efforts were required because I had to drive and rush to different places in one day. Sometimes, I had to skip my lunch in order to conduct an interview on time. Learning from my mistake, I made a better plan by setting up two interviews on the same day to meet both the parent and student at their house during the school holidays.

iv. 10 a.m. and 2 p.m. (Wed – Fri) – the best time to interview

The best interview time was 10 a.m. or 2 p.m. on Wednesday, Thursday, and Friday. During both phases of the interviews, most of the participants would agree to an interview on Wednesday, Thursday or Friday. Most of the participants suggested the interview to be conducted at 10 a.m. or 2 p.m. On Monday and Tuesday, people might be busier due to the beginning of the week. Also, the participants did not prefer the interview to be taken place during peak hours such as breakfast, lunch and dinner time. Since all the parents interviewed were the students' mothers, they could be busy preparing lunch and running errands during peak hours.

v. Culture Difference

I felt I needed to be more attentive to the cultural differences. Since most of the interviews in this phase were conducted at the students' houses, I had to be more attentive to the cultural difference between myself (i.e. Chinese) and the parents (i.e. Malay, Lun Bawang, Kelabit, Kenyah, Iban). Some of the participants preferred to sit on the floor instead of sitting on the chairs or couches. Since that were their preferences, I would conduct the interview by sitting on the floor with respect to their culture. Since some of the interviews were held during the fasting month, I had to be watchful not to drink or eat in front of them as this was a disrespectful action. There was an instance where I was about to finish interviewing a Muslim student, and I heard the Muslim prayer from a nearby mosque. I knew that the student needed to go to the mosque soon, so the interview was wrapped up quickly without affecting the interview data. I felt the warmth and welcome by all the parents I visited as they served me with snacks, drinks, fruits and gave me their planted *Sarawak red rice*. I was thankful to all the parents for their kindness despite our difference in race and religion.

After completing twelve interviews in this second phase of the interview, I had finally accomplished my goal of data collection. Before traveling back to Kuala Lumpur (KL) on Saturday (27th June), I visited both schools to thank the school principals and teachers. I was thankful and appreciated their help for granting me permission to collect data in their schools. Without their assistance, I would not be able to finish my data collection on time. I also thanked the school teachers who had helped me a lot, specifically Madam Voon and a counselling teacher. After collected all the required data, the next step was doing the transcription and translation.

4.5 Issue of Transcription and Translation

When data collection was completed, I started to work on the survey and interview data. The survey data was entered into the *SPSS Statistics* software within few hours. However, the interview data was much more complex with rich information compared to the survey data. The interview data required addressing the issues of validity and reliability of results obtained from the process of transcription and translation.

> *Transcription is a process of transforming qualitative research data, such as audio recordings of interviews or field notes written from observations, into typed text* (Johnson and Christensen, 2008, p.534).

I transcribed all the interview data from July to December 2015. The process of transcribing appeared to be a straightforward technical task, but it was much more challenging than what I expected. A five-minute audio recording took me an hour to transcribe, and each interview session took me one week's time to complete the transcription. It was a tedious job that required patience and detailed listening and fast typing skill into a word processing file. There is no single and correct way to do transcriptions, but the most significant concern is how and to what extent the transcription is beneficial and useful for the researcher to achieve the research objectives (Cohen *et al.*, 2007). After the process of transcribing, the next phase was to deal with the issue of translation.

In total, there were 22 interviews conducted – 14 in English; six in BM; one in English and BM; one in Mandarin and English. Thus, eight interviews required translation. In cross-language settings, the issues and process of translation are always neglected (Regmi *et al.*, 2010). Translation of interview data is not a straightforward procedure that merely involves word-to-word translation using a dictionary or the *Google translate*. In multilingual settings, interviews and translating the interviews data are both complex situations because translation or interpretation involves both language and culture (Filep, 2009). The process of translation requires an understanding of the words in the way that is connected to a local social context and cultural background. Language is not a neutral medium (Temple and Edwards, 2002). It is important to have a basic understanding of different concepts, views or thoughts of people from different ethnic, linguistic and cultural attachment to understand what and in which contexts interviewees are speaking (Filep, 2009).

The interview data was translated using the *back translation* model as discussed earlier with the help of two people who knew the local context. Our understanding of the culture, linguistic and social backgrounds of different ethnic groups did help us in doing the translation. For instance, during the interview, a parent said in BM, *Sebagai kerani di banyak tempat. Ada di Sesco selepas itu. Gaji tidak berapakan (Parent E).*

If using a direct translation from the *Google Translate*, the following result was obtained.

As a clerk in a lot of places. There are at Tesco after it. What salary do not (Parent E).

Understanding the local context, *Sesco* was a local company that stands for *Sarawak Electricity Supply Corporation*, and not the British multinational grocery, *Tesco*. Furthermore, we had to understand how local people talked. Sometimes, the grammar or the sentence structure was not right, but we could draw the meaning out of it. Therefore, the right translation would be as follows.

(I worked) as a clerk at many places. After that, I worked in Sesco. The salary is not much (Parent E).

When I was doing the transcription and translation, I started to analyse some of the quantitative and qualitative data in September 2015.

4.6 Process of Data Analysis

4.6.1 Quantitative Data

Before statistical analysis was performed on the quantitative data, normality test was conducted. *Kolmogorov-Smirnov* and the *Shapiro-Wilk* tests were used to verify the assumption of whether the sample data was drawn from a normally distributed population. It was found that both tests had a *p*-value that was less than 0.05 for all sample data. This result indicated that all the distributions were not normally distributed or failed to satisfy the normality test. Thus, non-parametric tests such as *Mann-Whitney* test and *Spearman's rho* test would be used. The *Mann-Whitney* test was used to compare two independent groups. The test is a reliable substitute of *t-test* if the assumptions of the *t-test* (e.g. normal distribution) are violated because the test is only slightly less powerful than the *t-test* (Morgan *et al.*, 2004). The non-parametric test, *Spearman's rho* test would be used to measure the statistical dependence between two variables.

In the data analysis of quantitative data, statistical significance (p) and effect size (r) would be reported. Many research studies did not report the effect size while obviously showing the *p*-value that was not sufficient for the reader to fully comprehend the result and impact of quantitative research (Sullivan and Feinn, 2012). Statistical significance (p) is the probability that the observed difference between two groups is likely due to chance and effect size (r) is the magnitude of differences found (Sullivan and Feinn, 2012). In non-statistical terms, significance (p) is used to confirm whether or not there is a difference between two groups. However, effect size (r) is used to measure the extent or amount of differences. Cohen's (1992) effect size was used as a reference: 0.1 for small, 0.3 for medium, 0.5 for large. In the analysis, an effect size of 0.3 and above will be the focus of discussion.

4.6.2 Qualitative Data

Analysis of qualitative data is a process of,

> *Making sense of data in terms of the participants' definitions of the situation, noting patterns, themes, categories and regularities* (Cohen *et al.*, 2007, p.461).

The main objective of qualitative data analysis is to reduce a large amount of data into manageable and understandable segments (Cohen *et al.*, 2007). In a phenomenology study, data collected through in-depth interviews are reduced to a common core or essence of the experience as described by the research participants (Johnson and Christensen, 2008). Nevertheless, there is no single correct way to analyse qualitative data because multiple interpretations could be made (Cohen *et al.*, 2007). Most importantly, researchers have to know how to reach the objective of a data analysis and abide by the principle of *fitness for a purpose* (Cohen *et al.*, 2007). This means it is important to pre-determine the purpose of the study, as this will determine what kind of analysis to be undertaken on the data.

This study has employed content analysis procedure to achieve qualitative data reduction. Content analysis is defined as follows.

> *A process of summarising and reporting written data – the main contents of data and their messages… Content analysis can be undertaken with any written material, from documents to interview transcripts, from media products to personal interviews* (Cohen *et al.*, 2007, p.475).

The content analysis procedure was performed in nine stages guided by the literature (Cohen *et al.*, 2007; Johnson and Christensen, 2008). In stage 1, the research questions in Chapter 1 were examined. In stage 2, the population was defined, which were the teachers, students, and parents.

Stage 3: Define the sample to be included - Purposive sampling was used to collect the qualitative data. The sampling rules for people are also applicable to documents and texts such as the representation, access, size and generalizable of the result (Cohen *et al.*, 2007).

Stage 4: Define the context of the generation of the document - The qualitative data was generated through a set of standardised interview questions. The interviews were conducted on a face-to-face basis.

Stage 5: Define the units of analysis - Categorical sampling was used and the sampling units were students, teachers and parents. Members in each category had a unique role and they had something in common. The sampling unit should be as discrete as possible, and does not distort the representation of the context and other data (Cohen *et al.*, 2007).

Stage 6: Decide the codes to be used - Code is defined as follows.

> *A word or abbreviation sufficiently close to that which it is describing for the researcher to see at a glance what it means* (Cohen *et al.*, 2007, p.478).

Before starting the process of segmenting and coding, a coding decision had to be made. It is essential to determine whether a coding is for the existence or the incidence of the concept (Cohen *et al.*, 2007). There are two types of coding systems - inductive codes and *a priori codes*.

> *A priori codes are codes that were developed before examining the current data. Inductive codes are codes that are generated by a researcher by directly examining the data* (Johnson and Christensen, 2008, p.539).

In this study, both *a priori* and inductive codes were employed. It is a common practice by many researchers to adopt both *a priori codes* and inductive codes (Johnson and Christensen, 2008). Before I started the process of segmenting and coding, some *a priori codes* had been determined. *A priori codes* may be established before the data analysis based on their relevance to the research questions (Johnson and Christensen, 2008). The research questions were examined, and *a priori codes* were established to ensure that the research questions were answered. One of the examples is shown in the following table.

Table 4.1: A Priori Codes for Analysis of Qualitative Interview

Research Questions	A Priori Codes
What are students', parents' and teachers' gaming experiences?	Favourite types of games played, frequency of gameplay, pros and cons of gaming

Stage 7: Construct the categories for analysis - Categories are constructed to show the links between units of analysis. An organising category is also known as a node. A node can be a process, group of people, concept, idea, place, or any grouping that the researcher defines (Cohen *et al.*, 2007).

> *Code is a label for a piece of text; a node is a category into which different codes fall or are collected* (Cohen *et al.*, 2007, p.479).

After categories had been formed, the relationships among categories were identified and presented as hierarchies. For example, the *a priori codes* (i.e. favourite types of games played, the frequency of gameplay, pros and cons of gaming) were categorised as a node called *gaming experience*.

Stage 8: Conduct the coding and categorising of the data - In this stage, segmenting and coding were conducted simultaneously because both processes were interrelated. Segmenting involves locating significant statements, and coding involves marking or labelling those segments (normally text data) with symbols, codes, descriptive words or category names (Johnson and Christensen, 2008). In a phenomenology study, the researcher should search for significant statements that could be a few words, a phrase, a sentence, or a few sentences that are relevant to the phenomenon being studied (Johnson and Christensen, 2008).

Before the process of coding and segmenting, I went through the interview data several times. According to Hammersley and Atkinson (as cited in Cohen *et al.*, 2007), a researcher should read and reread the data to note down any interesting pattern, any astonishing, puzzling or unanticipated feature, any obvious irregularity or disagreement. During the process of segmenting, the interview data was divided into meaningful analytical unit to ensure that all segments would be meaningful and significant to the research questions. During the coding process, I applied *a priori codes* if they clearly fit the segments of data. If the data could not be fitted into any of the *a priori codes*, an inductive code would be generated directly from the data. For instance, inductive codes derived from the students' gaming interview data were *gaming attractions* and *metacognitive skills.* After that, these *a priori codes* and inductive codes were categorised into a more meaningful and manageable form known as a node called *gaming experience*.

Stage 9 – Conduct the data analysis: This would be discussed in Chapter 5 to Chapter 7.

4.7 Conclusion

In this study, the process of data collection was one of the hardest tasks because I had to work tirelessly under great time pressure. During the process, I had to wrestle with many difficult situations that were beyond my control. It tested not only my research skills but also my problem-solving and interpersonal skills to interact positively and work effectively with different groups of people such as the school principals, teachers, students, parents, translators (i.e. teachers), a proof reader (i.e. BM teacher), pilot respondents (i.e. friends and colleagues), Malaysian government agencies, and UNMC ethics committee. The greatest worry of all was that disapproval or rejection from any of these parties would fail the whole process of data collection.

In addition to that, there were a few incidents that had constituted ethical concerns. For instance, during my courtesy visits to one of the schools, the school principal requested payments to be made to the research participants in return for their participations. It raised my ethical concern about the possibility that offering monetary incentives for research participation could constitute coercion or undue influence. Since all research subjects should be recruited on a voluntary basis, no payments should be made as was stated in my ethics application. Voluntariness was understood as free from coercion and undue influence. Being a researcher, I had to hold on to my ethical conduct despite being keen to achieve my research objective.

After all the data required for this research had been collected, transcribed, translated and made ready for data analysis, the next three chapters would be to discuss the major themes or categories derived from the interview data. As mentioned earlier, the sampling unit used was *categorical sampling* – students, teachers and parents. Therefore, the following chapters will be presented according to each of this sampling unit.

Chapter 5: Analysis of Mathematics Teachers' Interviews

5.0 Introduction

Teachers are the builders of a nation. They are the ones who drive and bring about educational change and the development of our young people. Reasonably, any innovation in teaching and learning should involve both the educator and the learner. Teachers' interviews have revealed various issues and concerns from the educators' points of view. It is important to note that this is not an experimental research design, where participants (in this chapter, the teachers) might be asked to test a computer game for themselves. This study is intended to explore the participants' experience with and exposure to computer games in the real world naturalistic situation. I do not want to manipulate the existing variables or set up an experiential environment. It is important to maintain the originality of data because this study is meant to propose a pedagogical change based on the existing situation in schools. In this study, it is important to explore the participants' views and perceptions in reality. One may argue that if participants never have been exposed to computer games, they may not know what computer games are. In fact, *not knowing about computer games* is exactly what the data showed. That is the fact in reality.

Being an educator myself, I tended to look at the interview data from the educational point of view. I focused on how teacher talked about how they teach and how they thought students learn. When analysing the data, I related automatically what the teachers said to my own understanding and experience when interacting with my own students. From a sociological point of view, I looked at the data from a symbolic interactionist perspective. I derived meaning from my everyday social interaction and communication, i.e. meanings were shaped through my encounters in schools and life. Being the former student of one of the case study schools, I went through the same education system about 20 years ago. Thus, I had some understanding of the school context, culture and examination system albeit from some time ago. My views and opinions were also somewhat influenced by my parents who were both school teachers. Since young, they had shaped my perspective towards education and teaching profession as a whole.

This chapter includes an analysis and discussion of the mathematics teachers' interview data. This chapter is divided into eight major sections:

1. Students' performance in TIMSS and PISA.
2. Students' learning attitudes and performance.

3. Teaching approaches.
4. Teachers' technological experience.
5. Students' technological skills.
6. Teachers' gaming experience.
7. The use of computer games to learn mathematics.
8. Suggestions and recommendations.

In certain sections, text boxes are placed at the end of the analysis that contain a discussion on the advantages of learning through gaming. In some cases, the learning context that is offered by gaming is different from a regular classroom. The discussion compares the learning context in the classroom and gaming environment, and draws out the similarities and differences. This will allow the identification of good practice in gaming that could be used in the classroom for improvement.

Table 5.1: Teachers' Background Profile

TEACHERS	A	B	C	D	E	F
School	M1	M1	M1	M2	M2	M2
Interview Language	English	English	English	English	English + Mandarin	English + BM
Gender	Female	Male	Male	Female	Female	Female
Age	39	29	42	56	42	40
Teaching Experience	9 years	5 years	16 years	30 years	18 years	14 years
Modules Taught	Maths	Maths	Maths & Add Maths	Add Maths	Add Maths	Maths
Level Taught	Form 1 – 3	Form 1 – 4	Form 4 & 5	Form 4 & 5	Form 4 & 5	Form 1 - 5

Note: BM – Bahasa Malaysia; Maths – Mathematics; Add Maths – Additional Mathematics

Six mathematics teachers have been interviewed in this study. The names of the schools and teachers would be kept anonymous due to ethical consideration. Instead, pseudonyms would be used to represent their names. Verbatim or the translated verbatim quotations would be included in the analysis and discussion to present the spoken words of the research participants.

5.1 Students' Performance in TIMSS and PISA

Malaysian students' performance in the various international benchmarking assessments is known to be poor (TIMSS, 2011; PISA, 2012). The Malaysian government has raised a deep concern on this issue especially in the subject of mathematics (Ibrahim, 2015). It would be worthwhile to solicit the opinions of school teachers on this particular issue to understand students' mathematics performance as benchmarked against the international assessments. Understanding of students' strengths and weaknesses in mathematics may reveal the potential that learning alternatively through gaming might provide. This is also a way of exploring teachers' viewpoints on mathematics capabilities of their students.

The interview would start with a question about students' rankings and average scores in both TIMSS and PISA [refer to Appendix A for the interview questions]. Concerning the relatively poor performance of Malaysian students in the international assessments, especially mathematics, five teachers (A, B, C, D and E) disclosed the reasons for the poor performance: (1) poor problem-solving skills, (2) lack of HOTS, (3) different assessment method, (4) over-reliance on a calculator, and (5) lack of motivation.

5.1.1 Poor Problem-solving Skills

The teachers mentioned that students' poor problem-solving skills were associated with: (a) inability to apply knowledge learned, (b) limited application questions. This finding is consistent with a report that has been published by the MOE (2012) indicating poor performance of Malaysian students in mathematics for the international assessments. The report states that Malaysian students are not proficient in the application of knowledge in solving problems.

a. Inability to apply knowledge learned

According to the teachers (i.e. Teacher A and B), the education system placed less emphasis on knowledge transfer. For instance, the teachers used the words *straightforward* and *straight* to describe the students' inability to solve non-routine problems. The teachers said,

> *Our questions are more straightforward to the point la… That means when they are asked, they can answer; asked, they can answer. But right now, when you are talking about something different situation, give the students a situation and you expect them to answer, definitely they cannot (Teacher A).*
>
> *Students are quite straight. They don't see can modify the question to get the final answer (Teacher B).*

The words *straightforward* and *straight* in this context would indicate that students could not apply what they had learned (i.e. routine problem-solving) to solve new and unfamiliar problems (i.e. non-routine problem).

This usually happens when students do not understand a particular lesson and they learn the routine problem-solving as an isolated skill (Carpenter and Lehrer, 1999). The students may have mastered the basic cognitive skills but they do not have the ability to *organise* and *control* the basic skills to solve non-routine problems (Mayer, 1998). Mathematics requires understanding and application of mathematical processes (i.e. not just computation) to enable transfer of knowledge.

In computer games, however, learning is transferable. In a single game, players are required to use the skills and strategies gained from the previous level and this knowledge is often applicable to other games or the entire genre (Becker, 2005). Games usually provide proper guidance and practice to ensure that the knowledge learned is transferable.

> *Learners are given ample support for an opportunity to practice transferring what they have learned earlier to later problems, including problems that require adapting and transforming that earlier learning* (Gee, 2007, p.142).

Very often, challenges given in games are new and unpredictable (i.e. non-routine), yet the players see the underlying similarities and differences between previous gaming experience and the current problems in the games. To enable transfer, players can recall and adapt the experience that they has obtained earlier in the games or even other games, or try something entirely new. As games progress, players usually have sufficient practice and the gaming skills are mastered and routinised. When they face a new challenge in games, players have to transfer the prior knowledge to mix with an innovation to enable problem-solving (Gee, 2007).

This innovation could correspond to the metacognitive skills in mathematics learning because solving of non-routine problems in mathematics requires metacognitive skills (Mayer, 1998). This could imply that good computer games support learning of metacognitive skills.

b. Limited application questions

Two teachers pointed out that the design of the mathematics curriculum did not focus on the application of mathematics concepts. The teachers said,

> *Our syllabus more of just maths only. No application. Very few topics got application daily life…very few. Mostly are just solving problem. Just mathematically only. Just like giving you an equation, a simple problem… Only certain topic will have application like linear programming application, they have solving problem; find the maximum profit (Teacher D).*

> *Because of the syllabus. Our syllabus is more rigid. Students learned whatever taught by the teachers. Students are lack of exposure in problem-solving or application questions [Translated from Mandarin] (Teacher E).*

These two teachers believed that the current mathematics curriculum mainly equipped students with routine problem-solving skills. Under the existing curriculum, students might presume that mathematics only involved memorisation and drill-and-practice of routine algorithm. The teachers strongly believed that more application questions should be included in the existing mathematics curriculum. Based on their descriptions, the application questions were most likely referring to non-routine problems.

These application questions, however, could be too abstract and unrealistic for the students to comprehend. In the conventional classroom teaching, most of the learning instructions occur outside of the contexts (Van Eck, 2006). Furthermore, students are not dealing with their own problems but someone's else problems (Pea, 1987). For instance, students may find it difficult to distinguish the difference between *speed* and *acceleration* merely through reading.

In computer games, however, the learning is situated within the learning context. In games, players are presented with pseudo-reality situations, and practice within the gaming contexts (Van Eck, 2006; Kebritchi and Hirumi, 2008). Furthermore, players usually recognise the significance of the problems in games because the problems are relevant and meaningful to them. They are solving their own problems and the gaming environment allows them to learn through exploration, and trial and error. For instance, when playing the *Need for Speed*, a player may implicitly learn speed and acceleration. In the game, there are car statistics that show the acceleration and top speed of a car. To race on a long straight road, the player may choose a car with better top speed, whereas to drift through corners, the player may choose a car with higher acceleration. Learning in games is more tangible and realistic because players can see the consequences of their decisions in the virtual reality.

5.1.2 Lack of Higher Order Thinking Skills (HOTS)

Three teachers revealed that students were underperforming in TIMSS and PISA because the Malaysian syllabus failed to prepare the students in HOTS. This finding is consistent with what has been reported by the MOE (2012). In response to this, the MOE (2012) has gradually introduced HOTS into primary and secondary education in accordance to Bloom's Taxonomy. The teachers said,

> *Because we have not really train the students in this. When they first introduce KBAT (i.e. HOTS in BM), it was more on 2013. Before that we are not talking about higher order thinking skill with the students… If they have started from Primary 1, and then you expect to do TIMSS and PISA, definitely they can do (Teacher A).*

The very basic question, they won't be able to answer. They won't be able to think in deep (Teacher C).

I think is because of Malaysian syllabus. We are given questions usually let say only the very few HOTS… Even other topics, certain topics none of the HOTS question, just using formula, solve problem (Teacher D).

Although HOTS has been introduced in secondary education in 2012, it appears to be something new because most of the teachers and students seem to be struggling to accommodate the new learning approach. This finding could suggest that both the teachers and students are not ready for the implementation of HOTS. The six teachers interviewed seem to focus on the lower order thinking skills (LOTS) in Bloom's Taxonomy (i.e. remembering, understanding and application) rather than the HOTS such as analysing, evaluating and creating. This could imply that HOTS is a great challenge for teachers to implement in the current secondary education.

HOTS includes metacognitive, logical, creative, critical and reflective thinking (King *et al.*, 1998). Metacognition refers to HOTS that involves active control over the cognitive processes engaged in learning (Livington, 2003). Thus, metacognitive knowledge is one of the knowledge dimension in HOTS (Krathwohl, 2002). Metacognitive skills are important for students to solve non-routine mathematics problems and develop mathematical thinking skill (Wong, 2002; Ozsoy and Ataman, 2009; Mayer, 1998). In other words, HOTS could help students to apply what they have learned to a new unfamiliar problem.

Computer games do develop HOTS especially strategy and simulation games because these two game genres comprise of all kinds of cognitive processes (Hung and Van Eck, 2010). For instance, students have mentioned that they have to think and sometimes *overthink* of the best strategy or solution to win the strategy games [refer to Section 6.3.4]. A student has also mentioned that playing *Little Big Planet* requires HOTS [refer to Section 6.3.7]. These examples show that students have implicitly developed HOTS through gameplay. This is implicit learning because knowledge is attained without conscious and thoughtful plans (Reber, 1989). Students could learn HOTS naturally without external force in computer games, but students are explicitly told to master HOTS in schools. In a classroom, learning activities are planned formally and deliberately to encourage HOTS. If HOTS are embedded into the mathematics curriculum in the same manner as in a gameplay, students may not be aware of learning of HOTS and the learning experience might be more engaging.

5.1.3 Different assessment method

Two teachers felt that the format of Malaysian national examination also had a significant impact on students' poor performance in TIMSS and PISA. The teachers said,

> *Add maths now have one paper we consider objective. Even though is like structure questions. But the structure question, they don't emphasise the working, they emphasise the answer. Once answer correct, they don't check the working already. Only answer wrong they check the working steps. The simple working steps, which involve a few steps (Teacher D).*

> *If students want to excel in exams, they just have to memorise. They are exam-oriented [Translated from Mandarin] (Teacher E).*

The teachers asserted that students were trained to be exam-oriented, and they could perform well through memorisation. Indirectly, the main objective was to get the answer right (i.e. product-oriented) without paying much attention to the effective steps or understanding (i.e. process-oriented). Evidently, the focus of TIMSS and PISA differed from the Malaysian schools' assessments.

In computer games, the objective of playing is not always about the outcome to win the games (i.e. product-oriented). For instance, students played computer games because they enjoyed the *process* of playing; because it was fun and thrilling [refer to Section 6.3.5]. None of the students mentioned that they played computer games because they enjoyed constant victory in games. In games, players can upgrade the capabilities of the game characters, planning for the best strategies and overcome the challenges in games. Players enjoy the *process* in gameplay and not entirely about winning the games (i.e. product). Some games even have no ending such as *EverQuest* and *World of Warcraft* because players can play as long as they wish. In mathematics learning, however, the objective is always to get the answers right or to obtain grade A (i.e. product). The learning experience (e.g. process - happy, stressful or suffering) is not significant.

5.1.4 Over-reliance on a calculator

A teacher mentioned that students performed poorly in TIMSS and PISA because students were over-reliant on a calculator. A teacher said,

> *Students from the young they are using calculator… So they actually not benefit their own brain to excel their mathematics. And of course, indirectly their logical thinking will be very very low (Teacher C).*

From the teacher's point of view, students were introduced to the uses of the calculator at a young age thus removing a natural form of training that required students to think *logically* or *analytically* when they were not using a calculator. Replacement of abacus with calculator had indirectly trained the students to rely heavily on the technology, which in turn, formed the habit of wanting to get the result easily and rapidly.

Although a computer game is also a kind of technology, it could help people to develop logical *thinking* or *analytical* thinking skills, especially strategy and puzzle games (Hung and Van Eck, 2010; Cherenkova and Alexandrov, 2013). Strategy games involve planning, decision-making, execution and adjustment of actions (Martinovic *et al.*, 2014), whereas, puzzle games can develop logical reasoning, arithmetic skills, mental calculation and mathematical intelligence (Van Eck and Hung, 2010; Becker, 2005; Baniqued *et al.*, 2013; Núñez Castellar *et al.*, 2014).

For instance, a student who played *Unblock M*e mentioned that she needed to find a way out in the game [refer to Section 6.3.4]. This game involved logical thinking and it required her to

> *infer an expected event as a result of the occurrence of its preceding event* (Hung and Van Eck, 2010, p.7).

In games, people usually learn logical thinking implicitly. Thus, many people are not conscious of engaging in logical thinking (Hung and Van Eck, 2010).

5.1.5 Lack of motivation

Students may not be attracted to learn mathematics because the conventional way of teaching is not attractive (Chang, 2009; Wilkinson *et al.*, 2001; Sedighian, K., & Sedighian, 1996; Venkateshwar Rao, 2016; Jablonka, 2013). Two teachers revealed that students were not motivated to learn mathematics. The teachers said,

> *If they see a long story, the problem-solving question… they will just give up. They are not going to read the question at all. They are going to… the straight mathematical equation; they just want to do that (Teacher A).*

> *Some of them are not really interested in maths (Teacher C).*

The teachers felt that mathematics problem-solving presented a significant challenge to the majority of the students. Students were struggling to solve problems, or they would rather give up. From the teachers' perspectives, the challenge in mathematics had demotivated the students to learn. Disinterest in mathematics among students could imply that there were flaws in the design of the education system that had failed to attract students' interest. Surprisingly, students interviewed in this study said that they were optimistic and positive towards mathematics learning [refer to Section 6.1.2]. Students described mathematics as challenging, yet interesting. In fact, some students asserted their preference for mathematics questions that challenge them to think more.

Similarly, computer game is motivating and fun because it is challenging (Malone, 1981; Amory *et al.*, 1999; Kiili, 2005b; Wishart, 1990). For instance, some students have revealed that they like to play certain games because they enjoy the challenges in those games [refer to Section 6.3.5]. In games, players willingly face new challenges as they progress and that each new level in games gets more and more difficult. Good computer games should operate within the players' *regime of competence*, whereby the players feel the challenges but achievable within their ability (Gee, 2007). If the players continue doing the same things and experience success, it is not good for developing new skills and creativity. Computer games should be challenging but within the players' resources, or else the players would be frustrated and give up (Gee, 2007). The same thing may apply to mathematics learning. Students may be demotivated and give up learning because the challenge is beyond their grasp.

5.1.6 Summary

Table 5.2: Factors of Poor Performance in TIMSS or PISA vs. Computer Games

Factors of Poor Performance	Computer Games
Inability to transfer knowledge • Students are trained with routine problem-solving.	***Knowledge is transferable to advanced levels*** • Players are trained with non-routine problem-solving.
Lack of application problems • Learning is out of context (e.g. reading about *speed* and *acceleration*).	***Application problems in gaming context*** • Learning is situated within the learning context (e.g. playing *Need for Speed* to test the difference between *speed* and *acceleration*).
Lack of HOTS • HOTS are taught explicitly.	***Learning of HOTS*** • HOTS are learned implicitly through gameplay.
Product-oriented • Focus on right answer and obtain grade A.	***Process-oriented*** • Focus on the gameplay that is fun and thrilling (instead of always winning).
Use of calculator • Remove logical thinking skill.	***Puzzle/Strategy game*** • Develop logical thinking.
Lack of motivation • Challenge is demotivating and discouraging.	***Motivated to play*** • Challenge is motivating and stimulating.

5.2 Students' Learning Attitudes and Performance

An understanding of students' attitudes and capabilities in mathematics is crucial for devising an appropriate strategy to adopt computer games into mathematics learning. In the existing lower secondary education (i.e. Form 1 to Form 3), students learn a mathematics subject (i.e. Mathematics). When students progress to the upper secondary education (i.e. Form 4 and Form 5), they are assigned to Science or Art stream. The Art stream students would learn a mathematics module (i.e. Modern Mathematics) while the Science stream students would learn two mathematics modules (i.e. Modern Mathematics and Additional Mathematics). The discussion in this section is divided into a few sub-sections: (1) mathematics subject in schools, (2) lack of motivation, (3) weak in problem-solving skills and (4) gender difference.

5.2.1 Mathematics Subjects in Schools

Students' interest and problem-solving skills in mathematics depended on whether it was Mathematics, Modern Mathematics or Additional Mathematics.

a. More Positive in Mathematics

All the teachers (except Teacher F) thought that most of the students were quite positive about Mathematics and Modern Mathematics. A teacher said,

> *Maths, they are okay. Because maths, no need to study so much in one topic. And the question come out is more or less like that. The scope, the variety, the format is more or less fixed already, is the same. So they can cope (Teacher D).*

From the teacher's point of view, students liked mathematics subject that was easier, less challenging and involved only routine problems. The students were perceived as having low abilities and only able to cope with problems that required routine practice and memorisation. In past studies, students were confident in solving routine mathematics problems but not the non-routine challenging problems (Fan *et al.*, 2005; Awanta, 2009). This finding could imply that students at lower forms would most likely had positive attitudes towards mathematics because the learning content was less abstract and did not require much HOTS.

A teacher who taught Mathematics and Modern Mathematics said,

> *Understanding is okay. Analytical is like that one moderate… They know what it means, but application wise they have a little bit trouble how to apply it. They know the thing, but when applying (Teacher B).*

Based on the teachers' explanations, students were proficient in the first two levels of Bloom's taxonomy – remembering and understanding. However, students were not capable in performing the third level of Bloom's taxonomy (i.e. application) and above. It was most likely that the problems given in Mathematics and Modern Mathematics were designed around understanding and memorisation skills.

b. Negative towards Additional Mathematics

Two teachers (D and E) who taught only Additional Mathematics claimed that most of the students had no interest in the subject. A teacher said,

> *I find that they don't like add maths actually. Because add maths need them to think, a lot of steps, they easily give up, no patience in solving add maths especially (Teacher D).*

From the teacher's point of view, students' negativity towards Additional Mathematics was mainly related to the students' personal behaviour whereby they were not motivated to learn. The negativity was amplified when they could not understand or solve a challenging non-routine problem. It is not surprising that as students move to upper forms, the learning content becomes more difficult and abstract, so their attitudes toward mathematics learning tend to be more negative (Kislenko, 2006; Awanta, 2009).

The two teachers (D and E) had the same opinion that students were weak in understanding and did not have analytical skills to solve problems in Additional Mathematics. One of the teachers said,

> *I would say at this stage they are still not that good (analytical and understanding)… Add maths is a culture shock for them. You see them getting fail, zero, one, two marks like that very often… You can see after many training, because we will train them once a syllabus over. Train them module by module… Then the ability to solve problem is getting better (Teacher D).*

According to the teacher, students failed badly in Additional Mathematics. It was a great challenge for teachers to improve students' mathematics results within a short period of time before exams. Therefore, the most effective way was to drill the students with many exercises. Time constraint could be one of the factors that drove teachers to use drill-and-practice approach in teaching mathematics.

This finding could imply that there was an enormous gap or discrepancy between the lower forms Mathematics and the upper forms Additional Mathematics. Mathematics taught in lower forms might lack of HOTS problems. Furthermore, teachers might have a misconception that students had negative attitudes towards Additional Mathematics because it was too challenging. Students' and parents' interviews revealed a contrasting view. A student and a parent mentioned that Additional Mathematics was more interesting and exciting than Modern Mathematics because it required much thinking; Modern Mathematics was boring [refer to Section 6.1.2 and 7.1.2]. Apparently, challenges might encourage or discourage learning.

Challenge is the fundamental element of any computer game. In games, learning is initiated by challenges presented in the gaming context (Kiili, 2006). Most of the challenges in games are novel and non-routine at the same time, but they are motivating. Children always take the challenge in games as a motivator to learn something new naturally (Prensky, 2001c). The challenge in computer games is very important because if there is no challenge, then there is no gameplay, no learning, and one will stop putting in effort. A computer game without challenges is a boring game so there is no point of playing. Furthermore, the nature of playing is characterised by challenges and intrinsic motivation (Weisler and McCall, 1976). Challenges in games are enjoyable and fun. Players can choose their preference of challenging tasks, and use their imagination or creativity to deal with their competitors (Corbeil, 1999). In brief, challenges in games are something pleasant and positive because they are neither too easy (e.g. analogues to Modern Mathematics) nor too tough (e.g. analogues to Additional Mathematics).

5.2.2 Lack of Motivation

Most of the teachers mentioned that students were not motivated to learn mathematics. There were a few factors leading to this problem.

a. No confidence

Four teachers (A, B, D and F) mentioned that students were not motivated to learn mathematics because they did not believe in their ability to succeed. A teacher said,

> *Some can say a little phobia about numbers… They tend to think maths is difficult because they see a lot of numbers in one. Like one equation, a very long equation, they think that is hard. Actually not that hard if break into simple parts (Teacher B).*

Students' confidence in mathematics is linked with their beliefs, which is an element of affective domain. Students' determination and achievements are influenced by their perceived self-ability and estimated difficulty of the task (Eccles *et al.*, 1983). Students will work harder and learn better if they believe in self-efficiency (Mayer, 1998). Belief is not reality but it seems to have an impact on students' motivation to learn mathematics. As what is stated in the *Law of Attraction*, negative thoughts may attract negative experience into life. This could imply that a student has the capability to learn but is hindered by self-confidence.

b. No interest

Three teachers (A, E and F) mentioned that students were not motivated to learn mathematics because they had no interest in the subject. A teacher said,

> *They do not like mathematics because they do not like numbers [Translated from BM] (Teacher F).*

Interest is a motivational factor (Mayer, 1998). A student who is interested in mathematics will work harder and spend more time and effort to solve a problem. Students learn more meaningfully when they are interested in the subject (Mayer, 1998). Unfortunately, students nowadays may be less interested to learn in schools because there are many interesting things outside the schools that grab their attention away, for instance, the latest viral news, photos or videos on social media. Conventional classroom instructions no longer stimulate students' curiosity to learn.

c. Exam-oriented

Two teachers (A and E) mentioned that students were *performance achievement learners* because they learned what was needed to achieve the performance. A teacher said,

> *Most of them have no interest. I think most of them study for the sake of exam. [Translated from Mandarin](Teacher E).*

In this context, students are learning mathematics because it is useful in helping them to obtain good exam results. Individuals' achievement-related behaviour can be explained by their beliefs about the value and usefulness of a task (Eccles *et al.*, 1983; Wigfield and Eccles, 2000). Usefulness of mathematics is determined by the importance of mathematics for students' future goals (e.g. obtained grade A or pass). These students may perform well in mathematics although they have no interest in it.

Computer games are motivating because players know that success is possible even though the problems seem to be difficult. There is always an answer in games (Beck and Wade, 2006). Players could gain more confidence and believe in their ability to succeed through sufficient practice. In addition to practice, computer games build up players' self-confidence by making them to believe that they are the main character in games, and they are in control of the game characters, and have full grasp of the strategies contained in the games. Autonomy is one of the innate psychological needs why someone pursue a goal (Deci and Ryan, 2000). In the games' world, players are the boss (Beck and Wade, 2006).

People usually play computer games on their own will without external force (e.g. exam-oriented) because they enjoy the gameplay. Computer games motivate people intrinsically by interest and curiosity. Computer games usually draw players' interest and curiosity by giving novel and surprises that are unpredictable (Malone, 1980). The uncertainties in games stimulate players to play and discover more (i.e. *mastery achievement oriented learners*). Curiosity and playfulness are human nature because people love to know the answer to everything (Stafford, 2012). The curiosity will drive the desire to play and this will create a fun and interesting experience (Denis and Jouvelot, 2005). When the players' curiosity has been satisfied by overcoming challenges in games, it creates a positive and pleasant experience. Therefore, the use of computer games as an alternative way to learn mathematics might eliminate the likelihood of students linking the negative beliefs to mathematics. The students who are proficient in gaming may transfer this confidence in games into classroom learning.

5.2.3 Weak Problem-solving Skills

From the teachers' points of view, there were two main factors causing students' poor problem-solving skills: (a) poor in cognitive and metacognitive skills and (b) digital native characters.

a. Poor in cognitive and metacognitive skills

Four teachers claimed that students had weak problem-solving skills because they could not master the appropriate cognitive and metacognitive skills required in mathematics. The teachers said,

Analysis

> *I think only 20% of them use their brain to do analytical thinking… If you want to teach this skill and look at their result at the same time, this is what happen now, A+, not A. But these A+ students, when they go out, they cannot survive, why? Because they do not have analytical and logic thinking [Translated from BM] (Teacher F).*

Application

> *They can solve it. But to read the questions and transfer the information, that becomes a problem. Transfer the information - that is what they can't [Translated from BM] (Teacher F).*

Monitoring

> *Some students are overcomplicating. For simple questions, they are thinking too much. They can answer difficult questions. But for easy question, they feel it is too easy. So, they are not certain whether it is right or wrong (Teacher B).*

Control

> *Once they cannot cope add maths, so many things to remember, so many concepts to apply, so they cannot cope la (Teacher D).*

Planning

> *They won't use their own strategy. Let say if you don't understand the won't learn from others [Translated from BM] (Teacher F).*

From the teachers' points of view, students were weak in the third (i.e. application) and fourth (i.e. analysis) level of thinking skills in Bloom's Taxonomy as well as metacognitive skills such as monitoring, control and planning. From the teachers' explanations, students seemed to be capable in LOTS such as memorising and understanding of mathematics knowledge.

Learning of HOTS and metacognitive skills, especially in problem-solving contexts is not a simple task. Cognitive and metacognitive skills are developed over a period of time (Grace, 2001). Unfortunately, teachers are facing time constraint and they are unable to spend enough time to meet the need of every student. A teacher said,

> *If you want them to have logic thinking, you have to sit with them. Like yesterday, I spent one to two hours for a question. You have to give them time to think… Now I can't even look after my students… Reduce the workload of teachers [Translated from BM] (Teacher F).*

Teachers were expected to teach HOTS in schools, but they were overburdened with schools' works. Due to the schools' aspiration to maintain good exams performance, teachers were forced to teach only the LOTS.

b. Digital natives' character

Some teachers related the students' problem-solving skills to the current trend of young generation. Students had the characteristics of a digital native. The teachers said,

> *Depending whether they are lazy or not (i.e. follow the step-by-step problem-solving strategies). Some are lazy. Some as long as they finish it, they will go to the next question (Teacher A).*

> *They think that they can combine everything into one. They want to be fast. And they don't want a lot of working… They want to be easy. They want to find the simplest. Actually I want them to step by step (Teacher B).*

> *They cannot think by themselves… I think it relates to the Y generation… They don't have common sense. Computerised, no common sense... They don't think whether the answer is logic? True, so how you want to survive in the real world… I said read slowly… They want to be fast. They like to be fast. When something requires reading, has to transfer, they have no patience [Translated from BM] (Teacher F).*

The teachers characterised the current young generation of students as needing information easily and quickly without much thought. In this section, the teachers seemed to perceive students' learning attitudes as the major factors behind their weakness in problem-solving.

Young generation is comfortable and capable of accessing information randomly rather than sequential access to information (Prensky, 2001b, 2001a). This could explain why some students refuse to follow step-by-step problem-solving instructions that have been laid down by their teachers. Young generation always wants to thrive on instant gratification and receive information fast (Prensky, 2001a, 2001b; Beck and Wade, 2006). Thus, students usually cannot bear with the slow and tedious learning instructions. Sometimes, teachers may have mistaken the students for being lazy (e.g. Teacher A).

The current young generation chooses different skills to learn and uses different methods to learn (Beck and Wade, 2006; Bennett *et al.*, 2008). They receive a significant digital input while growing up, so their brain operations process information differently (Prensky, 2001b). Digital technologies have changed the way young people learn (Helsper and Eynon, 2010). Computer technologies are making our lives more convenient and comfortable because they are getting better, faster and easier to use. Since young, the technologies have taught and trained the current generation of students to learn in a fast and easy way. So, they cannot bear having slow and tedious learning instructions in the schools.

The generation gap between teachers and students is not only in age, but how they grew up with or without digital technologies.

> *It's not just that boomers and gamers grew up differently; those differences have led to very different worldviews* (Beck and Wade, 2006, p.19).

The current young generation prefers self-educating as they learn best through trial and error, and usually disregard formal instructions (Beck and Wade, 2006). They would likely favour interactive learning environment such as computer games because they can access information easily and quickly without much thought.

5.2.4 Gender difference

When the teachers were asked about gender differences in mathematics learning, two teachers (B and E) commented that there was no gender difference. However, the other four teachers did observe that there were differences.

a. Students' behaviour

Two teachers reported that there was gender difference in learning behaviour towards mathematics. The teachers said,

> *In this level Form 4, Form 5, I can say almost equal. Of course boys will be a little of lazy or a little bit of naughty (Teacher C).*

> *Girls are better. Discipline better, easy to control. They are sort of more hardworking than the boys. Don't say so loud, later all the male teachers all come here…ha…ha.. (joking) But in terms of maths, my students usually the*

better one are boys. The top one, ranking one. Because some boys they have the mind (Teacher D).

Both teachers perceived that female students paid more attention in their study, while male students were more playful. Nevertheless, Teacher D said male students usually performed better in mathematics. Teacher C said he did not observe any gender difference in mathematics performance. However, the teacher could be making a cautious statement (i.e. for possible gender bias). Both teachers were teaching Additional Mathematics so most probably this subject required strong determination, practice and hard work.

b. Topics learned

Teacher A and Teacher F observed a difference in the topics learned. Teacher A and Teacher F said,

Some topics boys like it more… Like index, transformation, locus. And in certain topics like indices, the boys like it. Where else the girls do not like it…They like more on the normal straightforward question like linear equation, normal one, parameter, polygon. When they come to abstract, locus, geometry construction, they don't really like (but boys like it) (Teacher A).

If for Form 4, Form 5 mathematics, there is more imagination right? Female students cannot. I am surprise… Boys can get it. They can imagine. For example earth and sphere, you have to imagine the earth, the earth rotates and you have latitude, and you have the longitude. And then one more they have to think of plane and elevation. If you see the object you can imagine. You see the object like this, if you see this object at this side, girls cannot get it (Translated from BM) (Teacher F).

Teacher A and F had noticed that male students had a better imagination ability, and they could understand better on certain topics such as index, transformation, locus, geometry construction, earth, and sphere, plan and elevation. On the other hand, female students preferred topics such as linear equation, parameter, and polygon. Male students were claimed to be better at visualising an abstract object than female students. Two female students also did mention that they were weak in imagination and spatial skills [refer to Section 6.1.3]. Both Teacher A and F were teaching Mathematics and Modern Mathematics so most probably these two subjects required strong spatial abilities.

Males are known to be better than females in spatial ability due to genetic differences (Paul, 2013). The analysed data could suggest that boys have an advantage over girls because they could understand better in some particular mathematics topics that require imagination. Nevertheless, looking from a different perspective - mathematics is a subject that not only requires creativity and imagination but also requires much practice and discipline, so girls would have the advantage too.

To improve visualisation skill, females should play more computer games. Computer games could enhance one's spatial abilities (De Lisi and Wolford, 2002). Females have been urged to play more action games to practise and improve their spatial skills (Paul, 2013). Simulation games are also found to support spatial skills, iconic skills and visual selective attention (Mitchell and Savill-Smith, 2004). Therefore, females who play action and simulation games are expected to have good spatial abilities.

Students' interviews revealed inconsistent result between games played (i.e. simulation and action) and self-reported spatial abilities [refer to Section 6.1.3 and 6.3.2]. Although no experiment had been conducted, students' self-reported spatial abilities were used as comparison. In this study, simulation and action games did not seem to have a significant connection with students' self-reported spatial abilities.

5.2.5 Summary

Table 5.3: Students' Learning Attitudes and Performance in Mathematics

Mathematics or Modern Mathematics	Additional Mathematics
• Positive attitude. • Routine problem. • LOTS are required.	• Negative attitude. • Non-routine problem. • HOTS are required.

Students' Weak Problem-Solving Skills	
Students • Weak in cognitive & metacognitive skills. • Digital native character - random access and want to be fast and easy.	***Teachers*** • Unable to spend sufficient time to teach every individual student. • Student should be patient, read slowly and follow step-by-step predefined routes.

Mathematics Learning	Computer Games
• Lack of motivation. • No confidence - disbelief in self-efficiency. • No interest - no longer stimulated curiosity. • Exam-oriented - *performance achievement learners*.	• Motivating. • Autonomy - control and grasp of strategies and outcome. • Uncertainties stimulate interest and curiosity. • Satisfaction to overcome challenges - *mastery achievement learners*.

Male	Female
• Good in spatial ability. • Less disciplined. • Preferred topics: index, transformation, locus, earth and sphere, plan and elevation.	• Weak in spatial ability. • More disciplined. • Preferred topics: linear equations, parameter, and polygon.

5.3 Teaching Approaches

To explore the potential use of gaming pedagogy in mathematics learning, an understanding of the current teaching approach should be sought from the mathematics teachers. Firstly, there was a need to find out the current teaching approach in schools. Secondly, the adoption of computer games in mathematics learning must take into account the teachers' perceptions of the feasibility and challenges associated with their teaching profession. The teachers were using several teaching approaches: (1) classroom teaching, (2) group work, (3) computers, (4) problem-solving techniques and (5) motivation efforts.

5.3.1 Classroom teaching

All the teachers had spent most of their time teaching in the classrooms. The conventional classroom instruction was described by Teacher B. He said,

> *Give the basic first then example; ask them to do some of the examples in front to show their friends. Then drill them through exercise. Give exercise and they can discuss among themselves. Ask the teacher also can (Teacher B).*

In brief, the conventional classroom teaching starts with teaching the basic knowledge to the students that is followed by some examples. Students are then asked to do some exercises on the whiteboard in front of the classroom and to show their work to the class. Finally, more exercises are given to drill the students' problem-solving skills. During this process, they could discuss among themselves or ask for help from the teacher.

In fact, some teachers (e.g. Teacher A and D) still preferred the conventional approach. The teachers said,

> *I still prefer showing more examples on the board… Yes, traditional way… I still prefer face-to-face teaching with my students. I can see their face, I will know whether they understand or not, their reaction (Teacher A).*

> *If you say mathematics computer games, I think still classroom better (Teacher D).*

Teacher A said she preferred to have a personal interaction with students so that she could understand their problems easily. The presence of a good teacher in the classroom should not be underestimated.

Teachers have the most significant influence on students' motivation to learn mathematics because the support and recognition given by teachers can build up students' confidence in learning (Marchis, 2011). Looking from a different perspective, the teachers want to control the students' approaches to learning. They might be guided by a teacher-centred approach.

In computer games, players are self-educating. Players have full control and responsibilities for their learning experience.

> *The learner is an "insider", "teacher", and "producer" able to customise the learning experience and game from the beginning and throughout the experience* (Gee, 2007, p.208).

In games, players customise their game characters to create their own story. They can project what they want their game characters to be (e.g. heroic, aggressive or cooperative) and how to solve problems in games. Self-taught *trial and error* is the most popular and fundamental way to play a game. Other than that, players can read game tutorial, watch video, find the walkthrough or cheat on the Internet.

5.3.2 Group Work

Group works such as group discussion and project were the most popular and widely used method among the six interviewed teachers. A teacher said,

> *I always use group discussion. And also students present like teacher, mentor mentee system. Let say, the mentor comes out and presents their answer… They like actively involve them. Students like to hear their own friends presenting… Very effective. I can get them interested in my class. Else they fall asleep (Teacher D).*

Most of the teachers (i.e. A, D and E) had a standard approach to group discussion. Students would sit in a group or in pair to discuss a particular mathematics question. After the discussion, a student from each group would be asked to present the solution in front of the class. Though this method seemed to be simple and ordinary, Teacher D, who had 30 years' teaching experience in mathematics said, this was an effective teaching approach.

By chance, two teachers (i.e. D and F) used statistics as an example of a group project. A teacher said,

> *They learn statistics using field data. That means they go and find the data in this school… So, I give them a title, types of cars. Then, they go and jot down Toyota, Mazda, Ford. Find in the whole school. They count and then they have to do the statistics. Find the mod, median, mean [Translated from BM] (Teacher F).*

This could indicate that not all mathematics topics are suitable for this teaching approach. Some topics are too abstract, so the project-based activity may not be applicable. Statistics would appear to be the easiest topic to relate to daily life activities such as data collection, analysing data and presenting the findings.

There are a few similarities between group discussion and project. In both activities, students are actively involved, playing certain characters (e.g. researcher or mentor) and working as a team. Nevertheless, these activities are not competitive because it is not a competition.

Similarly, multiplayer computer games do actively involve the players. Every player is role-playing certain games' character and they work as a team. However, the games are very competitive because they are built on competitions and victory is a pride for the team members. Competition is one of the essential elements in game design (Ebner and Holzinger, 2007) because intrinsic motivation could be influenced by the perceived challenges (Wishart, 1990). People normally engaged in a strong team spirit when they have common opponents (e.g. World War II and World Cup).

Most of the computer games nowadays are also built on group work. For instance, MMORPG is the most popular and addictive genre of computer games (Dickey, 2011) because it is very competitive and built on a strong team spirit and culture where everyone works together to achieve a common goal.

> *Young people see game playing as almost entirely social, preferring to play in multiplayer settings of one sort or another* (Gee, 2007, p.8)

Multiplayer games suit the interest of many young people. The young generation performs best when they are networked (Prensky, 2001a, 2001b) and they can learn from their peers (Beck and Wade, 2006). In games, players can learn how to plan the best strategies to make the best use of the skills and abilities possessed by every team member.

5.3.3 Use of Computers

All teachers interviewed except Teacher B had used a computer to teach mathematics. This was surprising since Teacher B was the youngest teacher among all the teachers participated in this study and would therefore be expected to be the most digital native among all the teachers. Some of the computer technologies used were (a) courseware and (b) mathematics computer games.

a. Courseware

There were two types of courseware used by the teachers. The PPSMI courseware was provided by the MOE, and another courseware was provided by UNESCO. The teachers said,

> *(PPSMI courseware) Initially they were quite interested when they see it. But, if I used it too frequently, they get bored and they are not pay attention… Because the questions are very slow (Teacher A).*

> *(PPSMI courseware) I just used it to show 3 dimensional objects. How it rotates to form a solid… It is effective for the students who cannot visualize…*

Some of them think that it is boring because the CD is slow [Translated from Mandarin] (Teacher E).

(UNESCO courseware) Let say I teach the quadratic function or equation. I can show them how does the effect of A, how the graph look like (Teacher C).

Here, two points were highlighted – visualisation and interactivity. The courseware was useful in presenting diagrams and helping students to visualise abstract concepts. However, it was passive and boring. Teacher A and F had the same opinion that the PPSMI courseware was quite impressive when it was first introduced to the students. However, students got bored because the flow in the CD was too slow. Teacher A explained further that most of the time, students could not understand what was taught in the courseware because it was not interactive. Teacher A said,

Maybe if they are answering a quiz, this question answer, then it is okay la… They are doing a quiz on the computer, maybe they will be more interesting (Teacher A).

One of the possible reasons contributing to students losing interest in the PPSMI courseware was that students were not actively involved in learning. During the interview, both teachers (i.e. Teacher A and E) indicated that they had stopped using the PPSMI courseware because it was not motivating. The courseware was merely like a slow motion television show in which students were passively consuming the learning content. The courseware was good at visualising abstract concepts, but not interactive (i.e. passive learning).

Computer games, however, help to improve players' spatial abilities (Feng *et al.*, 2007; Cherney, 2008; De Lisi and Wolford, 2002) as well as engage them in active learning. Interactivity is one of the essential elements in computer games because players are *learning by doing*. In games, learning is a cyclic process because knowledge is constructed through constant practice. Given a problem in games, players devise a solution, test it, reflect on the feedback, refine the solution, and test it again (Kiili, 2005b). To learn, games have to provide instant feedback on what the players have done. The interactivity in games engages active learning. This is an experiential learning in which knowledge is a combination of grasping experience, and learning by doing (Dieleman and Huisingh, 2006). In games, knowledge is not passively consumed, but it is actively discovered. It eliminates the negative learning experience such as boredom and confusion in understanding.

b. Mathematics Computer Games

Teacher C had used and was still actively using computer games to teach mathematics. He said,

> *Only four basic operations just like plus, minus operations. There is a game called Command and Conquer (i.e. he was not sure of the actual name)… Even a student very good, sometimes they not perform very well in that game… Because they need spend their mind, how fast they can get… They will feel fun. After they feel fun, they will build their interest. After they build their interest, they will learn mathematics better (Teacher C).*

After the interview with Teacher C, I had the opportunity to look and play the computer game (refer to Section 4.4.2). The game taught ones with basic calculations and shapes. From my observation, the game was more appropriate for primary or lower secondary students because it involved basic mathematics. Nevertheless, it could be used to add little excitement to the classroom learning environment. Although the game was simple, I did have some fun when playing it because it tested my response rate in addition to my mathematical skills. From my point of view, it was the implicit skills required (i.e. fast response rate and concentration) that made the game interesting, not the quality of the questions in the game.

Computer games value not only explicit and verbal knowledge, but also the implicit knowledge that built into their movements, bodies and unconscious ways of thinking (Gee, 2007). Neither explicit nor implicit knowledge alone is sufficient to be a good game player. The need for multiple abilities and intelligences has made the game interesting. Children like to play games because games require different learning skills such as researching, thinking skills, problem-solving and social skills (Prensky, 2001c). A broad coverage of skills and knowledge is taught across different game genres because different genres require different of implicit skills.

5.3.4 Problem-Solving Techniques

Problem-solving is the fundamental activity in the teaching and learning of mathematics. Three teachers shared their problem-solving techniques, and adopted four primary stages - understanding the problem, devising a plan, carrying out the plan and looking back (Polya, 1945). They said,

> *Understand the problem, do proper sketching; we need to draw a simple diagram to understand yes, they do. Then write down your equation and then solve it and check your answer (Teacher A).*

We ask them to read question at least more than 3 times. And then try to identify what are the information given. Then try to plan out the strategy. What formula to be used. What have to find. Step by step (Teacher D).

They have to understand the question, and then they have to identify what is required by the question. I will ask them to underline the important points. Identify the formula and solve it. Finally, check using a calculator [Translated from Mandarin] (Teacher E).

In the first phase of understanding the problem, students are advised to read the question for at least three times. In this stage, students need to understand what is required by the question based on the information given and highlight the important points. During the second phase of devising a plan, students should plan their strategy (e.g. do proper sketching or diagram) and identify the formula to be used. The third phase is to implement the plan. Finally, the fourth stage is looking back, and students are advised to check their answers (e.g. using a calculator).

Problem-solving techniques that are stressed by these teachers include both cognitive and metacognitive skills. For instance, reading is a cognitive skill (Artzt and Armour-Thomas, 1997) while understanding the problem, planning a strategy and checking the answer are metacognitive skills (Artzt and Armour-Thomas, 1997; Yimer and Ellerton, 2006). The process of problem-solving seems to link with Bloom's Taxonomy – remembering (e.g. recall a formula), understanding (e.g. comprehend the question), applying (e.g. solve the problem), analysing (e.g. draw a diagram), evaluating (e.g. check the validity of the answer) and creating (e.g. planning a strategy). In this section, it is understandable that mathematics problem-solving is taught formally and in a step-by-step manner in schools.

In computer games, however, problem-solving appeared to be informal, natural and flexible. In games, players are not confined to a pre-fixed step-by-step problem-solving approach but free to adopt any strategy that they think will work through trial and error. The players can learn and progress by testing a hypothesis, taking a risk and reflecting on the mistakes (Gee, 2007). The persistent try and error help the players to construct a unique problem-solving strategy that could be different from others. Problem-solving strategy in games is learned and developed by making mistakes. The flexibility to derive a problem-solving strategy encourages creativity and inspiration. Even though the players may be stuck at the same level, every new attempt is a novel because the problem is randomised. Apparently, good computer games do not repeat the same pattern of problem again and again as in the drill-and-practice in a conventional classroom teaching.

5.3.5 Motivation efforts

Every teacher had different ways or strategies to motivate students to learn. There were two general approaches: (a) innovation in teaching and (b) psychological approach.

a. Innovation in teaching

Three teachers (A, C and F) tried to make their class interesting by using acronyms, diagrams, tables, technologies or students' prior knowledge. A teacher said,

> *I will think which is easier for my students to learn. And of course what is their prior knowledge, so I will match on their prior knowledge... So meaning it is continuous lesson… Second one would be, I try to integrate technology (Teacher C).*

The teachers generally believed that making the lesson easier to be understood would motivate students to learn mathematics. The appropriate use of teaching aids and computer technologies was very much depended on teachers' experience in the actual classroom setting.

b. Psychological approach

Three teachers (C and E) also tried to use a psychological approach to motivate students to learn, for instance, an understanding of students' backgrounds and the use of praise. A teacher said,

> *Normally I will praise them… If they are really motivated to learn, their result will improve significantly [*Translated *from Mandarin] (Teacher E).*

Teacher E always praised her students as a reward for completion of a task or whenever it was deemed suitable. Although praising students might seem to be a simple thing to do, it was a powerful internal motivator. It is worth highlighting that the current young generation has the *heroic belief* trait that desires for challenge and wants recognition from others (Beck and Wade, 2006). Praise seems to fit well into their *heroic belief*.

Computer games do promote players' *heroic belief* by making them believe that they are the boss, expert or tough guy after series of training (Beck and Wade, 2006). The players are driven to achieve great performance for their appeal to pride instead of greed and ambition (Beck and Wade, 2006). Although some of the games require teamwork and a player may collaborate with other players, he or she still holds the *heroic belief* to outdo other team members to be the leader. In games, players do want to be rewarded for achievement, and recognised for being the hero

(Beck and Wade, 2006). The recognition and rewards are strong intrinsic motivators in games.

5.3.6 Summary

Table 5.4: Existing Teaching Approach vs. Computer Games

Existing Teaching Approach	Computer Games
Classroom teaching • Teacher centred.	 • Self-educating.
Group work (discussion/project) • Active learning and teamwork. • Role-play as researcher or mentor. • Not competitive.	 • Active learning and teamwork. • Role-play game characters. • Competitive.
Courseware • Visualisation of abstract concepts. • Not interactive. • Passive learning – passively consuming the learning contents.	 • Visualisation of abstract concepts. • Interactive. • Active learning – learning by doing and grasping of experience.
Problem-solving technique • Taught formally. • Polya's four-step problem-solving. • Follow teachers' predefined strategies.	 • Learned informally. • Trial and error - learning from mistakes • Creative and novel strategy.
Motivation efforts • Innovations in teaching. • Compliment and personal approach.	 • Promote heroic belief – tough guy, expert, and boss.
Mathematics Computer Games • Learning of explicit and implicit knowledge. • Learning of broad coverage of knowledge and skills – multiple intelligence.	

5.4 Teachers' Technological Experience

To explore the potential use of gaming pedagogy to learn mathematics, it was crucial to understand teachers' technological experience. Two key points were necessary to gain insight into this knowledge. First, there was a need to find out the teachers' computer and mobile phone usage; and second, to understand the teachers' self-reported technological skills.

5.4.1 Computer Possession

The teachers' computer experience could be understood by examining their possession of different types of computer technologies and frequency of usage.

Table 5.5: Computer Possession and Usage

TEACHER	A	B	C	D	E	F
Desktop	2	0	2	0	1	0
Laptop	2	1	6	1	1	5
Tablet	1	0	4	1	1	3
Smartphone	1	1	1	1	1	1
Internet	Yes	Yes	Yes	Yes	Yes	Yes
ICT exposure	1996	2000	1988	University	Form 3	Form 5
Comp. experience (year)	19	15	27	32	27	23
Usage frequency	Daily	Daily	Daily	Daily	Daily	Daily
Hours spent per day	1-2 hrs	>4 hrs	>5hrs	2 hrs	1-2 hrs	5 hrs

All the teachers had at least 15 years' experience of using computer technologies and had access to computers on a daily basis for more than one hour per day (see Table 5.5). Teachers' computer experience did not seem to influence their frequencies and hours spent on the computers.

5.4.2 Computer Usage

The teachers' technological experience was examined from two different aspects: usage frequency and technological expertise (See Table 5.6 and Table 5.7).

Table 5.6: Usage Frequency for Various Computer Activities

Teacher	A	B	C	D	E	F
Works						
Typing documents	1	2	1	1	1	1
Analyse data	2	2	1	1	1	1
Prepare presentation slides	3	2	1	2	2	1
Do school work	1	2	1	1	1	1
Emails/ Communication	1	2	1	1	1	1
Entertainment						
Playing games	4	2	1	4	4	3
Watching movie	4	1	2	4	4	4
Listening to music	3	2	2	3	4	1
Social networking	3	2	1	3	4	4
Advanced Usage						
Using search engines	2	2	1	2	2	1
Search for medical information	2	3	1	3	4	3
Search for directions	3	3	2	4	4	1
Reading news	2	2	1	2	4	2
Online Shopping	3	3	2	4	4	4
1-always, 2-sometimes, 3-rarely, 4-never						

Table 5.7: Technological Expertise

Teacher	A	B	C	D	E	F
Office Applications Skills						
Typing skill	4	3	5	5	5	4
Word processing	4	3	5	5	5	5
Spreadsheet	3	2	5	3	4	4
Presentation	3	3	5	4	3	4
Entertainment Skills						
Social networking	2	3	5	4	1	1
Find/download song/video	2	4	5	4	1	2
Video sharing via YouTube	2	3	5	4	1	1
Advanced Skills						
Internet search	4	4	5	5	5	5
Download/ install software	2	4	5	5	3	2
Use of electronic gadgets	4	3	5	5	4	2
Basic computer maintenance	3	3	5	4	3	1
Basic troubleshooting	2	3	5	1	3	1
Other IT skills		Photoshop & graphic editing	Programming, networking, database			

1 would represent novice and 5 would represent expert

a. Office Applications

The teachers always used computers to do their school works. Having an equal responsibility to the teaching profession, both male and female teachers mostly used computers for administrative purposes such as typing documents, analysing data and sending emails. The use of presentation slides was less common because using computers (instead of using a whiteboard) to teach mathematics in the schools was not a usual practice. The frequent use of office applications had led to a conclusion that they were proficient (i.e. all rated 3 and above except one teacher) in typing, using word processing, spreadsheet, and presentation software. Comparison between male and female teachers revealed no significant difference in the usage and expertise in office applications.

b. Entertainment

Most of the teachers hardly used computers for entertainment purposes, especially the female teachers. All female teachers never used a computer to watch movies and three out of the four female teachers never played computer games. Conversely, the two male teachers always or occasionally used computers for entertainments (e.g. play games, watch movies, listen to music and social network). The male teachers typically rated themselves to be better in using computers for entertainment purposes in comparison to their female counterparts.

There might be two possibilities for arriving to this conclusion. Firstly, the female teachers might not have time to spend on themselves due to their busy schedule. Secondly, the female teachers might spend their leisure time differently without having to use a computer. For instance, they might watch movies on a television; play board games; have a face-to-face communication (instead of social networking), and listen to the song on a radio. These were the usual activities of digital immigrant before the booming of computers. The computer technologies seemed to have a stronger influence on the male teachers, and they would most likely have learnt new technologies in comparison to their female counterparts.

c. Advanced Usage

The teachers had the best advanced technological skills in the Internet search as all of them were rated as proficient (i.e. rated 4 or 5). That was followed by the use of electronic gadgets, software installation, computer maintenance and lastly, troubleshooting. In general, the male teachers used a computer for advanced usage more often, and rated themselves to be better than the female teachers. That was expected because Teacher B was capable in Photoshop and graphic editing, whereas Teacher C was capable in programming, networking, and database. None of the four female teachers interviewed had any additional technological skills.

The teachers seemed to portray significant gender gaps between male and female in technological skills. Most of the teachers especially the females were not too enthusiastic about computers or computer technologies. The female teachers normally used computers for work-related matters, and rarely used computers for entertainment or advanced usage. The male teachers had a higher affinity for entertainment usage and they not only used computers for job-related tasks, but also used computers at home for their personal interest such as playing games, watching movies, listening to music, and connecting to social network. The male teachers seemed to invest more personal time to explore the computer technologies due to their personal interest and positive perceptions.

This finding is supported by the literature that indicates that male teachers have better computer experience and are more positive about the computers and web technologies than females and they use the computer more often than the female counterparts (Yadollahi, 2015). The teachers' computer experience is grounded on the *need* to perform their jobs. Their computer usage has a pattern of bureaucracy. Their jobs involve technical usage such as typing documents, sending emails, analysing data and other clerical works because they are assigned, instructed and obligated to do so. The experience is not enjoyable, and they are doing the minimal to satisfy their job requirements. They need external motivation or coercion to accomplish the monotonous school works. Despite using computers on a daily basis, they are not progressing and expanding their technological skills - they are not experimenting or learning. Doing school works is a routine practice and no new insight or knowledge is gained through the practice. The teachers' attitudes towards the computer are similar to the students' attitudes towards mathematics. Teachers have to use a computer to get the school works done; students have to study mathematics to pass the exam.

5.4.3 Smartphone Usage

Every teacher owned a smartphone and he/she normally used it for making a call, using mobile messaging applications, checking emails and sending texts using SMS. From the teachers' points of view, having a smartphone was a necessity to help them in daily life communication and work (e.g. calling, SMS, messaging, email).

Table 5.8: Usage Frequency of Smartphone

Teacher	A	B	C	D	E	F
Phone communications						
Making phone calls	1	2	1	1	1	1
Sending SMS	3	2	1	1	2	1
Using messaging application	1	2	1	1	1	1
Entertainment						
Playing games	3	1	2	3	4	3
Taking photo/video	2	2	1	1	2	2
Watching TV/video	2	3	2	3	4	4
Using Facebook	3	2	1	1	4	4
Advanced Usage						
Web browsing	2	2	1	2	2	2
Checking emails	2	2	1	1	1	1
Using map/ directions	2	2	2	4	3	1
Reading news/ sports	2	2	1	1	4	2

1-always, 2-sometimes, 3-rarely, 4-never

The teachers' smartphone usage is grounded on the *need* for daily life communication. They have no strong interest or habit of *playing* with their phones such as accessing to Facebook, surfing the Internet or playing games even they have free time. For the teachers, a smartphone is not meant for fun, but a tool that allows them to be contacted conveniently.

Most of the teachers stop learning *formally* and *informally* once they have graduated from the university. They use the computer for basic administrative work and daily usage. Their computer knowledge is obsolete after they have left their universities. Most of the teachers have no interest to learn the cutting-edge technologies such as computer games, Facebook, Twitter, YouTube and many more because they do not see the necessity to keep updating with the latest technologies.

Teachers are then left behind by the technologies as compared to the students. One of the biggest problems in today's education is that the outdated digital immigrant teachers are struggling to teach the digital native students who speak an entirely new language (Prensky, 2001a). Although the digital immigrant teachers use computers and smartphones, they are not actively doing the digital native activities such as playing digital games, accessing the social network, surfing the Internet and listening to music.

In fact, they continue doing the old practice (e.g. calling, writing a letter, typing document and analysing data) by adopting the current new technologies. They are forced to change because the society is changing and the school requirements have changed as well. The technologies do not change their old practice or how they work (pragmatic accommodation). They are using the technologies to fit into their current working style, and they are not keen to learn the new digital native activities (assimilation).

> *Although a minority of teachers are clearly able to effortlessly assimilate and incorporate digital technologies into their learning, others are seen to reach a pragmatic accommodation of technology into their existing modes of working* (Selwyn, 2011, p.126).

Teachers *have to* use the new technologies, but students *want to* use the new technologies. The difference in motivation has driven a different learning outcome. Digital native students (i.e. exposed to various types of digital technologies since young) have an early advantage (accommodation) over the teachers who are limited in their computer knowledge. This could explain why most of the students are good and learn new technologies easily (assimilation).

5.4.4 Summary

Table 5.9: Technological Experience – Male vs. Female Teachers

Male	Female
• Always used computers for work, entertainments and advanced usage. • More proficient and interested in ICT.	• Mostly used computers for work. • Less proficient and interested in ICT.
Both male and female teachers: • Always used computers for work - office applications to type documents, analyse data and send emails. • Always used smartphones for communications - calling, texting and sending emails. • Accommodated technology pragmatically to fit into their existing working style. • Use computers mainly for schoolwork (i.e. routine work) - not for fun and not for learning.	

5.5 Students' Technological Skills

The use of computer games in learning mathematics requires an understanding of the students' technological skills. One of the methods that is used to achieve this understanding is by taking the perspective of teachers who have everyday interaction with their students. By exploring this, a general idea of the collective strengths and weaknesses in technological skills among the students could be obtained. In this way, however, only provides perceptions of the teachers as to the skills students showed in classrooms.

5.5.1 Strength

Most of the teachers claimed that students were good at using the computers for entertainment purposes such as social media (e.g. Facebook, Twitter), WhatsApp's, YouTube, uploading and downloading media from the web, video editing, playing computer games and use of electronic gadgets such as smartphones. The students who were born in the digital world would find it easier to keep up to date with latest technology development because they were the native of the digital age. Teacher B said,

> *They are sensitive to the news… Whatever that is popular, then they will go to it… They tend to focus on the popular one, popular game (Teacher B).*

The teachers were claiming that students were always updated with the latest technologies and good at many technological aspects, but they did not consider or even think about how students learn. The students seemed to know a lot and capable of doing many things that teachers could not do. The teachers viewed those skills as merely for entertainment without any educational value or possibility of learning. They seemed to put a boundary around it, and to make a partition it off from learning or education.

Students are learning technological skills outside the school and in their everyday life in this fast-paced world. However, most of the teachers are not learning outside the school, and some may perceive that learning only happens in schools. School exams usually do not assess students' technological skills in entertainment usage, so teachers perceive those skills as not useful. However, if students are gaining those entertainment skills by reading a book and those skills are assessed in exams, then most likely the teachers will value its learning benefits. Most of the teachers from older generations refuse or even stop learning in their daily life. The difference in learning attitude has widened the generation gap between the teachers and their students.

5.5.2 Weaknesses

Some teachers felt that most of the students did not use computers for learning purposes such as searching for academic learning content on the Internet. However, the claims were made based on their personal understanding and knowledge. The teachers' understanding of computer-based learning was confined to the academic learning content. The teachers also explained that students were not taught to use computers for learning in schools. Thus, students might think that computers were only useful for entertainment purposes because they hardly used computers in an educational context. This showed that students already had expertise in computer literacy but might need to have this skill legitimised for classroom learning.

Students are actively *learning* the latest technologies and constantly improving themselves. For instance in computer games, students are *learning* how to play the games. However, many older generations will say this.

> *Playing games is a waste of time because the child is learning no content* (Gee, 2007, p.37).

Schools usually do not recognise tacit or embodied knowledge built through practice and adaptation to change (Gee, 2007). Schools are exam-oriented and focus on the explicit *content knowledge*.

When it comes to technology, there is an enormous difference between the teachers of older generation and the students of younger generation.

> *The whole generation, including X and Y and letters to be named later - simply approach the world differently than their predecessors* (Beck and Wade, 2006, p.19).

The generation gap between the teachers and students is obvious even without any survey or interview. The life-style and the way of thinking of young generation are so much different from the teachers' generations. It poses a great challenge for the teachers to teach across the generation. Today's students (i.e. those born after 1980) are no longer the people our educational system is designed to teach (Prensky, 2001a).

5.5.3 Summary

Table 5.10: Teachers' Perceptions of Students' Technological Skills

Strengths	Weaknesses
• Use of computers for entertainment purposes. • Social media, WhatsApp's, YouTube, upload/download media from the web, video editing, playing computer games and use of electronic gadget.	• Use of computers for learning purposes. • Searching for academic learning content on the Internet.
• Students are learning outside of the school and in their everyday life. • Many teachers of older generation do not value learning of technologies - waste of time because it does not involve learning of content. • Schools value explicit content knowledge but not tacit knowledge.	

5.6 Teachers' Gaming Experience

To understand the potential use of gaming pedagogy to learn mathematics, an insight into the teachers' gaming experience is important. If computer games are to be incorporated into mathematics learning, teachers would be the first to embrace the new strategy and use the games as new teaching tools. The ability for teachers to adapt to this new teaching strategy will be one of the vital keys to successful implementation. Therefore, it is important to establish the gaming patterns of teachers, and secondly, to understand teachers' perceptions on computer games.

5.6.1 Gaming Pattern

Among all the teachers interviewed, only one teacher (i.e. Teacher E) never played computer games so she would be excluded from the gaming discussion. According to Teacher E, she had no interest in gaming. There were two gaming patterns seen among the teachers. The male teachers played different types of games such as fighting, strategy, puzzle, role-playing, sports, action-adventure and MMORPG, whereas, the female teachers played only puzzle games.

a. Male Teachers

A male teacher (i.e. Teacher B) played *Clash of Clans, King of Fighter, Street Fighter, DotA,* and *World of Warcraft*. He played these games because he enjoyed the competition with the other players in the games. Teacher B played digital games for two to three hours daily. The other male teacher (i.e. Teacher C) enjoyed playing *Command and Conquer* once a week for less than one hour. He said,

> *There is some part I need to learn how to use strategy to conquer the other world. There is one strategy I always used. How I can know my students, I*

> *need to know my students well. This is part of my strategy in my teaching and learning. So I get to know my students. So I need to conquer their mind. So basically they will follow me (Teacher C).*

Teacher C had an interesting teaching strategy adopted from gaming. Students were analogous to the opponents in games, and he used those gaming strategies to understand and to motivate his students to learn. His strategy seemed to be effective. From the students' and parents' interviews, I got to know that he was one of the best teachers in the school.

Comparatively, both male teachers were equally good and knowledgeable in gaming. According to them, they learned multitasking, land navigation, teamwork, problem-solving, and concentration through gaming.

b. Female Teachers

The female teachers were not active gamers. Other than Teacher E who never played any computer game, the other three female teachers (i.e. A, D and F) played only puzzle games such as *Candy Crush, Solitaire* and *Sudoku*. *Candy Crush* was their favourite game. Teacher D who spent approximately 30 minutes per day playing *Candy Crush* said,

> *Because you feel that you like to complete the level. If you don't get it, you will feel not worth it, angry and really not satisfied. You want to try again until get it done. The feeling of satisfaction. If you complete one level, you feel very happy… The happiness, enjoy doing that (Teacher D).*

Teacher D explained that the principle of *hard fun* (Papert, 1998) or *pleasantly frustrating* (Gee, 2007) had engaged her to play *Candy Crush*. In *Candy Crush*, learning was essentially hard and frustrating when she failed to complete a level, but the learning experience was fun, enjoyable, pleasurable and contented.

Another two female teachers (A and F) showed less interest towards gaming. Teacher A cited that she had stopped playing computer games although she had played *Solitaire, Sudoku* and *Candy Crush* in the past. She said,

> *Solitaire was numbers, because it is more like arranging. Candy Crush also is because finding the similarities… Just to stretch my mind. Ya, I forgot I used to play Sudoku in the smartphone… I like games that involve numbers. I don't know, just like it… Ya, logical thinking. Thinking to solve it and arranging it (Teacher A).*

Teacher A preferred playing puzzle games that required analytical and logical thinking skills. This could be related to her job as a mathematics teacher. As for Teacher F, she did not have much interest in gaming. She said,

> *Nothing interesting. Just to waste my time. That one minute is sufficient. No time to be wasted [Translated from BM] (Teacher F).*

Teacher F was not only having no interest in playing computer games, but also perceived playing games as a waste of time. As expected, the female teachers (A, D and F) did not recognise learning of multitasking, problem-solving and land navigation skills in computer games. However, two teachers recognised learning of teamwork and concentration skills.

Teachers' gaming experience (e.g. hours spent and types of games played) seems to be consistent with their self-reported metacognitive skills learned (i.e. multitasking, land navigation, problem-solving, teamwork and concentration). The male teachers who have claimed to be knowledgeable in gaming are well-informed of learning various metacognitive skills in games. Conversely, the female teachers who have played only puzzle games are being truthful for they have admitted that they are not aware of learning most of the metacognitive skills in games. It is a common notion of adults that they only see the negative side of gaming and miss some positive opportunities that gaming might offer.

The above finding could imply that the male teachers enjoy playing computer games, but not the female teachers. The male teachers seem to plan and have an intention to play computer games during their leisure time. However, female teachers play computer games only when they have some spare time without any significant purpose. The teachers' gaming experience is very much influenced by their gender differences.

Older generations hardly play computer games because they are not capable or they have no interest in gaming. The older generations may not see the enjoyment in using such technologies. They may view pleasure differently. For instance, they may enjoy more practical activities - fishing, reading and cooking. It is a tendency that the older generations do not enjoy playing games.

> *A boomer who can't pick up a new program is basically just not trying. But a boomer who can feel natural playing a game – is a real anomaly* (Beck and Wade, 2006, p.19).

The older generations were first introduced to computers when they were in high school, university or at the workplace, to complete a serious task. However, young generation nowadays were first exposed to computers to play games.

For the young generation, a computer is their close friend to play with or a learning companion since young; but for the older generations, a computer is like a friend that they know later in their lives (i.e. working companion) – they have grown up and they do not play like kids anymore. Different childhood experience may have formed different feelings and views about computer technologies.

5.6.2 Advantages and Disadvantages of Games

When the teachers were asked about the advantages and disadvantages of computer games, their responses showed different perspectives.

a. Type of games

Teacher A justified whether a game was good or bad based on the types of games. She said,

Good Games

> *Simulation, may be. Puzzle, yes… Sport yes. Sometimes when they play bowling or football, they learn techniques of playing…. Sometimes they play chess in the computer. Maybe that is good because they already stretch their mind to think (Teacher A).*

Bad Games

> *If they are going to play things like shooting, fighting and racing, I don't think it is really good. These violent game… They (i.e. action adventure games) make the students very hyper. They get too in the dream world than in actual reality (Teacher A).*

This classification of games might be based on her personal prejudice and dislike of violence. She might not see the attraction in shooting, fighting and racing games that children are looking for - the thrilling, excitement and competition. Most of the games that she has labelled as *violent games* are exciting and interesting to the children because those games are not our lived-in world. The games world is something novel and full of surprises. Children are full of curiosity and they want to try and experience something different that they could not do in real life. In games, children can do whatever they want such as shooting, killing and being killed many times because that is not real. The games that the teacher labelled as *violence* and *dream world* are in fact interesting to the children because they have been listening to different kind of stories since young. Thus, they want to experience those stories in games.

b. Skills learned

The two male teachers believed that there were certain skills that they could learn from playing computer games. The teachers said,

> *Considered good as to help them in problem-solving skills. Because strategy they need to think a lot. But, now they don't know how to apply it in studies… Cooperative skill also got because I have my DotA competition in school for this month. I can see a lot of interaction between the team members… Is a type of strategy game to see how they up their hero and buy items to defeat the opponents. They will need basic of the calculation of the damage and stuff. The timing how they want to attack their opponents. But they don't think of that in terms of mathematics (Teacher B).*

> *It will depend on how students play the game… Is not only playing the game, you must learn something from the game. That is a good thing. Now our students, basically will be only absolutely playing game only. They didn't learn anything from the game (Teacher C).*

Both teachers have the same opinion that computer games are beneficial, but students do not apply or relate the skills learned to their academic study. From the dialogues above, Teacher B has explained that some games do require mathematics (e.g. buy items, calculate damage and devise appropriate timing to attack). Players are subconsciously forced to do calculations to defeat the other players or the game itself. However, it would be up to the students to know what they have learned, and whether or not the skills could be applied into other aspects of their lives. This is a positive indication to introduce COTS games to learn mathematics.

c. Game addiction

In general, five teachers (except Teacher A) had a common opinion on the consequences of gaming that students should not spend too much time playing computer games since they might be addicted to it. One of the teachers said,

> *If you don't indulge in it, it's ok. Just to pass the leisure time... If you really spent too over the limit, is really bad for the health… Parkinson occurred now as young as 30 plus years old. Why? Doctor said one of the reasons why they get Parkinson such an early age because of the use of smartphone (Teacher D).*

The five teachers generally mentioned that students should limit their time on gaming. They were concerned about students' habits and health condition. From the teachers' points of view, spending excessive time on gaming was not good for the students' health. However, they did not seem to worry about students' health for spending long hours solely for academic purposes. Most of the time, students' psychological and emotional health were overlooked when compared to their physical health.

d. Effect on study

Three teachers explained the effects of computer games on students' studies. The teachers said,

> *I mean if they are supposed to do their homework. Before that they are playing, I don't think they can come back to work. Unless they already done their homework and they go to play during their free time (Teacher A).*
>
> *Different students have different ability. One of my nieces, every day play game more than 5 hours. Even they play the game; they still attempt to do their study (Teacher C).*
>
> *This one (i.e. MMORPG) considered heavy games… This one consider heavy for their concentration…. Normally one game is one hour. If one hour can affect already, that is quite tiring. Because they need to think a lot of the strategies… But simple game like Clash of Clans, just a few minutes, not much effect… Simple puzzle game is ok… Fighting also not much effects because one game is not that long and unless they continue to play many hours, then they will get the effects (Teacher B).*

Teacher A claimed that gaming might affect students' studies if they played games before completing their homework. This was the teacher's personal point of view and she had no evidence to support her argument. In fact, certain games might sharpen the students' mind and inspire them to think.

Teacher C had a difference stance. He said that every student was different, and some children could study even after playing digital games for a relatively long period of time (e.g. 5 hours).

Teacher B gave a detailed explanation for these two stands. He said certain games were quite exhausting. For instance, MMORPG required full concentration and students would be mentally exhausted after an hour of gameplay. However, he believed that puzzle and fighting games did not have such effect unless students played for a very long period of time. The effects of the game on the students would depend on the types of games played and the duration of the gameplay.

Teachers who have a strong affinity for computer games recognise the benefits of gaming through their personal experience. Conversely, the teachers without much interest and experience in gaming have a bias towards computer games as negativity in games is always reported in the local media. For instance, a local

newspaper recently has reported that game addiction is a growing problem among children and young adults in Malaysia because it causes violence and social problems (Loh *et al.*, 2016). Many older generations see computer games as a major threat and a waste of time for causing violence and sexism (Beck and Wade, 2006). Many older generations do not see what they can learn from the younger generations.

> *We non-gamers miss a lot because we are trapped in our own prejudices of the past* (Beck and Wade, 2006, p.20).

Beck and Wade (2006) have raised a question of whether there is a difference between prejudice and fear. Deficiency in gaming knowledge may stir up fear over the hidden uncertainties of the new alternating technology might offer. Fear may then turn into a phobia and prejudice towards the technology. For instance, a teacher has disclosed that she is not proficient in gaming and labelled herself as *old timer* [refer to Section 5.7.3]. So, she does not see the necessity to use computer games to learn mathematics. A computer game is a tool for learning, just like a knife is a tool for cooking. Just because someone uses a knife to commit crime, it does not mean that the knife should be banned from the schools (e.g. in the culinary classes).

5.6.3 Summary

Table 5.11: Gaming Experience – Male vs. Female Teachers

Male	Female
• Strong interest to play computer games. • Playing fighting, strategy, puzzle, role-playing, sports, action-adventure and MMORPG. • Motivated by competition and used gaming strategy to teach. • Recognised the benefits – learning of various metacognitive skills and calculations.	• Little interest to play computer games. • Playing only puzzle games and the most popular game - Candy Crush. • Motivated by hard fun and challenge to use logical thinking. • Recognised learning of teamwork and concentration. Concerned of the negative effects especially shooting, fighting and racing games – violence, hyperactive, game addiction, health hazard and disruption to studies.

5.7 The use of computer games to learn mathematics

In this section, I examine whether the teachers have prior knowledge, exposure and experience of using mathematics computer games. If they have then, the extent of utilisation of computer games in mathematics learning would need to be assessed. Their knowledge, feedback and perceptions will serve as a guideline for the potential use of gaming pedagogy to learn mathematics.

5.7.1 Exposure to Educational Computer Games

During the interview, the terminology *educational computer games* has been defined as digital games designed for educational purposes. These would include computer games that are used to learn mathematics, spelling, science and many more.

Among all the teachers interviewed, Teacher C was the only one who had used mathematics computer games for teaching. When he was asked how he had integrated computer games into his teaching, he said,

> *It depends. Because let say the teacher needs to go through the resources, what the teacher needs may be that small part only. When they are using quadratic equation, because the graph would be different. I can identify value, change value and the graph show to the students… Yes (depend on topic), may be only five minute, may be only ten minutes (Teacher C).*

From the teacher's point of view, the use of computer games was merely a learning aid. Two teachers (B and F) knew a few educational computer games, but they never used the games for teaching. Teacher B quoted two games - *Typing versus Zombie* and *2048*. Teacher F cited a mathematics game for primary education. The other three teachers (A, D and E) had no exposure to educational computer games.

5.7.2 Good Educational Computer Games

Each of the teachers was asked how he/she would describe a good educational computer game. All the teachers rated *strongly agreed* or *agreed* that educational computer game should provide training and practices, allow learning from problem-solving experience and provide real life application problems. The teachers perceived that educational computer games should depict the characteristics of the three generations of educational computer games as discussed in Egenfeldt-Nielsen (2007). Nevertheless, most of the teachers perceived the educational computer game as a tool to provide training and practices that had more emphasis towards behaviourism. For example, Teacher D said, *Not computer games. But proper maths computer, proper one, mean really need some basic or concept maths. And then, they have let say questions and answering part to test the progress of the students. And marks will be like give yourself assess test, answer the questions then you get how many marks. Not really computer games. But proper educational mathematics software is good (Teacher D).*

Teacher D has highlighted two important points – COTS games are not appropriate for learning; educational games should be designed around questions and answering. Apparently, the teacher does not think that a COTS game is an educational game because the learning content (e.g. mathematics concept) is not explicit. The use of computer games is only limited to practice such as simple puzzle games that are structured like multiple choice questions or simple fill-in-the-blank. The teacher's understanding of computer games is confined within the games that she has played. Obviously, her major concern is having more practice for exams.

Teachers do not have much exposure to educational computer games so they may not be aware of the benefits brought by the games. Furthermore, most of the educational computer games available in the market are edutainments, free and mostly designed for young children. For instance three online game sites to learn mathematics such as Maths Game Time (http://www.mathgametime.com), Maths is Fun (http://www.mathsisfun.com) and Fun Brain (http://www.funbrain.com) provide many interesting mathematics games. These games are designed specifically for kids to perform drill-and-practice and the learning contents are explicitly presented.

Giant computer games developers (e.g. Nintendo, Sony and Microsoft) have spent a huge amount money, efforts and time in producing COTS games that meet consumer's demand. It is interesting to see how much of these resources have been put in to create educational computer games. The lack of good educational computer games suggests a lack of research, budget and expertise to incorporate computer games for education. If a market survey can prove the profitability and the potential market of educational computer games, it might attract more computer games developers to invest in creating better computer games for education.

5.7.3 Possible Adoption

Since Teacher C had adopted computer games in his teaching, the other five teachers were asked to comment on the potential use of computer games to teach mathematics. The responses obtained were not very positive.

a. Concerns

i. Time constraint

Most of the teachers (B, D, E and F) did not totally agree with this proposal. Their major concern was time constraint. For instance, a teacher said,

> *Recommend, if and only if I have enough time okay… I think Add Maths we are rushing through… rush to finish the syllabus…If the computer games come in, we have to give way to the time… Then you see that you can only finish your syllabus very late. Then the time really left for revision is limited only… We need to train the students, prepare students for the exam… Time constraint… That is the main problem… It is a waste of time (Teacher D).*

Most of the teachers (B, D, E and F) have pointed out their time constraint due to preparing students for examinations. Thus, the teachers would not risk adopting the computer games in classroom teaching because it would jeopardise examination performance. The teachers focus on the explicit learning content, and they do not value implicit skills that could be learned through computer games. The teachers' concern for time constraints indirectly suggested that they viewed teaching of mathematics without computer games to be more effective in achieving better exam results. Teacher D has made an interesting remark that the use of computer games to learn mathematics is "a waste of time". This is a popular remark made by adults because no content is involved so it is not seen as learning (Gee, 2007).

ii. Suitability of topic

Two teachers (B and D) also raised their concerns about the suitability of computer games for the topics learned. The teachers said,

> *Depends on the topic… If there is a good game, then it is okay… They really can help in the chapter that they learn in mathematics (Teacher B).*

> *Games… I am sort of old timer. Games are hardly. I see the topics most of them are not suitable for games (Teacher D).*

Teacher D who was teaching Additional Mathematics had an opinion that computer games were not suitable for most of the topics. One possibility was that she had yet to be exposed to any computer game that was effective to teach advanced mathematics. Being the most experienced teacher among all the teachers interviewed, she admitted her lack of competence in using computer game. She was aware of the generation gap and disclosed that she was behind the technologies.

If computer game is to be introduced in schools, some teachers may not be able to manage the technological aspects of the computer games. This problem might introduce another challenge to computer games implementation.

iii. Assessment Method

Other than time constraint and suitability of topic, a teacher (F) was concerned with the method of assessment. She said,

> *Can teach (using computer games) but and then the exam? How ah? Exams also use the computer game? No right? It is even better if the exam is using computer game. Who scores the most in two hours? [Translated from BM] (Teacher F).*

Teacher F has pointed out an interesting point on assessing students in exams if they are learning mathematics using computer games. Students who perform well in mathematics computer games may not excel in written-based examinations because they need to do manual calculations.

iv. Computer Labs

Other than the constraints related to teaching and learning, three teachers (B, D and E) mentioned that schools had limited computer labs. A teacher said,

> *Unless all the classrooms having computer but now we don't have. So, if we have that type of using computer, we have to go to computer lab. At the moment, computer lab is not very friendly type, no air con, air con spoilt… We have one computer lab, one simulation room… They are meant for computer class in the afternoon. Usually they are class time (Teacher D).*

According to the teachers, not every classroom was equipped with computers, and schools had limited number of computer labs that were normally used for teaching IT subjects. Furthermore, the hardware and software available in the schools were outdated and might not support the use of computer games. Teacher B and E also mentioned the slow Internet connection in the schools. M1 and M2 are schools of excellence or smart schools and they are located in the city area, and yet there are claims that the schools are lack of computer facilities.

b. Disagreement

Two teachers strongly believed that the best mathematics pedagogy was the conventional classroom teaching. The teachers said, *Classroom teaching (better approach)… I foresee them too to be too engrossed in it. Maybe they forget the basic problem-solving. I mean basic of mathematics. The more usual of the addition, how to add, subtract or multiply… Because it is not hands on (Teacher A).*

If you say mathematics computer games, I think still classroom better. Because computer games ah, because students may get carry away with the purpose in playing games only. They don't know what their learning actually (Teacher D).

Teacher A seems to focus on the four basic arithmetic operations without considering the cognitive or metacognitive skills related to mathematics learning. In an earlier section, the teacher has claimed the possibility of learning logical and analytical thinking skills by playing puzzle games. However, she could not link those skills to formal classroom learning. She may not know how to adopt the games into teaching. Teacher D, however, sees computer games as just playing without learning. She may perceive learning can only happen formally. So for teachers to value the educational benefits of computer games, very often the content (e.g. mathematics concepts) must be salient and explicit as in edutainment.

In this section, it can be seen that all the five teachers (except Teacher C) are quite reluctant to adopt computer games in teaching by giving many concerns to its implementation. Looking at the existing situation, the use of computer games is deemed to be impractical.

However, Teacher C had a different view. He said,

For me, should be enough (computer lab facilities)… I think I have enough time… This depends on how you go through all the syllabus. For me, I'm not teaching whatever inside the syllabus. So, sometimes I will put it together… Sometimes I need to be fast… This is a new chapter for my students, now I need to be slow. But certain chapter which is related from previous study, then I grab their prior knowledge then I can be fast (Teacher C).

According to Teacher C, the school was equipped with sufficient computer facilities. As Teacher C also had to work within a given time constraint, he believed that proper time management was critical. He shared a few tricks and useful teaching techniques that he had practiced to make it possible to work within the time constraint and still be able to include computer games in his class. For new topics, he had to teach slowly. However, for some related topics, he would combine them together. Moreover, if students had prior knowledge of a topic, then he would go over the materials faster.

Most of the teachers could foresee many challenges that prevented them from using computer games in teaching. Time is the main constraint to adopt computer games in mathematics learning. From a practical point of view, the use of computer games for mathematics learning might not be an appropriate teaching approach in the schools. This is a real constraint, economically and technically especially for the schools in rural areas. Furthermore, a heavy dependence on high specification technologies might cause learning difficulties if any technical issue occurred.

Regardless of the teachers' responses, their major concern is always circled around *assessment*. Without doubt, the Malaysian education system is exam-oriented, and the whole learning process is also designed around skill-and-drill to ensure that students obtained a grade A since the performance of teachers and schools are judged by the number of grade As achieved. This defeats the purpose of education when the grade is a sole benchmark of learning. Recently, a computer game designed to learn Malaysian history has made a big impact when it receives an international recognition and reported to improve students' academic performance (Zulkipli, 2015). A computer game is regarded as good if students can obtain an A after playing it. For schools,

> *important knowledge is learning of content in the sense of information related to intellectual domains and academic disciplines* (Gee, 2007, p.22).

Schools do not honour tacit knowledge and skills tied to practice (Gee, 2007). The society has the same views on this. For instance, someone who has completed a four-year degree in agriculture is honoured more than a farmer who has planted various types of vegetables and fruits for 40 years. The whole education system is about getting a formal recognition.

5.7.4 Recommended Teaching Approach

Even though most of the teachers were quite reluctant to use computer games in teaching, they were open for the possibility of its implementation. They might adopt computer games as long as teachers were still playing the major role in teaching.

a. Teachers play a major role

Four teachers (B, C, D and E) stressed that technology could never replace the role of a teacher in teaching. A teacher said,

> *I don't think technology will replace classroom because classroom study important because they need to learn about basic. Because the theories and stuff, they need to know first, then they can apply maybe in games or other technological things, multimedia (Teacher B).*

From the teachers' points of view, teachers play the most significant role in educating students. Teachers prefer to take control of their students' learning. Teacher B has mentioned that students need to learn the *basics* of mathematics that he believes could not be learned through students' self-exploration or trial and error. This basic knowledge is important because cognitive processes have to build upon content. Once the basic knowledge is formed, more knowledge can be built from the process of *accommodation* and *assimilation* (Piaget, 1954). New information is incorporated into the existing schema through the process of *assimilation*, and if the new information is conflicting, the existing schema is altered through the process of *accommodation*.

b. Combination is the best option

From the teachers' points of view, the combination of conventional classroom teaching and computer games is the best teaching approach.

i. Classroom teaching followed by computer games

Three teachers (A, B and F) mentioned that if computer games were to be adopted, a lesson should start with the conventional classroom teaching and then followed by use of computer games. A teacher said,

> *Maybe teach and let them play. I need to teach first to check whether they understand before playing computer games (Teacher A).*

From the teachers' points of view, learning with computer games is only possible if it is built upon some prior knowledge.

ii. Computer games provide exercise

Three teachers (B, C and F) mentioned that computer games could be used to provide practice or exercise. A teacher said,

> *But certain part, let say like to practice, let say every time we give worksheets for the students to do it, they will feel bored. But let say, we put it in the form of game, they can practice the game. And then let say all the questions is randomize, may they will have fun there (Teacher C).*

Computer games are merely used as a replacement to conventional exercise books. The use of computer games for drilling purpose fits the teachers' teaching philosophies that are grounded on practice.

iii. Use of computer games is trivial

Three teachers (B, C and D) mentioned that the use of computer games was not that significant. The teachers said, *More to teaching than games. Games will be a little of to slot in only… 70:30 (classroom teaching: computer games) (Teacher B).*

We cannot solely depend on the game. Game is additional. Let say, certain difficult concept, sometimes we did it… 60:40 (classroom teaching: computer games) (Teacher C).

(Computer games) Just put part of it. But you cannot say solely for that. Maybe out of you would say just 20% of the learning process… Yes (80%), still classroom. 10% to 20% only (computer games) (Teacher D).

Three teachers have mentioned that the main emphasis should be placed on the conventional classroom teaching (70%-80%) that would provide students with preliminary knowledge and a basic understanding of mathematical concepts. A computer game is viewed as something *to "slot in only"*, *"additional"* and "*part of it".* The use of computer game is optional and trivial. They merely perceive computer games as something that could make the class more interesting and fun, without any added value on their learning content.

Teachers' focus on the conventional classroom teaching could be an indication that they lack confidence in handling computer games to teach effectively. Teachers feel more comfortable, self-assured and in control of the learning outcomes by using the existing teaching strategy. They perceive that the use of computer games may take away the control of the learning outcomes. They also feel that teachers are the only ones who can bring about learning. Most of the teachers have the perceptions that students are not prepared, lack of maturity and skills to learn independently. Although teachers may consider adopting computer games to teach mathematics, they are not changing their teaching approach that is built upon drill-and-practice. They are using the computer games to fit into their current teaching philosophy. Their perceptions might relate to limited experience of playing computer games in a learning context. They see a game merely for exercises without other learning possibilities.

5.7.5 Summary

Table 5.12: The Use of Computer Games to Teach Mathematics

Challenges	Possible Adoptions
• Lack of exposure to educational games. • Lack of good educational games in the market – mostly edutainments. • Preferably edutainments. • COTS games - not regarded as educational. • Time constraints. • Not suitable for all topics. • Inappropriate assessment methods. • Insufficient computer labs facilities.	• Good time management. • Connection to prior knowledge. • Possible approach: classroom teaching followed by the use of educational games for drill-and-practice (additional and optional). • Classroom teaching - major component to provide basic knowledge (teachers play the major role in teaching).

5.8 Suggestions and Recommendations

Despite this study being aimed at exploring the potential use of gaming pedagogy in mathematics learning, an understanding of the teachers' recommendations to improve mathematics learning is important. In any study, it is not possible to cover all eventualities. As such, an opportunity was given to the teachers to express their views at the end of the interview.

5.8.1 Practice is important

At the end of the interview, five teachers (except Teacher B) reemphasised the importance of practice and advised students to do more exercise. Two teachers said,

> *Definitely mathematics there is a lot drill for that… First they need more practice and second, understand the concept. The third one they need to teach another people… Because you teach, you will learn better (Teacher C).*

> *Very simple. They just have to do exercise that's all… Succeed in maths mean they just have to learn how to solve problem and do more practice… They can excel already… Solve more difficult questions, more variety questions… Let say the application of the concept the same but the questions come in different format (Teacher D).*

All the teachers described mathematics practice in a similar way – to do more exercises and expose oneself to different types of questions. Teachers placed a strong focus on practice and routine work since students' academic performance was the main focus of learning. Teachers were incorporating practice into mathematics learning without knowing the real purpose of practice in learning. Practice had become a social practice across generations.

5.8.2 Proper Use of Calculator

Two teachers (B and F) mentioned the importance students' foundation in mathematics. However, the use of calculator had changed how students learned mathematics. Teacher F said,

> *During my generation, I have to memorise the multiplication table. Now, the Form 1 students can't even memorise the multiplication table. Not able to do that because they can use calculator. And I don't understand why a calculator is allowed as early as in Form 1. I only used calculator in the university [Translated from BM] (Teacher F).*

In the past, students were required to memorise all the multiplication tables and master all the four basic mathematics operations during primary education. The students were trained to have fast and strong logical thinking in mathematics.

Today, calculator has taken over all the tedious calculation and students only have to know how to manipulate the tool to solve a mathematics problem. Students are trained to rely on the tool rather than building their skills and capabilities in basic logical thinking. The teacher's disagreement on the use of the calculator has been highlighted earlier by another teacher [refer to Section 5.1.4]. The use of calculator seems to be based purely on tradition rather than innovating in the way the subject is taught. Students nowadays use calculator because they are allowed to do so and this has indirectly changed the nature of learning in mathematics. Perhaps, the use of computer games in mathematics teaching is like the use of a calculator. Initially, teachers were very reluctant to allow the use of a calculator since it prevented the development of mental arithmetic. However, now in the current classroom learning, a calculator is a necessity.

5.8.3 Monitor Children to Practise More at Home

From the teachers' points of view, parents had a significant role to play in their children's studies. Two teachers (B and D) urged the parents to monitor their children to practise mathematics. A teacher said,

> *Monitor the students' work. Let say, okay this time this to this time, you have to sit down and do your work… Or even they send them for tuition… They just need the time tuition to practice only. So that they can get better or maintain the result (Teacher D).*

It was understandable that the responsibility to educate the students should not rely solely on teachers. Parents should play their important role to monitor and motivate their children to learn. Apparently, the teachers were urging the parents to encourage their children to do more practice and exercises after schooling.

5.8.4 Improve School Curriculum

When all the teachers were asked for any suggestion to the policy maker, most of them seemed to be quite reluctant to disclose what were in their mind. Most of the teachers were quite cautious and thoughtful in what they said because they might be afraid of losing their job or engaged with disciplinary actions for saying something against the policy maker. Teacher C said,

> *I think this is quite difficult for us. You know why (Teacher C).*

As for Teacher E, she would rather say she had no suggestion for the policy maker. Despite being reluctant, the teachers did provide some views and recommendations by having the assurance that their identities would be kept private and confidential. Most of the teachers (A, B and C) commented on the existing education system. The teachers said,

> *Maybe they need to revamp the curriculum… Some topics could be learned earlier… You see when they are in primary school, especially primary 4 to primary 6, they are basically learning the same thing. They just increasing the digit (e.g. 1 to 10; 1 to 100) (Teacher A).*

> *For every form is considered a lot of things to cover except for Form 1. Form 2 and Form 3 are quite heavy the chapters… Form 1 is okay... Form 4 is okay (Teacher B).*

> *First thing I will tell my students, our syllabus just like a firecracker. Why I say firecracker because certain parts of the syllabus, they only at that time only. After that there is no relation with other chapter (Teacher C).*

From the teachers' points of view, more learning content should be added into primary school education, content should be distributed evenly and the syllabus should not be designed *on the fly*. Teachers perceived that more challenges should be added into the syllabus and mathematics should be learned with a proper flow of learning experience. The difficulty of mathematics should be increased gradually with continuity from the previous topics and the amount of learning content should be appropriate at every level.

5.8.5 Reduce the Burden of Teacher

A teacher urged the policy maker to reduce the burden of teachers. She said,

> *Reduce the workload of teachers. Now I can't even look after my students. That's all [Translated from BM] (Teacher F).*

Stress and heavy workload in schools may also affect teachers' disinterest in using computer technologies to teach. Malaysian school teachers have been reported to be overloaded with more teaching and complex duties than teachers from other countries (Shafie *et al.*, 2014). The pressure from school work causes stress and depression among many school teachers (Shafie *et al.*, 2014).

Although other teachers did not mention about their heavy workload, it could be seen from their teaching timetable, school activities schedule and administrative works. Due to the teachers' tight schedules, it was difficult to find a suitable time to conduct the interview.

This finding could imply that there are some fundamental problems in the existing education system. A close analysis of the teachers' suggestions and recommendations has revealed that there is no proper plan related to use of computer technologies. Apparently, the teachers might think that the students are not ready for the adoption of computer technology in learning owing to the existing problems in our education system.

Teachers' suggestions and recommendations have revealed two important themes in mathematics learning – practice and motivation. Teachers believe that by doing more exercises is the best way to learn mathematics. In East Asian countries, routine or manipulative practice is a common and important mathematics learning style (Li, 2006). Teachers believe in *practice makes perfect*.

> *…East Asian countries, routine or manipulative practice is an important mathematics learning style. Many mathematics teachers and also students believe it and consider it a general principle for mathematics teaching and learning* (Li, 2006, pp.129–130)

Practice is not only a model of learning; it is also a culture artifice. Teachers place strong emphasis on practice without knowing what is learning and how students learn. Practice is more like a social practice and tradition in the school culture.

The second element in mathematics learning is motivation. Teachers believe that parents' attention and encouragement play a significant role to motivate their children to learn mathematics. Research has indicated that high mathematics achievement is not only attributed to school education, but also to parental help and tuition (Zhao *et al.*, 2006). Students need motivation to learn, and that the teachers need motivation to educate the students. Teachers' welfare and work burden are often being overlooked. If teachers are not enthusiastic to teach, then they would be less capable to motivate the students to learn. Teachers need a

justifiable teaching workload and conducive teaching environment in order to deliver a productive learning experience to the students.

5.8.6 Summary

Table 5.13: Suggestions to Improve Mathematics Education

Students	Parents	Policy Makers
• Doing more practice.	• Monitor children to practice more at home.	• Improve school curriculum. • Reduce the burden of teachers. • Proper use of calculator.

5.9 Chapter Summary

The results obtained from the teachers' interviews revealed that *conventional classroom teaching* was the major approach used to teach mathematics in schools. This conventional classroom teaching approach was teacher-centred but group working was often used to enhance students' participation in learning. Furthermore, courseware was occasionally used to help students visualise abstract concepts. However, inspite of this, the learning experience was passive and not encouraging. To motivate students to learn, the teachers had used different teaching innovations, gave compliments and provided personal attention to students. Nevertheless, many students claimed to be not motivated to learn mathematics. The students had no confidence and interest in mathematics.

Students' disinterest in mathematics was one of the reasons that likely led to poor performance in TIMSS and PISA. In schools, students were taught to solve mathematics problems using Polya's four-step problem-solving process and they were trained to follow the predefined strategy which was laid down by the teachers. The teachers expected students to follow the step-by-step predefined route but some students refused to follow the instruction because they wanted to get things done fast and easy. For this reason, the students were claimed to be weak in cognitive and metacognitive aspects of problem-solving. In view of that, many students could not apply knowledge learned to a new non-routine problem despite HOTS were taught explicitly in schools. Inability to transfer knowledge had resulted in students' disinterest in Additional Mathematics (compared to Mathematics or Modern Mathematics) because the subject required HOTS and mostly dealt with non-routine problems. Other than HOTS, spatial ability was also claimed to be important in mathematics learning. The teachers felt that the boys could understand better in some particular mathematics topics that required imagination. However, girls had an advantage too because they were more disciplined in doing more practice.

Apart from students' attitudes, students' low performance in mathematics was also caused by the design of the education system. The teachers revealed that the existing mathematics curriculum placed less emphasis on application of problem-solving and HOTS. Furthermore, the use of calculators had killed students' logical thinking skills. Since schools were exam-oriented (i.e. product-oriented), the teachers had to drill the students for exams because practice was claimed to be the most effective way to learn mathematics.

In the technological aspect, male and female teachers behaved differently. Male teachers used computers for work, entertainment and advanced usage. They also played variety of computer games such as fighting, strategy, puzzle, role-playing, sports, action-adventure and MMORPG. As for the female teachers, they mostly used computers for work purposes, and they played only puzzle games. As expected, male teachers were more proficient and interested in ICT and computer games. The male teachers recognised many benefits of gaming such as learning of metacognitive skills whereas female teachers were more concerned with the drawbacks brought by computer games such as game addiction, health hazard and violence.

In general, both male and female teachers always used computers for work and smartphones for daily communications. They pragmatically accommodated technologies to fit into their existing working style. The usage of computers for schoolwork was a routine process and it was not fun with no learning involved. On the other hand, students were claimed to be proficient in using computer for entertainment purposes especially the latest computer technologies. Students constantly learned new computer skills outside the school hours. Unfortunately, these technological skills usually were not recognised by schools.

When the teachers were asked about educational computer games, most of them had no personal exposure to the games. Nevertheless, they would prefer edutainments that provide training and practices. Most of the teachers were quite reluctant to consider adopting computer games in teaching mainly due to time constraints and insufficient computer labs facilities. They strongly believed that the conventional classroom teaching and practice were the best approach to learn mathematics. Nevertheless, they might consider the adoption of computer games provided the games were only used trivially to provide more training and practices. Regardless of the approaches used, they strongly felt that teachers played the most significant role in teaching and learning.

This is a group of teachers who come from different educational backgrounds and teaching experience. Though they have substantially different personalities, their attitudes to teaching mathematics are quite uniform across the board. In general, they are comfortable and confident with their existing conventional ways of teaching practices. The teachers' attitudes to teaching are similar to what they would expect from their students – *follow a predefined route*. In this case, it is the traditional "chalk and talk" method of teaching, e.g. first step: recall previous lesson; second step: teach new lesson with some examples; third step: students are working on similar problems in the class; fourth step: homework is given to reinforce the practice. The whole education system is about doing and teaching what the teachers know. It is doubtful whether this is a viable design for the future of Malaysia.

Consequently, the introduction of gaming pedagogy might face resistance from the teachers given the prospect that they would need to change their existing teaching behaviour. As an educator myself, I understand the stress and resistance to change among the teaching profession – something that is written about widely. For instance in Blin and Munro (2008), they have mentioned that technology has little disruption in academic teaching practices for various reasons: too time consuming; a mismatch between the technology and curriculum; complexities of the technology; a lack of skills, and mismatch of training and academic needs. In the study, they have found that a Virtual Learning Environment such as Moodle is merely used for administrative purposes and to disseminate resources, which complement or replicate existing practices. Although technology has been widely used in the education industry, the potential usability of the technology is always underused due to various practical constraints.

From the interview data, teachers' reluctance to use technology is a way to inform us that they can teach more effectively and confidently without the technology. An excellent and experienced teacher may deliver a poor lesson with computer games, e.g. Teacher D had 30 years teaching experience but labelled herself as "old timer". Teachers' resistance to educational technology policy has shown that they have been left out of the new education world. However, looking from a different perspective, many teaching innovations introduced in schools are too focused on the latest technology and fail to make the best of what the teachers own, e.g. content knowledge and teaching experience. Some teachers' self-esteem may be challenged by technology deployment in schools because they are slow learners of new technologies. Should we punish and belittle these digital immigrant teachers for not being computer literate?

Although some teachers (i.e. male teachers) appeared to be digital natives in their daily life outside of schools, they did not show their digital natives' capabilities in schools. Digital native capabilities (e.g. multitasking) seem to be irrelevant and been supressed to conform to the formal school education. The educational policy or school culture have somewhat constrained the teachers to show their digital natives' capabilities, creativity and innovation. In this case, teachers' reluctance to the pedagogical change could be a way to avoid risks (e.g. exam results) and complaints (e.g. parents or students). In this chapter, teachers' competencies in computer technologies do not seem to significantly influence how they teach in class. Computer expert teacher such as Teacher C is more likely to use computers in teaching but the underlying pedagogy is still the same – drill and practice. The teachers, regardless of their age and computer literacy have given similar responses to mathematics pedagogy and DGBL. Apparently, teachers' beliefs are the best indicators of their traditional teaching practices (not technology proficiency or age).

Forcing teachers to adopt a new pedagogy that contradicts their beliefs is destined to be a failure. Similarly, using coercion to turn poor teaching into an acceptable teaching may be necessary, but it will never produce an excellent teaching as personal commitment. The main question is not so much about the change of teaching practices, but their beliefs that drive these current teaching practices. Belief is something that will have developed over time and is not open to change instantly. Thus, it is important to accept where the teachers are, and try to understand what they think and why they do what they did, and start from there. Understanding teachers' views and perceptions enable us to explore the feasibility of DGBL.

From the educators' points of view, it is hard to justify the usefulness of playing COTS games (e.g. Angry Bird or Candy Crush) to learn mathematics. It should be noted that playing the games may not help children to develop explicit mathematics knowledge, but there are some implicit skills that could be learned, i.e. differentiate colours, identify targets and arrange the right steps. These are the skills that may relate to cognitive skills required to learn mathematics, such as analysis (differentiate colours and identify targets) and planning (arrange the right steps). However, not every educator could see the underlying benefits of computer games (e.g. Teacher D as one paradigmatic example).

It is also not unreasonable for teachers to indicate that computer games are not suitable for some mathematics topics – since pragmatically the curriculum is largely a collection of topics. For instance, to teach simultaneous equations, it could be hard to find a suitable educational or COTS game to teach the topic. Even if there is one, the schools may not have sufficient financial supports and the teachers may not have time, interest or expertise to manipulate the games for teaching. Even if one assumes that all these obstacles can be solved, there is a question of whether this innovation is worth the time spent. Would teachers spend a few weeks of their time to search, install, prepare, learn and play a computer game just to teach a small topic? Given the heavy workload in schools, it is unlikely that the use of DGBL would be considered.

However, there are benefits of computer games over and beyond their potential (or lack of) to teach mathematical topics as I will go on to discuss in the rest of this thesis.

In this chapter, the teachers do not seem to aware of other learning possibilities with computer games other than DGBL. This thesis aims to help educators to see their personal teaching practices from a gaming perspective (outsider's perspective), and how these relationships might lead to a new gaming pedagogy that complements their existing teaching practices. The motivating nature of computer games may supplement the conventional nature of mathematics pedagogy in schools.

Chapter 6: Analysis of Students' Surveys and Interviews

6.0 Introduction

Any educational research that attempts to deal with pedagogical change should address the learners' perspectives because they have the direct impact as a result of the change. In this chapter, I am trying to explore students' views and perceptions towards DGBL. Though students may not know what they want and what is the best for them, their views and perceptions are important as a way to address what they like and what they do not like; their predilections would go on to influence their behaviour and engagement in mathematics.

During the interview, I did notice that most of the students were puzzled when a future hypothetical question was directed to them, e.g. how to make a mathematics class more interesting? It was evident to me that they had limited understanding of mathematics pedagogy as one of the students (i.e. Student A) mentioned that she had never thought that computers could be used to learn mathematics. As a matter of fact, they are just learners; they are not professional and as such are unlikely to have considered the meta issues behind their own experiences in the classroom. Nonetheless, their views and perceptions of past experience are important because this study explores what they *like* about computer games, how they *use* technology, what is their lifestyle and what they *think* they have learned from games? Although these students are born digital, there is little understanding of how educators support the way that students learn (Helsper and Eynon, 2010). Thus, in this study I am trying to address the research gap by seeking to understand the students' current practices in mathematics learning and gaming as a window into their predilections

This chapter includes an analysis and discussion of the students' survey and interview data. This chapter is divided into five major sections:

1. Mathematics learning.
2. Students' technological experience.
3. Students' gaming experience.
4. The use of computer games to learn mathematics.
5. Suggestion for improving mathematics learning.

All Form 4 students participated in the survey and eight students were interviewed (see Table 6.1). The names of the students and schools were kept anonymous due to ethical consideration. Pseudonyms were used to represent the students and schools.

Table 6.1: Students' Background Profile

Student	Student A	Student E	Student H	Student N
Type of student	Boarder	Boarder	Day scholar	Day scholar
Interview Language	English	English	English	English
Gender	Female	Female	Female	Female
School	M2	M2	M1	M1
Ethnic	Malay	Lun Bawang	Malay	Malay
Hobbies	Play with handphone/ laptop, drawing	Play with handphone/ computer games	Read/ play chess/ develop games	Play guitar, read, watch TV series
Ambition	Doctor/ Graphic Designer	Engineer	Doctor	Doctor
Student	**Student L**	**Student P**	**Student S**	**Student Y**
Type of student	Day Scholar	Boarder	Boarder	Boarder
Interview Language	English	English	English	BM
Gender	Male	Male	Male	Male
School	M1	M1	M2	M2
Ethnic	Iban	Iban	Kayan/ Kelabit	Kadazan
Hobbies	Surfing the Internet, Playing football, basketball, hockey	Sleeping, playing badminton	Surfing the Internet, playing football, rugby	Playing sports, jogging
Ambition	Engineer	Psychologist	Doctor	Scientist

For the survey, the response rate from M1 School was 92% (116 out of 126 Form 4 students responded to the survey). M2 School reported a slightly lower response rate of 84% (59 out of 70 Form 4 students participated in the survey). Overall, 175 out of 196 of the students responded to this survey, with an average response rate of 89%. The response rates were adequate and acceptable.

Due to practical constraints, a response rate of 70% is recommended and considered acceptable in a survey (Johnson and Christensen, 2008). This recommendation is acceptable provided the respondents and the non-respondents are relatively similar (Mertens, 2010). Students from both schools have a similar educational background, culture and learning environments. Hence, I could assume that the perceptions of the responded and non-responded students are similar. Mertens (2010) also recommends a follow up with the non-respondents.

I had tried to do follow up with those students who had not responded but failed to get more responses. I was not allowed to approach the students personally (i.e. to avoid disruption to their daily school activities), so I asked help from the school teachers to follow up with the non-responded students. I was informed by the school teachers that the students refused to participate, or their parents disallowed their children's participation. Due to ethical concerns, I should not use coercion towards the non-responded students. From my point of view, there were a few possibilities why the students refused to participate in this study: (1) they did not see how this study could benefit them, (2) afraid of revealing their personal details, and (3) worried that it might affect their studies.

This chapter explores students' perceptions towards mathematics learning, technological and gaming experience and the use of computer games to learn mathematics. Each section will begin with a general overview of quantitative survey data. Then, a discussion of qualitative interview data is provided. The students' demographic information is attached in the Appendix D.

6.1 Mathematics Learning

Students' perceptions towards mathematics are important because they can reinforce or weaken their mathematical problem-solving ability (Artzt and Armour-Thomas, 1997). In this study, the students' perceptions towards mathematics are optimistic and positive which can be seen in both the survey and interview data.

6.1.1 General Overview

Students' attitudes towards mathematics can be obtained from MTAS (Pierce *et al.*, 2007) score in the following table.

Table 6.2: MTAS Score

	Affective Engagement (AE)	Behavioural Engagement (BE)	Mathematics Confidence (MC)	Technology Confidence (TC)	Learning maths with games (MTc)
Score	16.2	15.28	13.24	14.6	13.96

Score: 4-12 low, neutral or negative attitude, 13-16: moderately high, 17-20: a very positive attitude

Table 6.3: Correlations of MTAS Score

	MC	AE	BE	MTc
TC	.152*	.042	.091	.359**
MC		.592**	.521**	.092
AE			.505**	.262**
BE				.134

***.** Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

According to Table 6.2, students were positive and they had a strong interest in mathematics (AE). However, students' learning behaviour (BE) and confidence (MC) in mathematics were moderately high. Students liked mathematics, but they might lack confidence and motivation to work harder. These three elements (i.e. MC, BE, and AE) were positively correlated with each other (see Table 6.3). Students who had more interest and confidence in mathematics would put more effort to learn. Similarly, students who had more interest and put more effort to learn mathematics would develop more confidence.

6.1.2 Perceptions towards Mathematics

During the interview, eight students were asked to describe their feelings about mathematics. This is to verify further if students were positive towards mathematics.

a. Challenging but interesting

Students described mathematics in positive terms as challenging, interesting, important and fun. Four students explained that mathematics was challenging, yet interesting.

> *Challenging but it is interesting (Student E).*
>
> *It challenging and interesting because it is hard. But it is easy if you study (Student L).*
>
> *When it comes to exercises, it has to be a challenging type… Then that is a good thing (too challenging). Then we will approach the teachers and then we can discuss more with our friends (Student N).*
>
> *I prefer Add Maths to Modern Maths because Add Maths is more challenging and requires more thinking. Thinking a lot. As for Modern Maths, I don't have much interest in most of the topics (Translated from BM) (Student Y).*

The students mentioned that mathematics was interesting because it was hard and challenging. If something was easily achievable, it gave less fun. Apparently, the students were not interested in solving simple mathematics that did not require much HOTS. This finding contradicted with the viewpoint of the teachers [refer to Section 5.2.1].

b. Appropriate level of difficulty

It was important to get the difficulty right with a balance between challenge and support to avoid demotivation or adverse effect. Two students said,

> *Always challenging. But sometimes I find it boring… Boring when I cannot understand. Usually is Add Maths when I cannot understand the method. But I find it interesting when I understand fully the whole method (Student A).*
>
> *I think it is interesting for certain chapter. Because if they are not interesting, I find them challenging… When I don't find something fun, I lose focus. Then I won't be able to understand it that easy (Student N).*

The students explained that mathematics was interesting if they managed to grasp it. Mathematics problems should be challenging but achievable with the appropriate level of support given by teachers. Without challenge, students would not put in efforts to solve the mathematics problems because there was nothing to overcome and nothing to learn. Neither would they expend the effort to overcome the challenge, if it was too tough as they might relate it to past failures.

c. Boring presentation

Students’ perceptions towards mathematics also depended on how it was presented. A student said,

> *It is interesting and fun and challenging at the same time. Is just that, it is not shown to me in a fun way. Mostly is too bored. It is too serious. It doesn’t show me in a fun way. But I like it actually… (Mathematics is fun?) No, it depends on how it is directed to the students (Student P).*

Student P liked mathematics. Unfortunately, the teaching approach was not enjoyable. The teachers seemed to kill his learning interest and discouraged him from learning. When he mentioned that “it is too serious,” he was most likely trying to imply that the learning in school was not fun because the students were studying under the pressure of the exam. In the exam-oriented system, students were given much drill-and-practice in which he defined as “*too bored”*. Although students’ enthusiasm to learn was important, the teachers played a major role in nurturing and retaining students' interest.

d. Require practice

Students’ perceptions towards mathematics also depended on the nature of the subject. A student said,

> *I think is interesting and important at the same times. Interesting because I think it is the only subject that plays with numbers, I like it. I don’t really have to memorise much because I just practise it a lot, and I can understand it (Student H).*

Student H said she liked mathematics because it only required drill-and-practice but not much of memorisation. It was interesting to see the contradictory view given in her argument. The student had a misconception that drill-and-practice did not involve memorisation. The student’s misconception could be influenced by the teachers who believed in practice artifice [refer to Section 5.8.1]. In fact, the drill-and-practice approach is useful for rote memorisation learning, but it is insufficient for the development of sophisticated understanding (Charsky, 2010).

Students described mathematics as challenging (i.e. six mentioned that), interesting (i.e. five mentioned that), fun and important (i.e. three mentioned that). From the students' points of view, mathematics was fun and interesting provided that the challenge could be overcome with reasonable efforts. This was surprising given the absence of negativity. The students might truthfully like mathematics, or they were influenced by the social belief that they must like mathematics. Mathematics was one of the important subjects that would determine their future academic success. So, students might have to make themselves in believing that they *liked* mathematics because it was important. However, they might not know why mathematics was important other than being told by their teachers or parents. For instance, a parent mentioned that,

> *He never told me whether he likes or dislikes (mathematics). Even if he doesn't like it, he has to like it. Because it is important (Translated from BM) (Parent L).*

Children learned mathematics because they were told that mathematics was important and they grew up with this perception.

Children are not being told that playing computer games is important, yet they play the games naturally. Mathematics is challenging but so are computer games. What is the difference in challenge between mathematics and computer games? The challenge in good computer games is fun and motivating (Amory *et al.*, 1999; Kiili, 2005b) but the challenge in mathematics may cause an adverse effect. In computer games,

> *the learner gets ample opportunity to operate within, but at the other edge of, his or her resources, so that at those points thing are felt as challenging but not undoable* (Gee, 2007, p.68).

Computer games are designed carefully to get players to believe and be confident that they are competent. This perceived competence drives the players to continue to try and make an unlimited number of attempts because they believe that they can do it. In games, players are given sufficient time to learn, practise and complete an activity, able to experience success following small efforts and learn challenges at their personalised achievable level. The appropriate level of support motivates players to move on. Conversely, in a classroom, mathematics questions are given to the whole class of students regardless of their level of proficiency. Learning is discouraging because the challenge is not personalised to students' achievable level.

6.1.3 Strength and Weakness in Mathematics

Each of the students had different strengths and weaknesses in mathematics. The students highlighted four common mathematics topics: (1) quadratic equations, (2) indices and logarithms, (3) graphs and (4) functions. It was most likely that these topics were challenging yet interesting. Most of them (five students) claimed to be good in quadratic equations. Surprisingly, three students also claimed to be weak in quadratic equations and graph. Male students were good in quadratic equations but weak in indices and logarithms. However, female students could be classified into two categories - two were weak and two were good in spatial ability.

a. Females with poor spatial ability

Two students said,

> *I am not very good with diagrams (Student E).*
>
> *When it comes to graph, drawing graph, I am not really good at that. I am not good at finding how to do draw it… Yes, I think so (cannot imagine)… Maybe I am not interested in drawing all those graphs. So, then I don't find it as fun (Student N).*

These students said that they were not good in mathematics topics that were related to diagrams and graphs. They were weak in spatial ability because they could not imagine or visualise abstract concepts. Some teachers were aware of the problem too [refer to Section 5.2.4].

b. Females with good spatial ability

The other two female students claimed to be good in spatial ability. They said,

> *I am more fond of the geometrical; the one including shapes. The one that includes shapes like circle… I learn them (required imagination) much more easier (Student A).*
>
> *If last year topics, easiest will be indices and also geometrical construction and graph… Yes, it's (graph) very fun especially I learn radian (Student H).*

Surprisingly, these two students preferred topics that required imagination and visualisation. It was most likely that the spatial skill was developed through their personal interest at home. Student A loved drawing, and she wanted to be a graphic designer. As for Student H, she loved to play chess and design games (e.g. Kodu) during her free time. Student H was an expert in chess and participated in a few national chess competitions.

Females are known to be weaker than males in spatial ability (Paul, 2013). Playing chess helps to develop intuitive skill and world chess champions like Botvinnik and Kasparov are full with imaginative strategies (Wells, 2012). Essentially, intuition and imagination are essential to learning mathematics too (Wells, 2012). Spatial ability significantly influences students' performance in mathematics (Guay and McDaniel, 1977). Therefore, students are encouraged to play computer games or board games such as chess or *Go* to develop intuitive skill.

c. Females prefer calculation

The students with poor spatial abilities preferred topics that involved calculations. Student E said her strength was doing *calculation,* and Student N said,

> *Sets, you know the chapter sets? That one also I am not interested. As those types that doesn't involve a lot of calculations (Student N).*

These two students seemed to prefer topics that required mathematical calculation, rather than topics that required imagination and creativity. The teachers did mention that girls were usually good at topics such as linear equation, parameter, and polygon, but not index, transformation, locus, geometry construction, earth and sphere, and plan and elevation [refer to Section 5.2.4]. It was most likely that girls were more patient and careful in the calculation.

d. Long calculation

Two male students, however, expressed their fears and worries about mathematics problems that involved a long calculation or series of steps. They said,

> *Add Maths (most challenging) because of the complicating work step because if I miss one step, the whole question is wrong. Because of that I got a single digit for my exam. It is very confusing and the marking scheme is like that… (Confusing) Because it involves many unknowns so my head is very confuse seeing the question (Student L).*

> *I find it hard (Add Maths). The steps are so long and I'm afraid I might miscalculate some minor details. So that can lead to carelessness. That can lead to answer wrong. If we want to re-correct it, we have to look through whole steps (Student S).*

These students said that when they made a mistake on a long calculation chain, tracing the mistake was considered a tedious task. Furthermore, they had to recalculate it entirely instead of just correcting the mistake found. A teacher said this was one of the reasons why students disliked mathematics [refer to Section 5.2.1]. When solving a question, students could not predict when they were very likely to make a mistake before coming to the solution. If the mistake could be detected instantly, they would not waste too much time on the wrong path. They wanted errors to be corrected sooner rather than later.

In computer games, however, precise and timely feedback is provided for mistakes made. A good computer game comes with feedback that indicates the location of the mistakes (Kiili, 2006). The mistakes can be corrected instantly, and the learning is less time consuming. Players can recover from mistakes without forfeiting much or feel threatened (Sedighian, K., & Sedighian, 1996). Making a mistake in games is expected because the games work on trial and error strategy (Offenholley, 2011). Games work on the principle of learning from mistakes.

> *Mistakes became stepping stones for later success in the game allowing children to progress at their own pace towards the ultimate goal* (Sedighian, K., & Sedighian, 1996, p.4).

Making mistakes is how players learn and it is also called as *failing forward* (Offenholley, 2011). The mistakes are necessary to improve performance. Every step in games is reinforced or weakened through instant feedback. For example, in *Street Fighter*, a player can punch, kick and use an inconceivable number of attacks, but at the same time, the player may get beaten too. The instant feedback is shown by some hit points that indicate how soon the player or the opponent will be knocked out (KO).

e. HOTS

Two students mentioned that they were struggling in mathematics because they could not master the HOTS. The students said,

> *Yes (struggled in mathematics), when it comes to all those higher order thinking kinds of questions. You really have to understand right? So it takes me quite some times to understand. So, it's a struggle. You have to find the main points (Student N).*

> *Yes (struggled in mathematics), quite a lot. But there is one thing I notice about Maths and Add Maths. All those answers are a pattern. All are patterns. Just the questions are arranged in a fancy way but ultimately all those are just patterns. As long as I understand the pattern, I can catch up with the pattern, I don't see why not I can get a hundred (Student P).*

The students mentioned that they were struggling to master HOTS because they could not understand and grasp the pattern. In other words, the students failed to pick out the meaningful patterns from the pieces of information and to think strategically. They could not link new pieces of information to what they had learned previously.

One of the functions of HOTS is to build connections among the myriad pieces of information (Williams, 2003). Pattern recognition and making connections are two critical and interrelated thinking skills in learning. Human beings are powerful pattern recognisers, and we often think in terms of patterns (Gee, 2007). As humans, we understand the world based on our past experience by looking at the similarities and differences of patterns found.

> *Human think best when they reason on the basis of pattern they have picked up through their actual experiences in the world, pattern that, over time, can become generalised* (Gee, 2007, p.9).

Humans' brains not only thrive on the search for meaningful patterns but also for discerning and making connections (Williams, 2003). Our thoughts, abilities, and skills are determined by how our neurons are connected (Khoo and Tan, 2007). To foster pattern thinking and connectionism, HOTS should be encouraged. HOTS helps us to see the patterns, themes, and trends going on, and the more connections forms, the more learning can occur (Williams, 2003). That is why mere drill-and-practice is not sufficient, particularly to solve mathematics questions that require metacognitive skills.

When applied to computer games, HOTS helps players to make successful guesses about what to do based on what they have confronted earlier in the games. The situations and problems are carefully designed so that they lead the players to discover some meaningful trends or patterns.

> *Patterns and generalisations - useful ones both for playing the rest of the game and as the basis for more complicated patterns later when one faces more complex situations and problems* (Gee, 2007, p.137).

The core and fundamental patterns facilitate players to develop more complex patterns or to solve following problems. For instance, when playing a first-person shooter game, a player fights against another player (opponent). If the player can figure out the opponent's pattern of movement, the player can anticipate where he (opponent) will go so that the player has a better shot at him (opponent).

6.1.4 Qualities of a Good Mathematics Teacher

It is crucial to understand the qualities of good mathematics teachers from the students' points of view because they have the first-hand learning experience in schools. Though they may be ill-informed and they have different values from their teachers, their opinions are important to both fruitful and unsuccessful teachers. Teaching is a profession that requires experience and actual classroom practice. Teachers usually draw upon proven methods of instruction or use their intuitive sense to teach. Thus reasonably, the teachers may want to know whether they have met the students' expectations. Even if the students might be ill-informed, their opinion would inform us of how they expect a teacher to *work* with them in the class.

a. Patience and appropriate teaching pace

Five students (A, E, H, L, and S) believed that patience was the most important characteristic of all. Two of the students said,

> *Patience. But, Miss XXXX is very patient actually. She is very gentle… I heard that they say Miss YYYY (another mathematics teacher) quite strict and also very fast. They say she talk and teach like a bullet train (Student A).*

> *When I was primary 1 to primary 3, because I was afraid of the teacher because the teacher was fierce. So, I get low marks, like 50 to 70 something… The teacher is very fierce and I do not know how to differentiate the Chinese words. Because I am afraid to ask the teacher… Teacher shouldn't rush with the topics (Student E).*

The students wanted a teacher who was patient, kind, polite and would teach according to their learning pace that was neither too fast nor too slow. Students wanted to learn in a conducive and stress-free learning environment. Apparently, a teacher's attitude had an enormous impact on student's performance, interest and motivation to learn.

Here, patience and teaching at an appropriate pace are difficult when a teacher has a whole class of students working at different abilities and a large class size. When the pace of instruction is too slow, the good students may become bored and distracted. However, for a fast teaching pace, weaker students will be confused and unable to learn properly. Students seem to prefer playing an active role in learning to decide about, direct and control the pace of their learning activities. However, if the pedagogical design is about a model where an activity is directed in the way a game does, then it would solve the problem because a game would naturally be patient to all players and customise to their learning capabilities.

The computer game has no emotion or feeling like human beings. Players are free to make mistakes countless of times and play repeatedly to improve their gaming skills. It eliminates the likelihood of being scolded and criticised for making mistakes and ending up in an embarrassing situation. Furthermore, players can pace themselves and self-educate (Beck and Wade, 2006). They can play according to their needs for training, time, and convenience. Players can play at anytime and anywhere without a confined space and time. Some of the games also allow players to choose the appropriate level of difficulty and save the progress in games.

b. Attentive

Four students (A, E, P and Y) wanted a teacher who was attentive to their needs and interests. They wanted a teacher who could notice, guide and help them in what they desired. Two of the students said,

> *Maybe if they can explain why the method is used to find the answer. Because sometimes I cannot understand Maths if I cannot understand why we must use that method… Because I don't know okay where this sometimes is unknown. Where this A originate from? (Student A).*

> *Understands our weaknesses. The teacher that always intentionally targets the weakest persons. And expose us to the questions that students commonly cannot answer or the mistakes that students usually do. Allows us to use to the questions that require HOTS… I very much need it because if I am not expose then when I am shown in the exam, definite possible that I would not pass (Student P).*

These two students revealed their needs for learning with understanding and HOTS instead of rote learning. It was most likely that in an exam-oriented system, teachers were rushing to complete the syllabus, and it offered little space and time for innovative instructions.

A teacher requires years of experience to learn to be sensitive and aware of individual student's needs rather than waiting for students to express their difficulties. An experienced teacher may know students' needs just by looking at their facial expressions and body language. Given the current heavy workload in the school, it is a great challenge for teachers to be attentive to every student.

In computer games, however, players are getting all the attention because the game world is responsive to them. Players are the centre of attention in every game (Beck and Wade, 2006). They are given time, supports and resources to develop understanding and HOTS. Without understanding the fundamental rules and mastering HOTS required to resolve problems, it is very unlikely that the players can achieve their goals or win the games. In other words, it is impossible for someone to progress without understanding how to play the game. Games are designed in such a way that players can only progress once they have mastered all the necessary skills. In schools, students have to progress to the next topics or higher levels regardless of whether they have mastered the subjects learned.

c. Interesting example

Lastly, three students (L, N, and S) wanted teachers to use interesting examples that were related to their lives. Two of the students said,

> *Yes. I find it very easy to learn if we learn through diagram. If teacher use computer, the diagram might be some kind of object that really exist. Like teach us how to count, count the land (Student S).*

> *Like my Maths teacher, he always finds a way to make the class fun and very exciting to go to… In between the questions he will make jokes, tell story so that the class will not be boring… Story of his friend trying to be a computer engineer (Student L).*

The students have revealed that they want to have interesting examples given in the class - *real life* and *story*. However, it does not mean that those examples are important in learning. Sometimes, the actual life example given in a book may not be practical in reality. For instance, students are learning how to find unknown values using simultaneous equations in schools, but for many people they will never use the knowledge in their entire life, except for certain professions. The students may try to imply that they want a learning that is situated within the context. Reading a mathematics book to learn mathematics does not make much sense; this is analogous to reading a video game manual without playing the video game.

In computer games, the gaming experience is unique, meaningful and exciting because of the embodied nature of stories in games. In computer games, the meaning is situation specific and embodied.

> *You don't really know what it means unless and until you can give it a specific meaning in terms of the world through which you are moving as a character or the actual actions you carry out in that world… Meanings in video games are always specific to specific situations* (Gee, 2007, p.82).

Learning in computer games is effective because the meaning is formed within the gaming context. For instance, by role-playing a character in a first-person shooter game, a player has a powerfully direct experience of how to ambush, shoot on target, kill and being killed. The player can feel the thrill and emotion of competing or collaborating with someone. The experience and meaning are tied to the game – the meaning of thrill, competition, and collaboration in a first-person shooter game is different from racing or sports game.

6.1.5 Summary

Table 6.4: Students' attitudes towards Mathematics vs. Computer Games

Perceptions towards Mathematics	Computer Game
Positive towards mathematics	
• Interesting and fun because it is challenging and hard.	• Interesting and fun because it is challenging but achievable.
Moderate behaviour and confidence	
• Challenges are not personalised to students' achievable level.	• Challenges are personalised to players' achievable level - choose level to play.
• Learning or practice is boring and serious – exam-oriented.	• Practice is not serious - having ample time to learn.

Strengths and Weaknesses	Computer Games
Males dislike long calculations	
• Mistakes could not be predicted before coming to the solution.	• Precise and timely feedback (e.g. reward or mistake) is provided.
• Tracing mistakes is tedious.	• Mistakes are corrected instantly.
• Wasted time on the wrong path.	• Learning is less time consuming.
Females are weak in spatial ability	
• Cannot imagine or visualise abstract concepts – prefer calculations.	• Playing games such as *Chess* and *Go* can improve spatial ability.
Struggle in HOTS	
• Could not understand the patterns.	• Pattern and generalisations are important when players face more complicated situations or problems.
• Failed to grasp the meaningful patterns to think strategically.	

Qualities of a Good Teacher	Computer Games
Patience and appropriate teaching pace	
• Patient, kind and polite.	• No emotion and can repeat countlessly.
• Neither too fast nor too slow.	• Self-educating - convenient time/place.
Attentive	
• Explanation should be given to develop students' understanding.	• Players are the centre of attention - time, support and resources are given to develop understanding.
• Attend to students' weaknesses.	• Responsive to players' needs.
Interesting examples	
• Real life examples.	• Meaning is tied to the learning context - situated learning.
• Storytelling.	• Embodied nature of stories in games.

6.2 Students' Technological Experience

The current young generation of students is claimed to be digital natives (Prensky, 2001a). It is essential to understand students' technological experience because students' acceptance to the use of computer games in mathematics education could be influenced by their exposure to various computers technologies. Students' technological experience can be seen from both quantitative and qualitative data.

6.2.1 General Overview

Data collected using DNAS (Teo, 2013) showed that students agreed with being digital natives who *grew up with technology, performed multitasking, be reliant on graphic for communication* and *thrived for instant gratifications and rewards* (see Table 6.5). This claim was verified further with technology accessibility and usage (see Table 6.6 and 6.7).

Table 6.5: Characteristics of Digital Native

Digital Native Characteristics	Mean
Grow up with technology	5.30
Multitasking	5.61
Reliant on graphics for communication	5.15
Thrive on instant gratifications and rewards	5.61

Note: 1 strongly disagree to 7 strongly agree

Table 6.6: Technology Accessibility according to Schools

Technology		Desktop computer	Laptop	Tablet PC	Video Game Console	Cell Phone	Smartphone	Internet
School	M1	76%	92%	73%	65%	68%	90%	88%
	M2	81%	93%	62%	53%	66%	77%	75%
Total		78%	93%	67%	59%	67%	83%	81%

Students had high accessibility to various computer technologies, especially laptop (93%), smartphone (83%) and the Internet (81%) (See Table 6.6). Apparently, they had sufficient tools and access to play computer games. Furthermore, about 59% of the students owned a video game console and had been exposed to video games at home.

Comparison between two schools obviously showed that students from M1 had significantly higher accessibility to smartphone and the Internet. It was most likely that students who stayed at home had more freedom and access to various computer technologies than those who stayed in the hostel.

Table 6.7: Daily Activities - Hours Spent Per Day

Daily Activities		Sleep	Internet	TV	Listen to song	Call/ message	FB	Computer games	Academic	Sports
School	M1	6.66	3.91	3.17	2.81	2.27	1.27	2.21	4.53	1.68
	M2	6.92	4.25	4.13	3.17	3.38	1.93	1.64	3.89	1.58
Total		6.79	4.08	3.65	2.99	2.82	1.6	1.92	4.21	1.63

Based on Table 6.7, other than sleeping for approximately 7 hours, students spent most of the time on academic pursuits (4.21 hours), followed by surfing the Internet (4.08 hours) and watching TV (3.65 hours). Total time spent on computer entertainments (e.g. the Internet, Facebook and computer games) was much more than academic pursuits. However, it should be noted that students performed multitasking. For instance, they might listen to songs while doing homework.

In brief, quantitative data had shown that the students were characterised as digital natives and used computer technologies in every aspect of their lives.

6.2.2 Computer Usage and Skills

Qualitative interview examined further eight students' technological experience by looking at the pattern of information technology usage and possession of computer technologies.

Table 6.8: Use and Possession of Computers

Student	A	E	H	L	N	P	S	Y
Desktop	0	1	1	1	1	2	0	0
Laptop	3	2	4	2	3	2	2	2
Tablet	3	0	1	4	4	2	1	1
Smartphone	1	1	1	1	1	1	1 (parent)	0
Internet	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ICT exposure	Age 3	Age 7	Very young	Age 7	Age 10	Age 7	Age 9	Age 10
Usage frequency	Daily	Daily	Daily	Daily	Daily	2-3 times per month	Daily	Rarely
Time spent (each occasion)	2-3hr	1-3hr	1-5hr	2-6hr	1.5hr	4hr	5hr	2-3hr

According to Table 6.8, the students were most likely coming from middle-class family as they owned three to eight computers at home (i.e. desktop, laptop or tablet), and had access to the Internet. They had been exposed to computers before or during primary education. Most of them (6 students) used computers on a daily basis for at least one hour. It seemed that even though students were coming from different family backgrounds, they had similar exposure to computer technologies.

Table 6.9: Frequency of Computer Usage

Student	A	E	H	L	N	P	S	Y
Office Application								
Typing documents	3	2	1	1	2	3	2	2
Analyse data	2	3	1	2	2	2	3	2
Prepare presentation slides	2	2	1	1	3	3	2	2
Doing school work	2	4	1	2	2	4	1	1
Entertainment								
Playing games	2	1	2	3	4	3	1	3
Watching movie	3	2	2	1	2	2	2	1
Listening to music	1	1	1	1	1	1	1	2
Social networking	1	2	1	1	1	1	1	1
Advanced Usage								
Emails/ Communication	2	2	1	1	1	2	1	1
Using search engines	1	1	1	1	2	1	1	1
Search for medical information	2	2	1	4	3	2	1	3
Search for directions	3	3	2	2	3	3	2	3
Reading news	3	2	2	2	2	3	1	3
Online Shopping	4	4	3	4	2	4	4	4

1-always, 2-sometimes, 3-rarely, 4-never

Based on Table 6.9 students were more likely to use computers at home for personal interest than in schools for schoolwork. Three students always used computers to do schoolwork, but the rest of them were either occasionally or never used computers to do schoolwork. This result indicated that computers were hardly used for formal learning in schools. Most of the students used computers to surf the Internet, listen to the song, connect to the social network and communicate with someone rather than use office applications for study. The students seemed to view computers as entertainment to fulfil their needs for friends, relaxation and to receive the latest information.

Nevertheless, female students (A, E, and H) were more likely than the male students (L, P, and Y) to play computer games. This finding might infer that the female students played games on a computer more frequently than the male students, or there might be some discrepancies in judgement (self-reported data) between both genders. Another possibility could be the male students preferred a different platform of games such as video game consoles, mobile devices or arcades.

Table 6.10: Computer Literacy

Student	A	E	H	L	N	P	S	Y
Office Applications Skills								
Typing skill	3	5	4	4	4	4	4	1
Word processing	4	4	5	3	3	3	4	3
Spreadsheet	2	3	5	2	2	1	2	2
Presentation	4	5	5	4	3	2	4	3
Entertainment Skills								
Social networking	5	4	5	4	4	3	4	4
Find/download song/video	5	5	5	5	5	4	4	4
Video sharing via YouTube	4	3	5	3	3	1	5	3
Advanced Skills								
Internet search	4	5	5	5	4	4	5	3
Download/ install software	4	4	5	5	4	4	3	3
Use of electronic gadgets	4	5	5	5	4	4	4	2
Basic computer maintenance	4	4	5	4	3	4	3	1
Basic troubleshooting	3	3	5	4	2	3	4	3
Other IT Skills	Make video 3			Java 2				
1 would represent novice and 5 would represent expert								

According to Table 6.10, the students were proficient in all three aspects of computer literacy - office applications, entertainment, and advanced usage. The majority of them were proficient (i.e. between 3 and 5) in all the technological skills listed in the table, except for the use of a spreadsheet. The teachers showed a dissimilar pattern; most of them were only good at office applications especially the female teachers [refer Section 5.4.2]. The students, however, did not seem to portray significant gender gaps between male and female users in computer experience and skills, as in the earlier generation (i.e. teachers). While the earlier generation of female users would still lag behind male users in digital fluency in all aspects, digital literacy or digital savvy female students were helping to close the gender gap in future workplace.

In this section, the finding has indicated that the students have developed computer literacy at home rather than at school. Parents play a major role to expose young children to modern technologies at home. Even though parental supervision may limit the students' access to computers and the Internet, they have been exposed to computers at a very young age. The parents seem to be positive and believe that children's access to technology in their early years may help to develop and improve learning. This could explain why the students seem to be comfortable with various computer technologies in their daily lives. Apparently, they do not know how life before the invention of computers, video games, the Internet and cell phones because they may not live a day without computers.

6.2.3 Smartphone

The introduction of the smartphone has changed the way people use technology. Thus, it is essential to explore how students use a smartphone.

Table 6.11: Usage Frequency of Smartphone

Student	A	E	H	L	N	P	S	Y
Phone communications								
Making phone calls	2	1	2	1	2	2	3	-
Sending SMS	2	1	2	1	2	3	3	-
Using messaging application	1	1	1	1	3	1	2	-
Entertainment								
Playing games	1	1	2	1	3	2	1	-
Taking photo/video	1	3	2	1	2	2	2	-
Watching TV/video	2	2	1	1	3	3	2	-
Using Facebook	1	3	4	1	3	1	1	-
Advanced Usage								
Web browsing	2	1	1	1	3	1	1	-
Checking emails	3	2	1	2	3	4	2	-
Using map/ directions	3	3	2	2	4	4	2	-
Reading news/ sports	4	1	2	2	2	4	1	-

1-always, 2-sometimes, 3-rarely, 4-never

Based on Table 6.11, student Y did not own a smartphone. It was most likely due to his family financial background. Seven students owned a smartphone so the discussion in this section would focus on them. Similar to computer usage, the students used a smartphone for various purposes – communication, entertainment, and advanced usage. The smartphone seemed to be pervasive in many aspects of their lives. Most of them always used a smartphone to send messages and surf the Internet. This was then followed by playing games and accessing Facebook. The teachers showed a dissimilar pattern; most of them used a smartphone for communication [refer Section 5.4.3]. The students, however, used a smartphone to get connected with friends (e.g. WhatsApp, WeChat, Facebook); get the latest information (e.g. web browsing) and entertainment (e.g. games). This finding supported the characteristics of digital native reported in the quantitative data.

The students are characterised to: (a) function best when networked - always connected to the social network; (b) being used to receive information fast - always surfing the Internet; (c) prefer games to serious work - always playing games. A closer look at computer and smartphone usage reveals that the students play mobile games more frequently than computer games. It is most likely that they prefer playing at their convenient time and place. The smartphone has changed how students learn. Now, they can learn anytime and anywhere, and it is leading to mobile learning.

6.2.4 Parents and teachers' technological skills

This section explores parents' and teachers' technological skills from the students' points of view. Parents who are presumed to be knowledgeable in computer technologies might be more understanding and appreciative of the use of computer games. Understanding of teachers' technological skills from students' points of view may influence students' confidence and perceptions towards the teachers.

a. Incompetence of parents

Most of the students (A, E, L, N, P and S) cited that they had better technology skills than their parents. Only Student Y noted that he and his parents were equally good, and Student H said she and her father were the best in the family. Most of the students were self-assured and confident that they were one of the best people in their family to deal with the computers.

b. Proficiency of ICT and young teachers

When students were asked whether their teachers were technology savvy, most of the students (A, H, L, N, P and S) cited that it depended on the teachers' age and subjects taught. The students perceived that ICT or young teachers (i.e. age 20 to 40) were better than them, but older teachers (i.e. age 40 and above) were seen to be left behind in modern technology usage. Young and ICT teachers were perceived to be good in PowerPoint, blogs, computer maintenance, networking and video editing. None of the teachers were perceived to be good in playing computer games.

The students might believe that their mathematics teachers were not capable of handling computer games for educational use. Another possibility would be that the students and teachers never talk about or even play computer games together in the schools. The teachers seem to be not ready or equipped with sufficient knowledge and skills to handle computer games in teaching. This finding discloses the characteristics of digital immigrants who are showing less technological affinity and knowledge than the younger generations (Waycott *et al.*, 2010). Interestingly, the students are making this assumption based on their observation of what the teachers have been doing with their mobile phones, computers, and Facebook.

Constant use of computer technologies can, not only help in developing various technological skills that are explicitly seen, but also implicit skills. The use of technology develops informal learning (Bullock and Webb, 2015). Unfortunately, many people disregard informal learning and always believe that learning only happens in formal education and training.

> *Informal learning is largely invisible, because much of it is either taken for granted or not recognised as learning; thus, respondents lack awareness*

> *of their own learning… the resultant knowledge is either tacit or regarded as part of a person's general capability, rather than something that has been learned* (Eraut, 2004, p.249).

Using technologies in daily life is related to Eraut’s (2000, 2004) three topologies of informal learning - *implicit, reactive* and *deliberative* (Bullock and Webb, 2015). *Implicit learning* is undertaken unconsciously, and there is no intention to learn (Eraut, 2000, 2004). Learning from experience is a form of implicit learning and some learning from social media can be understood as implicit (Bullock and Webb, 2015). Implicit learning seems to very natural and spontaneous. *Reactive learning* resides in between implicit learning and deliberative learning. It describes situations where the learning is explicit and the learner is aware of it, but it is unplanned (Eraut, 2000, 2004). The use of smartphone applications is an example of reactive learning (Bullock and Webb, 2015). Deliberate learning is a planned non-formal learning from activities such as decision-making, planning and problem-solving (Eraut, 2000, 2004). The simulation would be a form of deliberative learning (Bullock and Webb, 2015).

Although Bullock and Webb (2015) give some technological examples to differentiate the three topologies of informal learning, the classification may depend on the *type of users* and *intention*. For instance, the students in this study may develop implicit learning (i.e. unconscious and unplanned) when using a smartphone, surfing the Internet, playing games and accessing Facebook because these digital native students have been exposed to all sorts of digital technologies since young. They can easily use various types of technologies without much thought, in which the skills are developed from their previous experience. However, for the digital immigrant teachers and parents, they may use reactive learning (i.e. conscious and unplanned) because they are not familiar with the technologies and they take some time to learn.

The *intention* to use a technology does influence the nature of learning too. For instance, the teachers who are not proficient in ICT may deliberately learn (i.e. conscious and planned) the office application because they need to use the software for their work. However, the students may use reactive learning (i.e. conscious and unplanned) when using the office applications to complete their school project because they do not deliberately have the intention to learn the software. The students’ learning of technologies is shifting towards implicit learning, but the older generation’s learning is shifting towards deliberate learning.

Deliberate learning is useful in helping to bring closer the generation gap between the digital natives and digital immigrants. When people get older, some aspects of memory change and there is a decline in various memory abilities. Studies have indicated that training can help individuals with moderate to severe memory impairment in the use of emerging commercial technology (Svoboda *et al.*, 2014, 2012). Deliberate learning may involve more time and efforts, but age does not stop someone from learning.

6.2.5 Summary

Table 6.12: Students' Technological Experience

<table>
<tr><th colspan="2">Digital Native</th></tr>
<tr><td colspan="2">• Students are characterised as digital natives.
• Use of computers on a daily basis.
• Learning computers before or during primary education.
• More proficient in ICT than their parents and teachers (except ICT or young).</td></tr>
<tr><th>Computers</th><th>Smartphones</th></tr>
<tr><td>• Learning computer literacy at home rather than at school.
• Proficient in office applications, entertainment and advanced usage.
• Computers usage - entertainments and advanced usage, specifically to surf the Internet, listen to the songs, communicate and connect to the social media.
• Females play games on a computer more frequently than the males.</td><td>• Smartphone usage - communication, entertainment and advanced usage, specifically to send message, surf the Internet, play games and access Facebook.
• Students play mobile games more frequently than computer games.</td></tr>
</table>

6.3 Students' Gaming Experience

It is a general perception that students will have more acceptance to computer games. Thus, by doing this study, I am putting a test on this general perception to find out the truth and to have the quantitative and qualitative information on student's gaming experience.

6.3.1 General Overview

a. Gaming behaviour

Referring to Section 6.2.1, the students were active gamers as they spent an average of 1.92 hours per day playing computer games. Someone is considered as an active gamer if he or she plays computer games for more than 7 hours per week (Simons *et al.*, 2014). However, further inspection of the data revealed that only 88% of the students played computer games, and 53% of them were active gamers. In the 12% of students who did not play games, 10% was female, and 2% was male. Essentially, female students were showing less interest in playing digital games.

Table 6.13: Gaming Patterns

Gaming Experience	%
1 to 2 years	22.9
3 to 5 years	24.2
6 to 10 years	35.3
> 10 years	17.6

Gaming Expertise	%
Beginner	23.4
Intermediate	56.6
Expert	8.0

Gaming Device	%
PC	33.8
Laptop	72.1
Console	40.3
Smartphone	71.4
Tablet PC	40.3
Arcade	13.6

Based on Table 6.13, about 80% of the students had less than ten years of gaming experience and rated themselves as beginner or intermediate in gaming expertise. This result indicated that most of the students had been exposed to computer games after they had entered into primary education. Laptop (72.1%) and smartphone (71.4%) were the two most popular devices used to play digital games. It made sense as the laptop, and smartphone possession was 93% and 85% respectively. It might be due to the portability and convenience of these two devices.

b. Time spent to play computer games

The time spent to play computer games was examined according to students' demographic groups (see Figure 6.14).

Table 6.14: Time Spent Playing Computer Games (hours per day)

School*		Gender**		Type of Student		Place of Residence	
M1	M2	Male	Female	Day Scholar	Boarder	Town	Rural
2.21	1.64	2.66	1.63	2.35	1.86	2.13	1.61

*Sig. difference at 0.05
**Sig. difference at 0.01

Further analysis was conducted using a Mann-Whitney U test to examine whether the hours devoted to playing computer games was significantly different between the demographic groups. The test indicated that there was a significant difference in the results of the time spent on playing computer games between school attended ($U = 2657$, $p < 0.05$, $r = 0.1792$) and gender ($U = 2378$, $p < 0.01$, $r = 0.2830$). Males spent more time playing than females, and the effect size was moderate. Students from M1 School spent more time playing than students from M2 School, but the effect size was trivial. Since all students from M2 School were staying in a hostel, a hypothesis was formed - students who stayed in the hostel were less likely to play computer games.

However, further analysis indicated that there was no significant difference found between day scholar and boarder ($U = 2795$, $p > 0.05$, $r = 0.1291$). Furthermore, there was also no significant difference in between students from town or rural areas (U =

1959.5, $p > 0.05$, $r = 0.0926$). Environmental constraints (e.g. staying at school hostel or rural areas) did not seem to stop students from playing computer games.

In brief, male students spent more time playing computer games than female students. Students regardless of boarder or day scholar; from M1 or M2 schools; from rural or town areas did not show a significant and huge difference in time spent to play computer games.

c. Favourite types of games

Students played different types of computer games, and they were asked to rate their interest towards each type of games from a Likert scale (1 strongly disagree, and 5 strongly agree). Students' percentage of agreement (i.e. agreed or strongly agreed) was shown in the following table.

Table 6.15: Favourite Types of Digital Games

	Racing	Action adventure	Shooter	Simulation	Strategy	Fighting	Role-play	Sports	Puzzle
Agreement (%)	81.7	77.8	75.1	64.7	60.2	58.9	56	55.6	54.3

Based on Table 6.15, students had the highest interest towards racing games, which was followed by action-adventure, shooter, simulation, strategy, fighting, role-play, sports, and lastly puzzle games. Further analysis was conducted to examine whether male and female students had a different interest towards different types of games.

Male students loved to play *sports* and *strategy* games the most. An analysis with Mann-Whitney-U test revealed that they obviously had more interest to play *sports* games ($U = 1168.5$, $p = 0.00$, $r = 0.4939$) and *strategy* games ($U = 1767.5$, $p = 0.00$, $r = 0.3066$) than their female counterparts. Male students also liked to play *racing, action-adventure, fighting* and *shooter* games more than female students but only trivial effect size ($p < 0.05$, $r < 0.3$). Both genders did not show a significant difference ($p > 0.05$) in *role-playing* and *simulation* games. However, female students liked to play *puzzle* games slightly more than their male counterparts ($p < 0.05$, $r < 0.3$). In brief, male students obviously liked to play *sports* and *strategy* games.

d. Favourite computer games

Students liked to play Facebook and video or computer games. Male students' favourite Facebook game was *Clash of Clans* and female students' favourite Facebook game was *Candy Crush*. The students also loved to play video or computer games from different genres. For instance, sports (i.e. *FIFA*); first-person shooter (i.e. *Counter-Strike, Call of Duty* and *Left 4 Dead*); racing (i.e. *Need for Speed*); life simulation (i.e. *The Sims 3*); strategy (i.e. *Clash of Clans*), multiplayer online battle arena (i.e. *Defense* *of the Ancients 2*); action-adventure (i.e. *Grand Theft Auto*) and tower defence (i.e. *Plants vs. Zombies*). Most of the video or computer games were mixed genres. Thus, *Google*'s result was used as a guideline.

Table 6.16: Students Favourite Video/Computer Games

Ranking	Overall	Male	Female
1	FIFA	FIFA	The Sims 3
2	Grand Theft Auto	Defence of the Ancients 2	Grand Theft Auto
3	Counter Strike	Counter Strike	Need for Speed
4	Need for Speed	Pro Evolution Soccer	Counter Strike
5	The Sims 3	Grand Theft Auto	Plants vs. Zombies
6	Defence of the Ancients 2	Call of Duty	FIFA
7	Plants vs. Zombies	Need for Speed	
8	Clash of Clans	Clash of Clans	
9	Call of Duty		
10	Left 4 Dead		

Gender comparison in Table 6.16 revealed that male students liked to play a variety of video or computer games. Surprisingly, female students also liked to play male-dominated games such racing, first-person shooter, and sports games. However, female students disliked any strategy and multiplayer online battle arena games.

In this section, there is an inconsistency between Table 6.15 (i.e. racing) and Table 6.16 (i.e. sports – *FIFA*) in reporting the most popular type of games. There are two explanations to this. Firstly, most of the computer games are commonly classified into multiple genres. Secondly, the students may not be clear with the classification of the games genres. Nevertheless, both tables provide useful insights.

e. Perceptions towards computer games

Students' perceptions and views towards digital games are necessary to make sure that students are positive and comfortable towards the technologies. Based on Table 6.17, students' perceptions towards computer games were very positive. About 87-96% of them loved to play computer games and described the gameplay experience as fun and enjoyable. Furthermore, 75-90% of the students agreed to learning problem-solving and metacognitive skills through gameplay. Lastly, more than 73% of the students agreed that computer games should be challenging, interactive and complex. In brief, most of the students recognised the benefits of computer games from metacognitive and affective aspects.

Table 6.17: Perceptions towards Video/Computer Games

Perceptions towards digital games	% Agreement	% Unsure	% Disagreement
<u>Affective</u>			
Fun	95.5	3.2	1.2
Enjoyable	95.4	2.6	2.0
Love to play	87.7	6.5	5.8
<u>Problem-Solving</u>			
Understand the problem	84.4	11	4.5
Develop a plan	82.5	13	4.5
Carry out a plan	79.9	15.6	4.5
Look back	78.6	15.6	5.8
<u>Metacognitive Skills</u>			
Multitasking skill	75.2	22.2	2.6
Land Navigation skill	74.5	22.2	3.3
Teamwork	81.8	12.3	5.8
Problem-solving skill	89.6	9.1	1.3
Concentration	90.8	5.9	3.3
<u>Intrinsic Motivation</u>			
Like challenging game	92.2	5.8	1.9
Like interactive game	88.8	9.9	1.3
Like complex game	73.2	22.2	4.6

6.3.2 Active and Non-active Gamers

To further explore students' gaming experience in more detail, qualitative data was collected from eight students (see Table 6.18).

Table 6.18: Gaming Pattern

Student	L	P	S	Y	A	E	H	N
Gender	Male				Female			
Hours per day	0.5 to 1	<1	Holiday - 2 School Day - 0	Holiday - 1 School Day - 0	Holiday - 0.5 School Day - 0	Holiday – 2 School Day - 0	Holiday – 4 School Day – 0.5 to1	5 minutes
Gaming devices	• PC • Smartphone • Video game console	• Smartphone • Video game console	• PC • Tablet • Smartphone • Video game console	• PC • Tablet	• PC • Tablet • Smartphone	• PC • Smartphone	• Smartphone • Video game console	• Smartphone • Video game console
Favourite games	• FIFA • NBA • WWE	• Clash of Clans • Alice of Hearts	• FIFA • WWE • Far Cry • GTA • Hunting 101 • Leaf 4 Dead	• DotA	• The Sims • Unblock Me • Pet Society • Buttons and Scissors	• The Sims • House of Death • Need for Speed • Cooking Dash • Magic Academy • Dead Trigger	• Tekken • Rich Racer • Little Big Planet • Hakuna Matata • Resistance Fall of Man	• Crossy Road
Favourite types of games	• Fighting • Strategy • Shooting • Role-play • Sport • Action-adventure	• Strategy • Puzzle • Shooting • Role-play • Action-adventure	• Racing • Fighting • Strategy • Shooting • Role-play • Sport • Action-adventure	• Racing • Fighting • Strategy	• Simulation • Racing • Fighting • Strategy • Puzzle • Role-play • Action-adventure	• Simulation • Racing • Fighting • Shooting • Role-play • Action-adventure	• Racing • Fighting • Strategy • Puzzle • Shooting • Role-play	• Puzzle • Role-play • Sport
Expertise (1-novice, 5 expert)	4-5	3	4	4-5	3	3-4	5	3

The students' hours spent to play games differed across the school days and non-school days. During the school days, all the students were non-active gamers. Some parents might limit their children's play time while some students were too burdened with school activities, homework, projects or tuitions. For instance, a student indicated his busy schedule and he had no free time to play computer games. He said,

> *This year I got really busy. So for my free time, I just take nap and sleep. Because it is not often that I get enough sleep now. Too much of works (Student P).*

During non-school days, some students had different gaming pattern as most of them could put aside their studies and had the time for themselves. During the school holiday, two male (S, Y) and two female (E, H) students were active gamers as they played computer games for more than 7 hours per week. They loved to play computer games mainly from a few genres: shooting (e.g. *House of Death, Dead Trigger, Resistance Fall of Man, Far Cry* and *Left 4 Dead*), racing (e.g. *Rich Racer* and *Need for Speed*), fighting (e.g. *Tekken*), action-adventure (e.g. *Grand Theft Auto* or *Grand Theft Auto*) and multiplayer online battle arena (e.g. *DotA*).

However, two male (L, P) and two female (A, N) students remained non-active gamers even during holiday time. They usually played sports (e.g. *FIFA, NBA* and *WWE*), simulation (e.g. *The Sims*) and mobile apps or Facebook games (e.g. *Unblock Me, Clash of Clans, Buttons and Scissors, Crossy Road, Alice of Hearts,* and *Pet Society*). One of the students explained her disinterest in computer games. She said,

> *I am quite old to play game (Student A).*

Apparently, Student A perceived playing as children's activity and adults should not play like children. In fact, the play is a major component of human health and development that should not stop at a particular age (Corbeil, 1999),

In this section, an analysis of games played has indicated that shooting, racing, action-adventure and multiplayer online video or computer games (mostly played by active gamers) could be more competitive and require more active skills and strategies. In contrast, games that are played by non-active gamers such as sport, simulation and mobile apps or Facebook games would appear to be less competitive and mainly for leisure purposes. This finding shows that time spent on gaming may be affected by the types of games played.

6.3.3 Addictive and non-addictive games

A student said,

> *I seldom played. Because currently, there is no game that addictive. I just play (Clash of Clans), sometimes it is interesting but not addictive enough for me… Because most of the games now are really really short and really not enough for me to get addicted into it… I am not saying that no good game. I am just saying that the gaming period is too short. Not enough for me to be really into it (Student P).*

When Student P said that those games were *too short* for him to get addicted to it. One might assume that short period games are not addictive. Short period games would start and finish in approximately 1 hour time for a game. Long period games such as story-based games most likely would take a minimum of 48 hours from the start to the end of a game. Furthermore, open world games would take as long as the player would need with no ending.

Games such as *Clash of Clans, Angry Birds, Counter Strike* and *DotA* are not open world games, but they are addictive too because some players may spend an enormous amount of time on those games. In contrast, a player like Student P most probably would spend a small amount of time for open world games like *War of Warcraft* or *Grand Theft Auto*. Players may spend an enormous amount of time on one single short period game, or spend a huge amount of time on a single long period game. Games' duration is not the sole factor of games addiction. No one will spend an enormous amount of time on non-addictive games and vice versa. Addictive games tend to be more competitive and require more active skills and strategy, as opposed to non-addictive games that appear to be less competitive and mainly for leisure purposes.

The finding in this section suggests that the use of computer games for mathematics education could be implemented at home or during school holidays. From the practicability point of view, there is insufficient computer labs at schools. Nonetheless, students have unlimited access to gaming devices and the Internet at home. At home, students may feel more comfortable, stress-free, casual and relax to play the computer games (mathematics education). In a formal setting in schools, the students may feel coerced to play the games because they are monitored and instructed by the teachers to do so. Besides that, if computer games for mathematics are implemented at home, this can prevent putting more stress or work pressure on school teachers that are struggling to complete the syllabus. If students and educators feel stressed and are pressured to its implementation, it would fail the whole purpose of learning that should be fun and engaging.

6.3.4 Favourite Types of Games

In this section, students' favourite types of games are discussed and supported by quantitative data reported earlier.

Table 6.19: Favourite Types of Games according to Gender & Active/Non-active Gamers

	Active Gamers		Non-active Gamers	
Male	Student S Racing Fighting Strategy Shooting Role-playing Sport Action-adventure	Student Y Racing Fighting Strategy	Student L Fighting Strategy Shooting Role-playing Sport Action-adventure	Student P Strategy Puzzle Shooting Role-playing Action-adventure
Female	Student E Simulation Racing Fighting Shooting Role-playing Action-adventure	Student H Racing Fighting Strategy Puzzle Shooting Role-playing	Student A Simulation Racing Fighting Strategy Puzzle Role-playing Action-adventure	Student N Puzzle Role-playing Sport

All active gamers liked to play *racing* and *fighting* games, whereas all non-active gamers liked to play *role-playing* games (See Table 6.19). Gender comparison revealed that all male students liked to play *strategy* games, whereas all female students liked to play *role-playing* games. Quantitative data also showed that male students liked to play *strategy* games more than their female counterparts, but there was no gender difference in *role-playing* games. Female students seemed to be non-active gamers. However, self-reported gaming expertise revealed that two female students (E, H) were proficient in games and could play equally well as the male students.

Further analysis and comparison between male and female students indicated that some female students also liked to play *fighting* and *shooting* games (male preference). Similarly, one male student (P) liked to play *puzzle* games (female preference). Therefore, discussion on games should not be classified according to gender, instead the overall popularity (i.e. favourite games) among the eight students interviewed is discussed.

a. Ranking 1: Role-playing

All female students (A, E, H, and N) and three male students (L, S and P) liked to play *role-playing* games. Two students said,

> *For role-play, I grew up playing role-play game such as Pokémon. So I guess it has a soft spot in me (Student P).*

> *For role-play games because we can see the storyline. And another reason is when I start playing the kind of role-play game, I want to quickly finish the whole games (Student N).*

The male student (P) mentioned that his pleasant childhood experience had significantly shaped his positive feeling for *role-playing* games. As for the female student (N), she liked *role-playing* game for its captivating storyline and shorter duration of gameplay.

In this game genre, players can take on the role of a character and interact within the games' world. The students may like to undertake the roles of characters in a fictional setting. Even though this genre is not highly ranked in the quantitative data, the fact is many games are multi-genre or cross-genre that can fall into this category too.

b. Ranking 2: Strategy and Fighting

Quantitate data revealed that male students favoured *strategy* and *fighting* games more than their female counterpart.

i. Strategy

All the male students (L, S, P and Y) and two female students (A and H) liked to play *strategy* games. Three students said,

> *Strategy game is fun because we have to think of the best strategy to win. So it is challenging (Translated from BM) (Student Y).*

> *For strategy game and puzzle, it allows my brain to think, sometimes I overthink things. Sometimes I like to think things inside the game, but not so much. Because some games make me really fed up with it (Student P).*

> *I think strategy and puzzle because I have to think for the solution (Student H).*

These students had the same opinion that *strategy* games required them to *think* and they liked the challenge of devising the best strategy to win the games. In *strategy* games, players had to test their decision-making skills, and their judgments would significantly bring impact on the games' outcome. One of the strategy games that was popular among the male students was *Clash of Clans*.

ii. Fighting

Surprisingly, female (A, E and H) and male (S, Y and L) students liked to play fighting games equally. Two students said,

> *In fighting games, you can see the actions. So it is more satisfying (Translated from BM) (Student Y).*

> *Fighting and racing because is like a sort of competition with my brothers usually, so if I win, I have that sort of satisfaction (Student H).*

According to the male student (Y), the main attraction of *fighting* games was to see the actions or movements shown by the game characters. As for the female student (H) who liked to play *Tekken*, she enjoyed the competition in *fighting* games. Both students said *fighting* games were giving them a kind of *satisfaction*. Male and female gamers might play *fighting* games for different reasons. Male gamers might enjoy the fighting scenes whereas female gamers might enjoy the competition.

c. Ranking 3: Shooting, Racing, and Action-Adventure

The third most popular games among the students were *shooting, racing* and *action-adventure*. Surprisingly, these three genres were ranked as the top three most popular genres in the quantitative data.

i. Shooting

As expected, more male students (L, P and S) liked to play shooting games than the female students (E and H). Some popular shooting games among the students were *Counter-Strike, Call of Duty* and *Left 4 Dead*. A male student said,

> *For shooting, I am not too sure. I just like inside the graphic (Student P).*

Student P liked to play shooting games because he liked the scene and design of the virtual world in games. It was surprising to me that two female (E, H) students were interested in playing shooting games such as *House of Death, Dead Trigger* and *Resistance Fall of Man*, which were considered as violent games. Student E and Student H said,

> *I like to play Instinct. Like shooting game, it's fun to see I constantly move (Student E).*

> *I think that I should keep my eyes open especially in Resistance. The bad guys can come anywhere and I should regularly check how many bullets I still have and how many have I picked up because we don't really show how many case of bullet you have right now. Is like strategical game… Shooting based or Resistance, I could actually bond with my brother that's some of the things he and I like. It is very hard to find something we like together because he is a boy and I am a girl. Spend quality time (Student H).*

These two female students liked to play shooting games for a different reason. Student E enjoyed moving around the game interface while the game followed a specific route, and Student H enjoyed collaboration and competition with her brothers. Although two female students liked to play shooting games, the other two female disliked shooting games. Student A and N said,

> *Because shooting normally is quite cruel. Like Counter-Strike, if they shoot they are blood and I don't like to see that (Student A).*

> *Some games might be distracting and addicting. Like GTA all that. All those action kind (Student N).*

Two female students (A, N) did not enjoy shooting games mainly due to the violence and killings scenes. Active gamers like Student E and H seemed to enjoy shooting game, but non-active gamers like Student A and N did not enjoy it.

ii. Racing & Action adventure

Other than shooting games, five out of the eight students also enjoyed playing racing and action adventure games. Student H who liked to play *Rich Racer* said that she liked to play racing games because she liked the competition with her brothers. For *action-adventure* games, Student A and Student P said,

> *Sometimes there are games like Escape the Room (point-and-click adventure game). We think, to think, okay how to escape from the room. Sometimes I like to challenge myself but usually I lose (Student A).*

> *For action-adventure, I am the kind of guy that likes the stories. So sometimes, action adventure games they tell a really good story, so it draws me into it (Student P).*

Student A liked the challenge in the game, while Student P was drawn to the storyline. Again, male and female students liked to play the same genre of games but for different purpose. Quantitative data also revealed that *racing* game like *Need for Sp*eed and an *action-adventure* game like *Grand Theft Auto* were popular among both genders.

d. Ranking 4: Puzzle

As expected, three female students (A, H, and N) and one male student (P) liked to play *puzzle* games. Quantitative data revealed that female students liked to play *puzzle* game slightly more than male students. Student H and Student P had mentioned earlier that they preferred playing puzzle games because they liked to *think*. The other two female students had similar perceptions. Student A and N said,

> *Maybe Unblock Me, like the challenging one, they can improve our thinking. For me la… Because we are desperate to find a way out or maybe they can*

use something or can triggers my mind. Like Unblock Me, we need to find a way. Our mind will think outside the box (Student A).

For puzzle games, it is challenging for some of us. So we end up thinking and we try our best to solve it (Student N).

When all the students were asked for the reason for liking *puzzle* games, they gave a similar answer. *Puzzle* game was *challenging* which helped them to *think* in a logical way and to arrive at the right response to the *puzzle*.

e. Ranking 5: Sport

The sports game was ranked number five as only three male students (L, S, and N) liked to play the game. Quantitative data also revealed that boys liked to play *sports* games the most and obviously more than the female students. *Sports* games such as *FIFA* and *Pro Evolution Soccer* were ranked number one and number four, respectively. Surprisingly, *FIFA* was also one of the popular games among the female student but was ranked number six. Two students said,

The sport, the action involved games, it will stimulate my head and brain more because it is more interesting and fun to play with (Student L).

It is sports related. Helps my hand coordination. Because this types of game really makes my finger to move. The action. I can do things that I cannot do in real life. The surroundings inside this game, surroundings and scenes are not the local scene. So, I can learn new culture (Student S).

According to both students, they liked to play *sports* games because they liked the *action* in games. Student L said *sports* game was motivating, while Student S said he enjoyed the virtual reality in games that was so fascinating to him. Both Student L and S were physically active in sports such as soccer, hockey, and basketball. Therefore, their interest to play *sports* genre games might be influenced by their personal interest in sports.

f. Ranking 6: Simulation

Finally, the least popular game among the students was *simulation*. Only two girls (A, E) liked to play *The Sims*. Surprisingly, quantitative data revealed that the most popular game that was played by the girls was *The Sims 3*. Student A said,

Usually I play (The) Sims or maybe I like to challenge myself with the one need to like playing Escape (Student A).

Student A liked to play *simulation* games because she liked to *challenge* her mind to overcome the difficulties in the games that reflected various activities of real life.

g. What is a boring game?

Simulation and *puzzle* games were perceived to be *boring* and less appealing by some male (L and S) and female (E and H) students. These students said,

> *Because simulation and puzzle very boring (Student L).*
>
> *Simulation, I find it boring playing simulation because very slow, doesn't involve much adventure, no thrill. Because it involves things that I can do (in real life). Puzzle games is boring (Student S).*
>
> *If puzzle is just focus on that thing. Because it (shooting game) is more heart pumping than puzzle (Student E).*
>
> *I don't like simulation games because sounds boring to me (Student H).*

Three students labelled *simulation* or *puzzle* games as *boring*. The students seemed to enjoy computer games that were thrilling and not real; involved multitasking and enabled them to do things that they could not do in real life. They wanted something different from our lived-in world.

Even though there was a slight discrepancy between the quantitative and qualitative data, it should be noted that male students obviously liked to play computer games more than female students. Most of the students liked to play *role-playing* games. However, male students preferred sports and strategy games such as *FIFA, Pro Evolution Soccer* and *Clash of Clans w*hile female students preferred simulation and puzzle games such as *The Sims 3* and *Candy Crush.* It was surprising to see that some female students liked to play *racing, first-person shooter,* and *sports* games and some male students liked to play *puzzle* games. Although girls still lagged behind boys in playing computer games, the students did not seem to portray significant gender gaps in gaming behaviour and experience.

6.3.5 Gaming Attractions

Every student had a different preference of games. Students played for various purposes and were attracted to different elements in computer games.

Challenges to outrival in the games

> *The satisfaction actually. Like maybe for the challenging games like how to escape and unblock me because I can overcome the challenges. Oh! And "Buttons and Scissors". It's quite challenging (Student A).*
>
> *The challenge (Student E).*
>
> *The way they direct to the player like me. It emphasises the interest and it keeps our interest to keep continuing to play it… In some games is based on*

high score system where they are challenges to beat the high score all the time (Student P).

Capabilities of the characters in games

I like the capabilities that the character has, such as the power, the weapon. I also like the alias of the characters (Student S).

Every character in the game has the potential to win the game. But it depends on the skills of the player who plays the character [Translated from BM] (Student Y).

Constant upgrade

Like if Dead Trigger you can upgrade weapon or the uniform (Student E).

And some games like Clash of Clans, where you constantly have to upgrade things inside (Student P).

Role-play of different characters in games

I was bored one time. So, I just downloaded it. Then I just played for a while. Getting knocked by car (interesting) and we can switch characters (Student N).

DotA is simple. The map is similar. The best part is it has many characters and heroes that we can use to play. Every player has their favourite character [Translated from BM] (Student Y).

Teamwork or competition with other players

Oh ya… both favourites Hakuna Matata, Resistance Fall of Man. We play this so many times during last holiday. But Hakuna Matata is one player only. So, mostly me la playing. Planet up to four so I can play with my siblings at the same time. But my sister and youngest brother is not into game that much compared to me and other brother (Student H).

DotA not much strategies. But if we play together as a group, it is interesting because there is competition among friends [Translated from BM] (Student Y).

Appealing multimedia components such as graphics and songs

The graphics. It can upgrade and the song is really really good (Student E).

Thrills and excitements

> *Really thrilling, can bring excitement. Will have adrenaline rush let say somewhere the last stage of the game. Playing game lets me want to finish it as fast as possible (Student S).*

Learning of sport rules in games

> *Because it teaches me to play sports so that I know the rules. Even though I am not very good at it. But if I play game, I will know how the sports are played. It teaches me to understand the rules (Student L).*

Relieve boredom and release stress

> *But for the pet society or building the career… just I love to live in "The Sims" life sometimes, to get away from my life (Student A).*
>
> *For puzzle and sport games mainly just to kill time when I have nothing else to do (Student N).*

From the interview data, the students seemed to look for particular elements in games - some sort of progression; achievement and reward system; challenge and competition. Most of the students (E, N, S, P, and Y) were drawn to computer games for the tractability to role-play different games' characters that had special capabilities, upgradable power, and properties. Most of the students were fascinated to role-play and being someone with super power to overcome challenges that they could not accomplish in real life. For instance, playing a role of the opposite gender, jumping from a high building, fighting with martial arts, battling in a war, shooting and killing the enemies, and being murdered and alive again. Students were looking for challenge, excitement, thrills, *heart pumping* and *adrenaline rush* in the fantasy worlds. This result could justify why the role-play games were the most popular computer games among the students in the qualitative data.

Role-playing was the most popular game genre in the qualitative data (i.e. interview), but it was ranked number seven out of the nine genres in the quantitative data (i.e. survey). In fact, most of the game genres such as action-adventure, racing, shooter, simulation, strategy, fighting and sports involved some degree of role-playing in the games. Without the interview data, I would have assumed that students enjoyed racing, shooting, adventure, and action games, as shown by the quantitative data. I would not know that the students enjoyed the role-playing task in those games. The students were interested in playing, acting and imagining themselves as the game characters that required them to compete, kill or being killed, going through the journey and doing different actions in games.

However, both qualitative and quantitative data came to the same conclusion that male and female students had an equal interest in role-playing games.

The qualitative or quantitative data alone may not tell the whole story, but the combination of both types of data could provide a more comprehensive view of the finding. This finding shows that the shortcomings of one approach can be compensated by the strengths of the other approach (Creswell and Plano Clark, 2011). The quantitative data provides a general overview of students' gaming behaviour, but the qualitative data provides rich information about their thoughts and feelings.

A player has three essential identities that operate together in role-playing games (Gee, 2007).

> *A virtual identity, a real-world identity, and a projective identity - this tripartite play of identities in the relationship "player as virtual character" is quite powerful* (Gee, 2007, p.53).

A *virtual identity* is one's identity as the virtual character in games (Gee, 2007). For instance, a player may change various characters in the games (e.g. being a hero or being knocked by a car). The virtual character normally has certain capabilities and properties such as power, weapon, and alias.

A *real-world identity* is the player's non-virtual identity that should be motivated to try, to put in lots of efforts and to achieve some meaningful success in the role-playing games (Gee, 2007). For instance, a player should put in efforts to overcome the challenges in games such as escape from a room or solving a puzzle.

A *projective identity* is an identity who the character ought to be based both on their values and on what the game has taught them about (Gee, 2007). For instance, to make their game characters powerful and stronger, some players will upgrade their game characters' capabilities through possession of various assets (e.g. weapon and uniform).

The connection with a virtual character is quite powerful because the player may feel responsible to and for the character and they do not want to *let their character down* (Gee, 2007). In role-playing games, the players may have unconsciously immersed into the game characters.

Role-playing can be used in a classroom teaching. Students may be given a role to act like someone else, for instance, as a mathematics teacher. The role of a mathematics teacher is the *virtual identity* who is an expert and knowledgeable. The students should try to put in efforts to bridge their *real-world identity* (as a student) to the *virtual identity* (a mathematics teacher) by projecting the teacher they want to be (*projecting identity*). The students can act like a teacher they projected, and teach or guide their friends in mathematics.

6.3.6 Good and Bad of Computer Games

When the students were asked whether playing computer games were good or bad for them, the responses were quite positive.

Improve knowledge

> *It's good, because it helps me to learn new vocabulary. And it helps me to learn new skill and navigation skill. There is a game that I play but I don't remember the name, it helps me to learn how to survive in an island (Student E).*
>
> *If I play (sports) game, I will know how the sports are played. It teaches me to understand the rules (Student L).*
>
> *Playing games sometimes I find out new thing like I find out new hobby. Before this I don't find football interesting. After playing football (FIFA), I started to like (Student S).*

Improve thinking skill and spatial ability

> *It will teach us to be more creative. It also improves my reaction (Student L).*
>
> *I think it is good. Playing games helps me to think fast, helps my eyes coordination, such as I can learn to spot thing fast. I can know the difference by seeing those something, I know the difference (Student S).*

Leisure activity

> *Good thing is it will release my study stress (Student L).*
>
> *For me, it is good. I only play during school holiday. So, it won't affect my study… It could release stress and entertaining. Played for short period of time, about one hour, not more than three hours (Translated from BM) (Student Y).*
>
> *It is good for because it release stress and gave me thinking. But is should not affect my study (Student H).*

Beneficial if manageable

> *Good… (But bad) If we are addicted to it (Student A).*

So in a certain period of time, this game can help the brain relax. So I would say digital game is good if monitored… In a long period of time, it is not good because it shows a sign of addiction and addiction usually affects the players (Student P).

Health hazard

If I play too long I will be dizzy, so it affects my health. Wasting time (Student L).

It takes away some time. Maybe won't be good for my eyes (Student S).

The students believed that the benefits of computer games outnumbered the drawbacks. They highlighted a few advantages such as learning new vocabularies, navigation skills, and sports rule; improving eyes coordination, fast thinking, response rate, creativity and eyes capabilities; and for leisure purposes. They said the main drawback of excessive gameplay was health hazard such as eyes strain and dizziness. In general, the students perceived that computer game was beneficial, provided that there was a proper self-control and time management to avoid game addiction and adverse effect on their studies.

Playing computer games is a form of informal learning. As discussed earlier, there are three topologies of informal learning – *implicit learning*, which is unconscious and unplanned; *reactive learning*, which is conscious but unplanned; and *deliberative learning*, which is conscious and planned (Eraut, 2004, 2000). Students play computer games for fun without a deliberate intention to learn within a specified time. Thus, it is not a *deliberate learning*. Through gameplay, students are consciously aware that they have learned new vocabularies, navigation skills, sports rules and survival skills. The games show them the knowledge by walking through it and also let them practise on the new insights. So, this is a form of *reactive learning*. However, in games, students unconsciously learn to think faster, enhance physical coordination, and improve creativity and response rate. Thus, *implicit learning* is formed. Learning in computer games is very natural and motivating because it is unplanned.

6.3.7 Metacognitive Skills

Metacognitive skills such as multitasking, land navigation, teamwork, problem-solving, and concentration could be improved as a result of playing computer games (Cherenkova and Alexandrov, 2013).

a. Multitasking

Quantitative data showed 75% *agreement* on learning of multitasking skill. Six students (A, E, H, L, S and Y) had claimed of learning to multitask in computer games. They said,

> *Maybe. Usually the building up the character or the city, because there are some notifications that need us to do it now, or maybe to sort out the career. We need to do the job for the career. So we need to plan, first we must do this and then do this (Student A).*

> *Yes. In Sims, we can play a lot of sims. Then if this Sim wants this kind of thing, then we have to do it while handling other sims (Student E).*

> *Not sure. Maybe playing game while eating corn chips. Is that multitasking? The game I choose usually has one task at a time, one goal at a time. Even though I am given this long list of goals, I usually do the first thing first then (one by one) (Student H).*

> *Yes. Because in each game, there are many many missions. Mission like to do this. After I do the first mission, I will go to the second mission. It involves two and it has two objectives. If I accept the first mission and I accept the second mission, the missions will combine together (Student L).*

> *Yes. For example in hunting game, while hunting around for prey, have to check the GPS whether somewhere in the area where there are a lot of animals. While playing football, while say I drifter around, I have to check for offside line, check for nearby players. For shooting game, while shooting, players have to be aware. There will be some indicators whether the bad players already finish or they will still come for more (Student S).*

> *Yes, listening to a song while playing (Translated from BM) (Student Y).*

Two students (E and S) explained well how they had learned to multitask in the simulation, first-person shooter and sports games which they had played. These games might require players to role-play certain character and strategise how to play the games. Multitasking can be learned through the games that involve role-playing and planning of strategies (Cherenkova and Alexandrov, 2013).

Although the other four students (A, H, L and Y) tried to explain how they could learn to multitask in computer games, their explanations were not evident. Lastly, Student N and P denied learning of multitasking, and most probably the games they played did not require multitasking skills.

b. Land Navigation

Quantitative data showed 75% *agreement* on learning of land navigation skill. Seven students (except Student Y) mentioned that they had learned navigation skills in computer games. They said,

> *Yes… Since that I am exposed to game at my early age. I think I learn navigation by there (Student A).*
>
> *Yes. If it is like island games, it will reveal a map to us where we go. It will show a compass. Then if they say north, then we have to go north (Student E).*
>
> *Yes in Resistance and in Hanuka Matata too. That's another reason why I like those two games because I am not really good at walking compass myself, but in the game I feel I'm expert at it. I can understand map. For example in Hanuka Matata. Too bad I don't have Geography now in Form 4. If I do, if they happen to ask anything about Africa, then I can answer it (Student H).*
>
> *Yes, in shooting games. Where you have to find the enemy based or the direction you are heading to using game compass (Student L).*
>
> *Yes. Role-play kind. It's called Persona Four. In that game only. Because when we need to find a way out from the place, we need to see the map. So we just use the map to go out (Student N).*
>
> *Yes. I can't really think of any. Because nowadays game developers make hyper realistic games so they will actual real life inside (Student P).*
>
> *Yes. Like when driving a car in GTA, there will be a GPS to lead to the place or direction where I'm heading (Student S).*

The students explained how they could learn map, compass, direction, geography and places through computer games. This finding indicated that many computer games simulated the real world, and required land navigation skills. For instance, Student P said, "Nowadays game developers make hyper-realistic games."

c. Teamwork

Quantitative data showed 82% *agreement* on learning of teamwork skill. Five students (E, H, L, S and Y) agreed that they had learned teamwork in computer games. Four of them said,

> *Yes. I sometimes play Call of Duty. Because they have teamwork. We help our teammate not to get shot, not to get killed (Student E).*

> *Oh yes, definitely. For example Game Resistance, there are this chimaera, say half zombie but there are intelligent zombie right? So my brother will ambush them in two ways like, me from the front and my brother from the back door, then like shooting la. Since he is a first person view right, he may be didn't see a zombie behind him, so I can say "watch up behind you"… In Little Big Planet, there is a mini game where two players need to push two buttons at the same time. And the third needs to climb the stairs. After we release the buttons, the stairs will disappear. And then once this person is upstairs right, pull the level and then the fourth person needs to go down. It is very interesting. We usually yelled push now! Push now! Very high teamwork skill (Student H).*

> *Yes, for example in Dota II, it involves other players from other countries. I need to have teamwork with other players to win the game. Mostly strangers, random stranger from all around the world (Student L).*

> *Yes. Like playing sport game, shouldn't be a solo player. We need to make full use of all players in the field (Student S).*

These students explained how they helped each other to achieve the mission in games. Computer games such as *Call of Duty, Resistance, Dota* and *Little Big Planet* expect players to attempt to deduce another's identities. Games that involve role-playing promote strong teamwork skill (Cherenkova and Alexandrov, 2013) because the virtual characters cannot exist in isolation in a fictional world. The players cannot achieve the goal without teamwork.

d. Problem-solving

Quantitative data showed 90% *agreement* on learning of a problem-solving skill. Six students agreed that they had learned problem-solving skills in digital games. They said,

> *Yes, sometimes I play the CSI games, something that related to forensic and investigation… Usually we need to find the clue. Maybe we need to make a very accurate decision. Because sometimes they give us the bubble and we need to pick the right one. Example people ask why do you go here. We have*

the solution. Our solution affects our life in the game whether we succeed or not succeed (Student A).

Oh yes. For example in Little Big Planet they give us a lot of square cushion stuff, we need to reach the key at the top. We need to assemble it like maybe a stair of thing. Sometimes we don't have enough blocks, so one of us needs to help up for one of the block. One person can reach up and get the key. It could say is a high thinking skill. But it is really children friendly. That's not only the game I played. Actually I play chess also (Student H).

Yes, one of my games is Sherlock Holmes. This game wants you to find the mystery, solve the mystery also. There will be murder cases, murder Investigation. You have to find the killer before it is too late (Student L).

Yes. When we need to search for something like a quest in the game, we need to solve it. Find the solution in Final Fantasy (Student N).

Yes. I have to buy items and weapons, I have to buy the most suitable according to the situation and in the amount of money that I have. Also have to check make sure the balance; still have balance (Student S).

Yes. For instance, looking for something to get out from a place (Translated from BM) (Student Y).

These students explained how they achieved an objective (e.g. solved a mystery, reached a key, bought weapons, and looked for something) with the resources available in the games (i.e. money, clues, blocks). However, a student gave an interesting view. He said,

Most of the problem-solving in games is very exaggerated. It doesn't really apply in real life. So I have to say disagree… A lot of games. Action-adventure like some survival games, they don't apply physics or knowledge of physics. Because in some cases like the characters jump from a high building and they don't break their legs. We can specifically, it's impossible. Really cannot trust those kind of scenario (Student P).

Student P gave a rational justification, and he asserted that many games were too exaggerating and impossible in real life (i.e. the characters jumped from a high building and they did not break their legs). Since many elements in games were irrational, he perceived that skills learned in games could not be transferred to real life application to solve problems. Games might be different from the real world, but it is a perfect training of real life for being responsive, focused on technique and simple (Beck and Wade, 2006).

e. Concentration

Quantitative data showed the highest *agreement* (91%) on learning of concentration skill. When students were asked if they had learned concentration skills in computer games, most of the students (except Student A) responded *yes*. They said,

> *Yes. If we don't concentrate we will either die or lose (Student E).*
>
> *Oh yes because especially multi-player games, if one person mess up, the whole operation collapse (Student H).*
>
> *I think so. If I don't concentrate in the game, I will lose the game (Student L).*
>
> *Yes. Because when I play the game, I will concentrate. I won't bother anything else of my surroundings (Student N).*
>
> *If concentrated on the game, then I guess so (Student P).*
>
> *Yes. Like aiming for prey and aiming for enemies (Student S).*
>
> *Yes (Translated from BM) (Student Y).*

According to the students, concentration skill was important because they had to aim at their preys or enemies in games, else they could lose the game (e.g. failed the whole operation). Active gamers such as Student S, Y, E, and H had something in common; they loved to play action (i.e. fighting) and racing games.

Action and racing games could improve concentration skills (Cherenkova and Alexandrov, 2013; Boot *et al.*, 2008). Normally, active gamers outperform non-gamers on measures of basic attention (Boot *et al.*, 2008).

In this section, the students have claimed that they have learnt metacognitive skills, but the self-reporting data might not be the fact. The students might believe in something that may not be real, or students' beliefs would not make it true. Either way, the students' self-reported data is opinion. These views might be addressing their preferences as a step to achieve motivation. The students may imply that they prefer or enjoy doing multitasking, using compass or map, learning direction, collaborating, solving challenging problems, and focusing while playing computer games. If they do not enjoy doing those activities, they will not play the games.

Through the self-reported data, it may not be possible to verify whether the students have learned metacognitive skills just because they have made the claim. However, the claim has greater validity when it is supported by literature drawing in other studies. For instance, past studies have found that playing computer games can develop skills involving multitasking (Cherenkova and Alexandrov, 2013; Zelinski and

Reyes, 2009), land navigation (Cherenkova and Alexandrov, 2013), spatial abilities (De Lisi and Wolford, 2002; Zelinski and Reyes, 2009; Cherenkova and Alexandrov, 2013; Paul, 2013; Mitchell and Savill-Smith, 2004), teamwork (Dickey, 2011; Gee, 2007), problem-solving (Gee, 2007; Cherenkova and Alexandrov, 2013) and concentration (Latham *et al.*, 2013; Cherenkova and Alexandrov, 2013; Zelinski and Reyes, 2009; Boot *et al.*, 2008).

This finding is a good indication that computer games enable students to develop or improve metacognitive skills. Metacognitive skills can be developed or enhanced by playing certain types of computer games (Cherenkova and Alexandrov, 2013). For instance, metacognitive skills that are strongly related to mathematics such problem-solving and land navigation skills can be improved by playing strategy, adventure and action games (Cherenkova and Alexandrov, 2013). However, it raises another matter of concern whether these metacognitive skills (in games) are transferable to daily life or classroom. Even if the skills are transferable, they are not easily assessed like cognitive skills.

Through the interview, I did observe students' rich vocabularies, and they explained well their experience in games, but I could not observe the metacognitive skills that they had learned through games. Evidently, today's computer games have enriched players' vocabulary and exposed them to many different scenarios in virtual worlds. Computer games have provided a suitable platform to embed both the cognitive and metacognitive components that are primarily necessary to learn mathematics.

6.3.8 Summary

Table 6.20: Students' Gaming Experience

<table>
<tr><th colspan="2">General Gaming Behaviour</th></tr>
<tr><td colspan="2">• Played computer games during primary education.
• Spending an average of 1.92 hours per day playing – active gamers.
• Popular gaming devices - laptops and smartphones.
• School and place of residence - no significant difference in game playing time.
• Most popular games: role-playing - tractability to role-play different games' characters that had special capabilities, upgradable power and properties.
• Simulation and puzzle games - boring and less appealing.
• Benefits outnumber the drawbacks – cognitive, affective and metacognitive (i.e. multitasking, land navigation, concentration, teamwork and problem-solving).</td></tr>
<tr><th>Male</th><th>Female</th></tr>
<tr><td>• Spend more time in gameplay.
• Favourite computer game - FIFA.
• Favourite Facebook game - Clash of Clans.
• Like to play sports and strategy games the most. Also like to play racing, action-adventure, fighting and shooter games more than females.</td><td>• Less interest in gameplay.
• Favourite computer game - The Sims.
• Favourite Facebook game - Candy Crush.
• Like to play simulation games the most. Also like to play puzzle games more than males.</td></tr>
<tr><th>Active Gamers</th><th>Non-active Gamers</th></tr>
<tr><td>• Play shooting, action-adventure, racing, fighting and multiplayer online battle arena games.
• More competitive and required more active skills and strategies.</td><td>• Play sports, simulation and mobile apps or Facebook games.
• Less competitive and mainly for leisure purpose.</td></tr>
</table>

6.4 The Use of Computer Games to Learn Mathematics

This section discusses students' exposure and experience of using educational or mathematics computer games. Then, students' opinions on the potential use of computer games to learn mathematics are discussed.

6.4.1 General Overview

This analysis is intended to explore students' understanding and exposure to educational computer games.

Table 6.21: Characteristics of Educational Computer Games

Characteristics	% Agreement	% Unsure	% Disagreement
First generation			
Combination of education and entertainment	82.3	16.3	1.3
Training and practices	84.4	15.6	0
Straightforward content delivery	65.6	33.1	1.3
Memorise answer	52.6	38.3	9.0
Second generation			
Develop metacognitive skill	58.9	39.2	2.0
Learn from problem-solving experience	76.6	21.4	1.9
Learn from observation of the phenomena	72.0	26.6	1.3
Learn from challenges and mistakes	83.1	16.2	0.6
Third generation			
Learning in realistic context	68.8	26.6	4.5
Learning with authentic activities	61.7	33.1	5.1
Explicit of tacit knowledge from decision made	54.5	42.2	3.2
Knowledge constructed through social interaction & collaboration	63.6	31.2	5.1

The students perceived that a good educational computer game should consist of the characteristics of the three generations of educational games (see Table 6.21). However, students had the highest *agreement* on the first and second generations – combination of education and entertainment (82%); training and practices (84%); learn from mistakes (83%); learn from problem-solving (77%) and learn from observation (72%). It should be noted that about 15% to 42% of the students were not sure in their responses. This finding could imply that the students were not exposed to educational computer games in schools. They might have known about the games through their personal initiatives.

Referring to MTAS in Section 6.1.1, although students tended to *agree*, they did not show a firm *agreement* towards the use of computer games to learn mathematics (MTc). Students' acceptance towards learning mathematics with computer games was influenced by their technology confidence (TC) and interest in mathematics (AE). Students who had a keen interest in mathematics and proficient in technology were more likely to have a positive attitude towards learning mathematics with computer games.

6.4.2 Exposure

In the follow-up interview, students were asked if they had ever played educational computer games. Educational use of computer games was quite limited. Only some students had ever played educational computer games. They said,

> *Scrabble. That one also, they give us the meaning and then we find the word…*
> *Ya (useful) sometimes, they are very useful actually… Yes (entertaining), quite*

so… They are monotonous. Like maybe for scrabble it is monotonous; no excitement; no story line (Student A).

Yes, when I was in From 1 to Form 3. He (mathematics teacher) usually teach us in the in computer lab. He will log in a website called http://www.mathisfun.com, and then he will teach us and then there will be a game with Math… Yes (fun and entertaining)… Yes (helpful) in daily application skill (Student E).

There is this game this block is held up by lots of threads and I don't really remember the game, Cut the Rope or something? I don't know but we should cut and it falls, cut and fall, and we have to let it land on the moon or something… I think I learn angles and also inertial, also physics. When I learn some subjects, I remember that games. There is one game about car, you should stop it before it hits the bricks wall. That was also inertial I think… It is interesting. We calculate our time how to make tarts and pies and then lots of customers barging in with us… We should use common sense or calculate how much time, some pies take two hours to finish… Time management also.. It is puzzle but not much level, one or two levels and end (Student H).

Yes, I remember I played a few of those for English and Science during primary school… Yes, the borrowed textbook. Sometimes, they have those CD… Is game. Just simple games that teach you the basic of the subject… It's quite useful actually because kids they are more interested in playing (Student P).

There is one kind of spelling game… Last year in school… Yes (fun and useful)… Spelling game is less thrilling. It won't last… Only (entertaining) at the start (Student S).

The game, Keyboard Shark trains us to use keyboard faster. Typing keyboard skills… Entertaining but it is difficult if we are not skilful (Translated from BM) (Student Y).

It could be seen that only two students (E and H) had ever played mathematics computer games. Moreover, only two students (E and S) reported playing mathematics and spelling games in schools a few years ago. The rest of the students (A, H, P and Y) played the games at home on their initiative. Even though they described the gameplay as fun, entertaining, helpful, interesting and useful, the games could not retain their interest. The games looked interesting at first, but later they realised that the game was monotonous, not exciting, with no storyline, not thrilling and only consisted of a few levels. Apparently, students were not attracted to the existing educational computer games because the games were less complex and gave limited control to the players (e.g. predefined route).

6.4.3 Good Educational Computer Games

The students were asked further how they described good educational computer games. Most of the students strongly agreed that educational computer games should allow learning from problem-solving experience and provide real life application problems. These explained the characteristics of the second and third generations of educational computer games. The students had the least agreement that the games should provide training and practices. Drill-and-practice, regardless of effective or not, was less motivational. The students had less preference for learning based on drilling and memorisation, as in behaviourism. However, the teachers preferred this type of learning instructions [refer to Section 5.7.2]. Two students said,

> *I prefer learning mathematics while playing the games (Student S).*
>
> *It is like sugar coating study. It teaches you but then at the same time, it also let you have fun… At that time, the game was still quite easy. So it doesn't really put much entertainment but I still have fun. Only few years then I realised I was actually studying (Student P).*

Even though these two students never played any mathematics computer games, they preferred learning through exploration and problem-solving in the games. In this case, knowledge was learned implicitly as Student P said, "Only few years then I realised I was actually studying". These students seemed to prefer educational computer games that were built on experiential learning, constructivism and situated learning. Although students' quantitative and qualitative data yielded some contradictory findings, both types of data came to an agreement that students liked to learn from problem-solving in games – the focus of the second generation of educational computer games.

Children nowadays do not have much exposure and interest to play educational computer games compared to COTS games. When a computer game has been classified as educational, the children may have formed some pre-conceptions before they start playing. If they have perceived education as something serious, boring and stressful, then they may not enjoy playing the games that have been labelled as *educational* because they might link it to the previous unpleasant learning experience.

Looking at educational computer games with a different perspective, the main purpose of the games is for educational purposes and not for enjoyment as in COTS. However, students have been benchmarking the educational computer games against COTS that are interesting and engaging. Conversely, many educational computer games are monotonous and developed based on drill-and-practice, but most of the teachers will think that the games are appropriate and useful. Normally, the teachers have the buying power in schools, and the game developers will certainly design the games according to their views and needs.

If educational computer games are built on drill-and-practice, the games merely replace paper-based tutorials and exercises with something on the computer interface that is virtually making no difference to learning experience. It defeats the whole purpose of having interactive games that provide instant feedback, fun and motivating. Substituting paper-based exercises with games do not exploit the availability of technology.

6.4.4 Possible Adoption

In this section, the students were asked for the potential use of computer games to learn mathematics. Although they were not keen to play educational computer games, most of them were quite positive.

a. Positive response

According to most of the students, they were happy, enthusiastic and excited if computer games were used to learn mathematics. They said,

> *Excited… Because it is different from others. Maybe happy (Translated from BM) (Student A).*

> *Happy. Instead of just writing on the whiteboard or another PowerPoint, is something different. When come back home I can tell my parents all about it. Whenever I forgot about it or don't understand I can just open up the game and play it. I like it (Student H).*

> *I will feel very excited and surprise at the same time. Because my (math) teacher never use computer. Others (teacher) they don't use computer games, they just used slides presentation. I am excited because I want to try the game (Student L).*

> *Excited because it seems more interesting (Student N).*

> *First I feel odd. Before this the teacher is always depend on markers and whiteboard. I will be happy. I will be both happy and nervous because I want to see whether using computer games will suit my way of learning (Student S).*

> *Enthusiastic because maybe interesting because first experience (Translated from BM) (Student Y).*

The students expressed their interest in trying something new and looked interesting. They did not want merely a PowerPoint presentation as denoted by Student H and L. It was most likely that students wanted to be involved actively in learning. The use of PowerPoint was only replacing a whiteboard and students learned passively. Furthermore, the students wanted to have more control of their learning. For instance, Student H liked to have a computer game that she could play at her convenient time. The students' responses were quite positive as they showed the initiative to learn.

b. Type of games

Student P gave an interesting and rational justification of computer games appropriate for learning. He said,

> *It depends on how is the game. If it is too simple, too focus on kids, then I won't say it's very good. If the game is more maturely conveyed, then I guess it's really grabs my interest… Because I feel like it doesn't really take me seriously. If something about learning I will prefer it to be more serious… Games can really arouse our mind. So, in mathematics, our mind needs to be aroused to think better. So, I would say using games in mathematics is very good as a start to let the students learn better. Before start getting into certain exercises; mostly on higher order thinking skills, a sort of exercises. Some people they are not aroused, their engine are not started yet. So, they feel lazy to think. As an aid to let the brain to start processing (Student P).*

The student said computer game was something that grabbed students' interest and motivated students to think critically. However, the game should be designed properly to suit the target users. The student mentioned that the educational computer games should be *maturely conveyed* and *more serious*.

Secondary school students should not be treated like kids as they have mature thoughts. They could think like adults. Adults can make a distinction between real life and game, and they have to relearn to pretend in games (Corbeil, 1999). Therefore, educational computer games designed for kids may not be appropriate for matured students.

c. Uncertain

A student was a bit doubtful and uncertain with the benefits brought by computer games. She said, *I don't know. I think if teacher using computer (game), other students cannot concentrate because they don't really listen to the computer (game). But if teacher teaches us, I guess ya (Student E).*

The student was concerned about the classroom management and afraid that the use of computer games might divert the whole purpose of learning. Student E was more pessimistic as she worried that students might engage in gameplay and did not pay attention to the learning content in games. It was not surprising to see that students value the learning content rather than the implicit knowledge (e.g. metacognitive skills) because only the learning content was meaningful to them.

6.4.5 Recommended Learning Approach

During the interview, the students were asked to imagine that there were three mathematics teachers - Teacher X, Teacher Y, and Teacher Z. Teacher X teaches using blackboard, chalk, and talk. Teacher Y teaches using blackboard, chalk, and talk and then followed by the use of mathematics computer game as an exercise. Teacher Z teaches using mathematics computer game; no blackboard and no chalk and talk. Which teacher do they like best?

a. Classroom learning followed by games

Most of the students chose Teacher Y with a few justifications given as follows.

Teachers' explanations are important

Because sometimes I need the teacher to explain and I need to see figure in front. I am visual, so I need to see where it goes, how to do it. Only after that I can understand and play (Student A).

Because she explains first, and then she let us do exercises in computer games… I think is 50:50 (Student E).

40% (game). They still need to talk and explain it. There are something we need explanation from human being. They have experience in subject that they teach (Student H).

Because the students need understand the theory first before start playing the games. With that, they can understand more in the game. If not they will be confused when playing the game. 60% chalk and talk and 40% games (Student L).

Because all the other teachers they only talk. Like Teacher X, they talk and they teach but then it won't be as fun. And Teacher Z, they only give exercises (in computer games) like that. So, there is no explanation so it will confuse the students. So Teacher Y is the best (Student N).

Practice is important

It's not supposed to be just computer games. It can be practice and exercise. Because if teachers just teach like theory, and if we don't understand it completely by doing exercise, we might not be able to do it either… Yes (both teaching and exercises are important)… Yes (exercises not necessary in the form of computer games) (Student E).

Teacher as the facilitator

If no teacher and only computer games, the focus will be on other games instead of educational games (Student L).

No culture shock

Teacher B… 60% (teaching)… So that no culture shock. Maybe they are used to whiteboard. So, it would be more comfortable and acceptable if the use of computer games in mathematics comes with whiteboard (Translated from BM) (Student Y).

The students explained the importance of teachers in clarifying their confusion and helping them to understand better. The games were used as practice. This approach allowed the teacher to act as a facilitator so that students would not experience a drastic change of teaching approach. Nevertheless, they seemed to describe the first generation of educational computer games that merely focused on drill-and-practice.

This result contradicts with what they have mentioned earlier that educational computer games should allow learning through problem-solving experience or real life application problems. Even though the students have given contradictory views, one thing is certain; the presence of a mathematics teacher is significant. School teachers have taught the students since young, so it has been a tradition to have the teachers in a classroom. The students have been trained to rely on the teachers to acquire knowledge, and they are not confident to learn without teaching staffs.

b. Learning through games

The other two students also agreed on the combination of computer games and teachers, but with a different approach. The students said,

Because when we play games, we don't notice that we are actually learning. We only notice that we are learning after a few years… So first, if he shows the computer games first. After what we can use in the computer games, then we can apply inside the actual exercises. Then it would complete the learning experience… During the lesson (use of computer games) just to make sure the students are awake… If they play the game after teaching, they won't listen for the first half. They just wait until the final part (Student P).

Can I add another option? Teacher gives us video games and asks us to solve the problem. And by the end of class, the teacher tells us the answer. She teaches us the concept, how the concept is used inside the video games (unknowingly learned from the gaming experience) (Student S).

These two students preferred learning of mathematics through problem-solving in games. Instead of learning explicit content, they preferred implicit learning as Student P said, "We don't notice that we are actually learning" and Student S said, "Concept is used inside the video games." Apparently, these students preferred the second or third generation of educational computer games, which coincided with what they mentioned earlier. In fact, if the computer games were doing a good job, teachers might be redundant in the classroom. However, the students believed that the presence of teachers was still significant.

The Asian learning culture strongly influences the students – teachers play the major role in teaching and learning. Since young, the Asian students have been taught to respect and obey teachers, as the teachers are portrayed as someone knowledgeable, respectful and important. Deep inside every student, there is a unique bonding between students and their teachers that is not easily replaceable by any form of technologies.

In the classroom, Asian students are usually characterised as passive learners, the recipients of knowledge, less autonomous, more dependent on authority figures, more obedient and conforming to rules (Xiao, 2006). This generalisation is so widespread that it has become a stereotype (Xiao, 2006). In Hofstede's (1986) four-dimension model of cultural differences, Malaysia falls under the dimensions of large power distance and low individualism (i.e. collectivism). Based on this classification, a teacher merits the respect of his/her students; the education is teacher-centred, students expect the teacher to outline paths to follow, students should learn but not the teacher, and most importantly the effectiveness of learning is related to the excellence of the teacher (Hofstede, 1986). Apparently, teachers play the most significant role in the success of students' learning. This stereotype is evident as students recognise the important role of teachers in teaching and learning for fear of getting poor education results.

Students may think that learning or education cannot happen without a teacher. The students did not realise that they have *learned* multitasking, land navigation, teamwork, problem-solving, concentration skill, English, and sports knowledge in computer games without a teacher. In computer games, the students put in efforts to discover the concepts and theories without being told by the teacher. The students are exploring, finding new knowledge and *learning* the games through

their own initiative and trial and error. In this study, seven out of the eight students have mentioned that they use trial and error to learn a new game. Apparently, students do learn informally and independently without a teacher.

6.4.6 Summary

Table 6.22: The Use of Computer Games to Learn Mathematics

Challenges	Possible Adoptions
• No firm agreement towards the use of computer games to learn mathematics. • Educational computer games - monotonous, not exciting, with no storyline, not thrilling and only consisted of a few levels – lack of complexity and limited control.	• Possible adoption – conventional classroom teaching (major element) followed by educational computer games (practice). • Preferred the 2nd generation of educational computer games – learn implicitly from problem-solving, challenges and mistakes. • Educational computer games must suit the target users – mature and serious.

6.5 Suggestion for Improving Mathematics Learning

At the end of the interviews, the students were asked for their opinion on how to make a mathematics class more interesting. Students gave different responses.

6.5.1 Existing Approach was Fine

Three students (E, N, and P) mentioned that they preferred the conventional classroom learning. From their point of view, the current teaching approach was fine, and no improvement was required. In a way, this could imply that the use of computer games to learn mathematics was deemed to be unnecessary.

6.5.2 Active Learning

Four students (A, H, N and S) mentioned that they wished to be actively involved in learning through the use of a computer, the Internet, computer games, experiments and role-playing activities. A student said,

> *Maybe we could do this acting in class for example function. Like maybe students confused what is inverse function, why function inverse f(g), maybe students can walk to the other side of the room and go back, this is how inverse. It is interesting seeing Mr LXXX do it. He didn't do it, but it will be interesting la. I would be forever arched in our mind (Student H).*

Regardless of using computer games or having other learning activities, the students wanted to be involved actively and experience different learning approach. They wanted a fun and interesting learning environment. Only one student suggested the use of computer games, so this could imply that many other learning tools or activities could be useful to learn mathematics. The use of computer games was optional.

In this section, it is surprising to me that none of the students suggests to have more practice for exams. The students seem to be very enthusiastic to learn instead of focusing only on the academic performance. Although the students have given some suggestions to improve mathematics learning, they may not know what is the best for them as they are always the passive learners. The students may not think like the teachers or adults.

6.5.3 Summary

Table 6.23: Suggestions to Improve Mathematics Education

Existing Approach	Active Learning
• The conventional classroom teaching - satisfactory	• Classroom activities - the use of computers, the Internet, computer games, experiments and role-playing.

6.6 Chapter Summary

The results obtained from the students' interviews revealed that most of the students were positive towards mathematics. They described mathematics as fun and interesting because it was challenging and hard. However, their confidence and learning behaviour towards mathematics were moderate as the mathematics problems might not be personalised to their achievable levels, and the teaching approaches might not engage them actively in learning. The students preferred teachers to use some interesting examples such as real life examples and stories in teaching mathematics. Moreover, the students wanted teachers to be patient, attentive and adopt an appropriate pace in teaching.

Male and female students faced different difficulties in mathematics. Male students disliked long calculation as they found it tedious to trace mistakes made and wasting time on the wrong path. Female students, however, had asserted their weakness in spatial ability. In contrast to male students, female students preferred mathematics problems that involved calculations. Nevertheless, both male and female students highlighted their difficulties in learning HOTS. They found it hard to understand and grasp the meaningful pattern in mathematics problem-solving which required ability to think strategically.

In technological aspects, the students were characterised as digital natives. They were exposed to computers before or during primary education and they mostly used computers on daily basis. The students developed computer literacy at home rather than at school. They always used computers to surf the Internet, listen to the songs, communicate and connect to the social media. They were proficient in many aspects of computer usage such as office application, entertainment and advanced usage. Similarly, they also used smartphones for various purposes such as communication, entertainment and advanced usage, specifically to send message, surf the Internet, play games and access Facebook. The students claimed to be more proficient in ICT than their parents and teachers (except ICT and young teachers).

In term of gaming, most of the students liked to play computer games, especially during school holidays. The students reported many benefits of gameplay such as learning of cognitive, metacognitive and affective aspects. On the average, they spent 1.92 hours per day on gaming and they were more likely played games on mobile devices (i.e. laptops and smartphones). The students were classified into active and non-active gamers. Active gamers generally liked to play shooting, action-adventure, racing, fighting and multiplayer online battle arena games that appeared to be more competitive and required more active skills and strategies. On the other hand, non-active gamers liked to play sports, simulation and mobile apps or Facebook games that appeared to be less competitive and mainly for leisure purpose.

The students regardless of school and place of residence did not show significant difference in time spent to play computer games. However, male students had more interest and spent more time playing computer games, and they liked to play strategy (i.e. Clash of Clans) and sports games (i.e. FIFA) the most. Conversely, female students liked to play puzzle (i.e. Candy Crush) and simulation games (i.e. The Sims), which were claimed to be boring and less appealing by some students. Nonetheless, both genders liked to play role-playing games as they liked to imagine themselves as the virtual identities in games that had special capabilities and properties.

Although most of the students were active in playing computer games, they were hardly exposed to educational computer games. Even if they did, they described the games as monotonous, not exciting, with no storyline, not thrilling, and lacked complexities and control. The existing educational computer games might not be suitable for the students at secondary school level. Furthermore, most of the students preferred learning from problem-solving, challenges and mistakes in games instead of drill-and-practice as in edutainments. Since the students were positive towards gaming, it was conjectured that they would be positive towards the use of educational computer games in learning mathematics. Surprisingly, the students were not strongly supportive to using computer games for teaching and learning in the classroom. They would agree provided that the teachers were still playing the major role in teaching and the use of computer games was regarded as trivial for providing more practices.

In this study, the students seem to have two learning patterns. Outside of schools, students are active, independent and fast learners of latest computer technologies, new devices and communication platforms. This is now a natural way of how students learn. They like creativity, instant gratification, role-playing, teamwork, problem-solving and multitasking – all the 21st century skills. In schools, however, students are trained to be disciplined and routine learners. They are trained to follow certain rules and procedures laid down by teachers. For instance, mathematics examples are given in class, and students are learning how to match a problem given to the right type of rules or procedures shown in the examples.

Apparently, there is a disconnect between formal education and the reality of life - a fast-paced digital world. This raises a concern over whether schools are preparing students for the real world. We cannot change the world; we can only change our education. To bridge the gap between reality and education, there is a need to consider changing the pedagogical roles of teachers and equip students with the 21st century skills. The proposal of DGBL was thought to be ideal and feasible. However, the students in this study are not ready to learn with DGBL or to learn without the assistance of a teacher.

The data from students indicates a deep contradiction between embracing the new and respecting the old; between speed within a digital world but living in a culture of education that hold different values and draws on different technologies. This study does not intend to challenge the existing culture of education, but to highlight the contradiction between how students learn formally and informally. Students want an interesting learning experience, and most likely to try something new and innovative as in the fast-paced technology world. On the other hand, these young generations have to conform to the society's expectation to respect and obey the elderly, especially teachers in schools who are most likely left behind with old technology and culture of education. The contradictions may not be resolved easily, but the findings of this study enable educators to understand and appreciate students' informal way of learning and this might drive future educational change.

The data from students also indicates their strong self-confidence in computer technologies and games, but not mathematics. Apparently, they are not low self-esteem students; rather teachers are the ones who have failed to help their students to develop into persistent and confident mathematics learners. The students seem to response differently to the difficulties in computer games and mathematics. Playing games is viewed as a *challenge*, but learning mathematics is viewed as a *problem*. The differences in beliefs elicit different levels of motivations – *challenge* is empowering and motivating, but *problem* is suffering and demotivating. Beliefs come from modelling the significant people around us (Khoo and Tan, 2007). For the students, they tend to take on beliefs similar to those people who are most influential in their lives - parents, teachers and friends. Since the teachers believe that many students are weak in mathematics and not motivated to learn, the students are likely to take on those beliefs themselves. What further reinforce their beliefs is their parents [see Section 7.1.2] who are also weak in mathematics. The students may believe that there is nothing they can do as they probably inherited the parents' genes. That solidifies the students' beliefs and stops them from even trying to work out any problem. However, the students are confident and capable in technological skills. They may not have strong computer knowledge or be academically brilliant, but the *action* is the driving force that makes them learn the technological skills. In computer games for example, they change their strategy and consistently take even more action, they will eventually get the results that they want. Learning is defined by action, but this action is often hindered by negative emotional states, e.g. lack of confidence. Thus, the whole package of pedagogical change should embrace not only new teaching approaches but also new learning attitudes.

Chapter 7: Analysis of Parents' Interviews

7.0 Introduction

In this study, parents' interviews are included to explore their perceptions and acceptance to DGBL. Parents' views are thought to be important as a way to support the potential use of computer games to learn mathematics at home or during school holiday. Though my data indicates that parents' responses to DGBL may not be positive, their views and perceptions are important as they may address some novel and interesting issues from outsiders' perspective (instead of within an educational perspective). Furthermore, parents' interviews enable me to understand the local culture, students' background and norms in the local context. The location of study is unique compared to other states in Malaysia because Sarawak has its own immigration control, and different indigenous groups coming from a different history and cultural background. The indigenous people originate from long houses in rural areas with limited access to schools facilities. Certainly, they have a different perspective towards education compared those who come from the cities in Malaysia. As such, they represent a fascinating insight into the tensions felt by students seen in Chapter 6.

This chapter includes an analysis and discussion of the parents' interview data. This chapter is divided into four major sections:

1. Mathematics education.
2. Parents' technological experience.
3. Parents' gaming experience.
4. The use of computer games to learn mathematics.

Eight parents were interviewed in this study. The names of the parents were kept anonymous due to ethical consideration and pseudonyms were used.

Table 7.1: Parents' Background Profile

Parent	A	E	H	N	L	P	S	Y
Interview Language	English	BM	English	English	BM	English	BM	BM
Occupation	Secondary School Teacher	Tailor	Home-maker	Business entrepreneur (oil & gas)	Home-maker	Home-maker	Primary School Teacher	Home-maker
Age	46	45	35	45	39	53	44	49
Highest Level of Education	Master's Degree	Form 6	Form 5	Form 5	Form 6	Form 5	Bachelor's Degree	Diploma
Number of Children	4	4	4	4	5	7	3	7

This chapter explores the views held about mathematics education by the parents. To propose a gaming pedagogy for future pedagogical change in mathematics, it is crucial to understand the parents' beliefs about mathematics, computer games, technology and the use of technology in learning mathematics. Parents' attitudes, perceptions and beliefs about mathematics will strongly influence and have an impact on their children's attitudes and performance in mathematics (Pritchard, 2004; Hartog and Brosnan, 1994; Muir, 2012). For example, if the parents consider mathematics to be important, their children are more likely to work harder to please the parents (Hartog and Brosnan, 1994). As such, it would be useful to address the parents' perceptions of mathematics education because the children tend to model the attitudes and behaviour of their parents. If the school is planning to introduce computer games in mathematics learning, the parents need to be convinced of the future change so that they can support their children to learn at home. It is important to be aware of the parental views as those views might come into conflict with the teachers' views on mathematics learning. The parents' views may also reveal their expectations and concerns that could be taken into consideration for making future educational change.

7.1 Mathematics Education

During the interview, the parents were asked about their opinion on mathematics education, their children's attitudes and performance in mathematics, and the mathematics teaching in school.

7.1.1 The Importance of Mathematics

The parents indicated the importance of mathematics in three major aspects: (a) for daily life usage, (b) to further study, and (c) for work. A parent said,

> *Very important… Because mathematics is important in our everyday life, education and workplace (Translated from BM) (Parent E).*

The statement given by Parent E was a representative comment illustrating several issues discoursed by many parents.

a. Daily life

In addition to Parent E, the other four parents (A, N, P and S) also cited the importance of mathematics in their everyday lives because they had to deal with numbers and calculations in their daily routines. Parent S shared the problems faced for being weak in mathematics. She said,

> *For your information, I am weak in mathematics. Therefore, it is hard for me to learn this and learn that. Even sometimes, when I need to do some calculations, I find it hard. I'm aware of this situation, so I do not want my children to face the same difficulties. So since young, I stress to them the importance of mathematics as one of the main subjects because I know how hard it would be without a good foundation in mathematics (Translated from BM) (Parent S).*

From the parents' points of view, mathematics was necessary even for the most basic calculations in day-to-day life. They seemed to prioritise arithmetic that involved core techniques of calculation with numbers.

Mathematics is a broad field of study. Arithmetic is a branch of mathematics that is concerned with numerical computations that include addition, subtraction, congruence calculation, division, factorization, multiplication, power computation and root extraction (MathWorld, 2016). Parents' misconception of mathematics as *just* arithmetic has made them believe that mathematics is useful in their daily activities.

b. Further study

From the parents' points of view, mathematics was not only important in everyday life, but also for their children's further studies. Five parents (E, H, L, N, and Y) agreed to this, and Parent N explained further the importance of mathematics in various disciplines.

> *Like whatever work or I mean like in studies, they want to further studies, most of the courses required mathematics. Ah, you know. Even my second son was going to take law… And he's in the social science at the moment. He's also required to do, to take the exam, Mathematics exam, statistics (Parent N).*

The parents were implicitly indicating the importance of a mathematics result for their children to be admitted into a university. They did not talk about how mathematical skills could help their children in future learning.

Mathematics is perceived to be important because it is one of the entry requirements to many university degree courses. A child who fails to enter a university could be linked to failure in life. Mathematics is one of the keys to get into the university. So, children are expected to obtain a grade A in mathematics and other related subjects.

c. Work

Besides Parent E, the other three parents (A, N, P) also mentioned that mathematics was relevant for work. Parent N explained how mathematics was required in some professions.

> *As a lawyer, you still need to know the figures. Correct? Like most cases, like banking cases and all that, you will still have to know the figure. And if you're doing business, for example, you'll have to know the figures as well (Parent N).*

Mathematical knowledge was claimed to be important for work, but it was surprising to see some working parents mentioned that they were not proficient in mathematics [refer to Section 7.1.2], which seemed to be a contradiction. Many parents believed that mathematics was important but presented it as only involving the core techniques of calculation with numbers. The parents did not talk about specific mathematical skills (e.g. analytical skills, logical skills) and how these skills could have an impact on their children's learning and understanding.

This may imply that many professions do not actually require a great deal of mathematics. Most probably arithmetic alone is sufficient, but many hold on to an unjustified belief that mathematics is important for work. Many jobs require mathematics, but mathematics should not be regarded as numbers and basic computation only as discussed earlier.

One parent also presented another misconception about mathematics:

> *Mathematics is the hardest subject to teach if the kid is weak… For me, if a kid is weak in mathematics, he/she will be weak in other subjects. Mathematics is only about the brain. If the kid is weak in mathematics and failed, he or she hardly learns other topics (Translated from BM) (Parent Y).*

From this parent's point of view, mathematics was viewed as a measure of intelligence - if a child was weak in mathematics, he or she would fail in other disciplines and that mathematical skills was an inborn ability rather than acquired through learning.

This is an ill-informed, but a common misconception that mathematics is only for clever people (Sam and Ernest, 2000), that people who are good at mathematics are very intelligent people (Allexsaht-Snider and Hart, 2001), and mathematical ability is an inherited talent (Pritchard, 2004). Instead, mathematical skills are developed because no one is a born mathematician or a problem-solver (Handley, 2014). A person who is good at mathematics may not be more intelligent than others, rather they are more capable of using better strategies (Handley, 2014). Mathematics is a complex discipline that includes many different mathematical skills. Mathematics not only includes numerical computation as parents believe, but it also requires various types of cognitive and metacognitive skills.

According to most parents, mathematics was necessary due to the reality of life - to get into a university and to guarantee a well-paid job in the future. However, only three students recognised the importance of mathematics [refer to Section 6.1.2]. Nevertheless, most of the students were talking about the mathematics learning experience that was challenging and interesting. This was an interesting distinction between the parents' and students' perceptions.

In this section, mathematics is claimed to be important because it is *useful* for someone's better future. *Usefulness* is a factor that could motivate someone to learn mathematics (Marchis, 2011). The motivation force is distinguishable from interest. A person may be driven by its *value* (e.g. usefulness) although he or she is not interested in doing it (Lesgold and Welch-Ross (eds.), 2012). According to the expectancy-value framework, individuals' achievement-related behaviour (i.e. choice, persistence, and performance) can be explained by their beliefs about how well they will do in the activity (*expectancy*) and the extent to which they value the activity (*value*) (Eccles *et al.*, 1983; Wigfield and Eccles, 2000).

Value is one's beliefs about whether a task is useful, meaningful, enjoyable and worth of time spent (Lesgold and Welch-Ross (eds.), 2012). Usefulness or utility is one of the major components in task *value* that determines the importance of a job for someone's future goals and how a task fits into an individual's plans (Wigfield and Eccles, 2000; Eccles *et al.*, 1983). In this section, the parents value the importance of mathematics as an instrument that could help their children to get into the desirable universities and courses in the future – a pragmatic perspective.

> *The value of mathematics in this case is high precisely because of its long-range utility* (Eccles *et al.*, 1983).

Children, however, could not appreciate the usage of mathematics for their future goals because they have no experience of the future. They always live in the present; play and live fully, and the future is very hard for them to grasp.

> *Children live in the present and do not have an adult conception of the future - so improvements in the present can be all important to them* (Bell, 2011, p.201).

Children are not mainly motivated to learn mathematics for their future goals. They are motivated by experience in the present. For instance, students are motivated by the satisfaction to overcome challenges in mathematics that is regarded as interesting [refer to Section 6.1.2]. This is an interesting tension between the importance of mathematics (i.e. a pragmatic perspective) and the motivating learning environment desirable by the students.

The students' achievement behaviour (i.e. task persistence) is seemed to be linked to their expectancies. *Expectancy* is influenced most directly by self-concept of ability and estimate of task difficulty (Eccles *et al.*, 1983). Students are motivated to learn mathematics when they perceive themselves to be competent and able to overcome the challenges and when the difficulty of the task is achievable [refer to Section 6.1.2]. Hence, the utility frameworks are quite different between the children and adults.

Many adults perceive computer games as not useful because like schools, they do not recognise playful learning. Schools usually see playful learning as just playing (Resnick, 2004) with no educational benefits to be gained through the process. According to *value* in the expectancy-value framework, playing is not useful because it is not the entry requirement for the university. Useful learning is always perceived to be formal and can only happen in the school or organised circumstances. Some people also believe that learning should be painful, and it is a form of suffering (Prensky, 2002). Thus, computer games that are usually fun and enjoyable for the children are deemed to be not serious and going against the tradition of education. Many people are benchmarking and defining the *usefulness* of certain knowledge and skills against the schools' practice. There is an old belief that school is always right. Especially in the Asian culture, teachers are highly respectable people for their knowledge and expertise in the subject matter (Hofstede, 1986).

From the adults' points of view, children playing computer games is a waste of time (Gee, 2007) because it is not useful for their future goals. However, children's sense of time is entirely different from that of adults because neither the past nor the future interest them (Wein, 2007). Children live in the present without thinking about tomorrow. When they want to play, they mean now and they cannot wait like adults (Fox, 2014). Many adults can endure the most tedious process of classroom learning, but children expect the present to be worthy of attention so they will do something enjoyable for themselves. Children always play and for them, playing games is as essential as sleeping (Wein, 2007). Unfortunately, many adults and even the teachers tend to overlook the fact that children learn through playing.

7.1.2 Children's Mathematics Performance

This section explores the parents' perceptions of their children's mathematics performance to determine whether there is a mismatch between the parents' expectations and the potential use of gaming pedagogy in learning. The literature has documented the importance of parents' expectations in shaping students' self-concepts and general expectancies of success (Eccles *et al.*, 1983). Parents' expectations and perceptions are important as they may influence the children's perceptions of their abilities and interest in mathematics. Parents' involvement in their children's mathematics learning is also influenced by the parents' attitudes, beliefs and understandings of mathematics education (Pritchard, 2004). Parents may have a different view from the teachers about mathematics education.

a. Mathematics Attainment

When the parents were asked to describe their children's mathematics performance, most of the parents expressed their satisfaction towards their children's academic endeavour. The parents replied with various levels of knowledge of students' attainments.

Uncertain

> *I don't know. Normally C when he was in Form 3. Now I don't know his result (Translated from BM) (Parent L).*

Good Result

> *Student A so far she's quite good in her Maths. Quite good ah… They have very strong foundation for maths (Some words are translated from BM) (Parent A).*
>
> *Excellent I think. She's one of the top students; I talked to the teacher… The PT3 Student H got A (Parent H).*
>
> *Of course if you ask her, she would humbly say no… I would say above average. But she, she's not very confident with her Mathematics… Her Maths (PT3) was a B I think (Parent N)*

Significant Improvement

> *Moderate, but she told me that she received a Quantum Leap Certificate because her recent academic performance is good… At the beginning she*

only obtained 10++ marks. After that in her latest exam, she obtained 50++ marks (Translated from BM) (Parent E).

At this stage, his mathematics is ok. Once he entered Form 4 maybe he drop. However, he got B for Add Maths, Modern Maths, so there are improvement (Translated from BM) (Parent Y).

The majority of the parents are happy with and proud of their children's performance and improvement in mathematics. However, a study has revealed that sometimes parents could be biased in their perceptions that their children are more mathematically competent than they are because the parents are not competent in mathematics (Pezdek *et al.*, 2002). This could be true as some of the parents have disclosed that they are not good in mathematics.

One parent (L) seemed to avoid discussion of her son's mathematics performance by giving an uncertain response. The parent may feel embarrassed of her son's poor grades in school. In the Asian family, there is a common belief that poor academic achievement brings shame and embarrassment to the family (Huang and Gove, 2015). Regardless of the parents' responses, one thing is certain – they place the highest priority on academic achievement.

From the parents' points of view, being academically successful is more important. For the parents, the exam result of their children is the most precise measurement and the sole benchmark to assess their children's capabilities and performance in mathematics. The parents seem to prioritise academic achievement over their children's interest, intrinsic motivation or enjoyment. However, it is a norm for the Asian parents to be highly demanding over their children's academic achievement, and this is also termed as *high demandingness* (Huang and Gove, 2015). In the exam-oriented system, the parents are usually too focused on exam results and less on development of other skills. A parent mentioned that,

I mean like, the teacher know what to give and what come out in the exam. They know the requirement so, it's very important that they do their homework (Parent N).

From the parent's point of view, the main purpose of doing homework is to prepare for the exam – the sole performance measure.

In computer games, however, there are different ways to measure players' performance depending on the types of games played. Player's performance can be measured by accumulated scores, win-loss rate, virtual currencies, virtual gold, levels achieved, properties owned (e.g. pets, legendary weapon, armour, mount), percentage of completion, kill-death ratio, guild level, and the time of completion and the capabilities of the game characters. Children not only have a preference for different types of games, but they also have a preference for various performance indicators. Some children may prefer score-based games, but others may prefer kill-death ratio games. In some games, players' performance is measured in various facets. For example in the *World of Warcraft*, the player's performance is measured by the properties owned, level completion of certain dungeons (e.g. killed the boss) and the title given to the player.

In addition to that, computer games are operated based on the principle of *performance before competence* (Gee, 2007). Players can play the games and perform *before they are competent*. If a player could not achieve the desired performance, he or she could try again and again until they master a certain level of competency. There are no serious consequences of failure because players can always replay the games.

However, the situation in classroom learning is different. Failure is a kind of embarrassment as expressed by one of the parents (i.e. Parent L). The education system is exam-oriented especially in the Asian culture.

> *Asian families have high academic expectations and the attitude they demonstrate to their children is one that is achievement-driven* (Vijaindren, 2015).

Whenever students sit for an exam, the usual assumption is that they are well-prepared and competent. If they sit for the exam (perform) before being competent, they will face serious consequences of failures (e.g. being expelled from the school or being stopped from entering into a university). In the exam, there is no second chance given and the students cannot change or improve their answer to get a better result. Students may find it pointless to correct the mistakes or no point to learn from mistakes because the grades are unchangeable. Marks and grades are the sole performance indicator in the schools, but computer games represent a more holistic measure of learning in gameplay.

b. Difficulties in Additional Mathematics

Although most of the parents were happy with their children's academic performance, they did express the mathematics difficulties faced by their children.

Challenges

> *She, I would say on average. She would come with problems. But then she's taking tuition for the Add Maths… But Maths, she said it's boring because it's not exciting… Modern Maths is boring. It's not like Add Maths. Because after doing Add Maths of course Modern Maths becomes nothing (Parent N).*

He is having problem with Add Maths… Ah, yes (culture shock), that's right. Because he never experienced that. He told me that "aiya, Form Four quite tough, Form Four" (Parent P).

In Form 4, he said mathematics is ok but he is still working hard and thank God in the recent exam, he got 55 for Add Maths (Translated from BM) (Parent S).

Learning Approach

It's not only the formula, it's the application. Because Add Maths uses more applications and then they have to think… Even if they know how to solve it, they have to know the link to it. Isn't it? If they doesn't know the link to it, how does it goes about, how to join the thing? (Parent P).

He told me "Mom, he said, to learn Add math, there is a way. We must do it continuously, when continuous like this, sooner or later we will get used to the method. If we always perform the method, we will understand, comprehend and able to master it". So, I am happy too (Translated from BM) (Parent S).

Some of the parents raised their concern over the difficulties of Additional Mathematics. Firstly, a few parents (P, S) asserted that the substantial increase in difficulty from the lower forms' mathematics to the higher forms' Additional Mathematics had led to a drop in marks in exams. Secondly, one parent (S) said that Additional Mathematics required much practice. Thirdly, a parent (P) asserted that Additional Mathematics required metacognitive skills (e.g. how to solve it, how to link and how to join the thing) in addition to cognitive skills (e.g. knowing the formula and how to use it). Although Additional Mathematics was regarded to be a difficult subject, Parent N explained that the subject seemed to be exciting.

Similarly, computer games are interesting and fun because they are challenging. Computer games work on the principle of incremental and bottom-up core competencies (Gee, 2007).

> *Things they use and do repeatedly and combine in various ways turn out to be basic skills in the genre* (Gee, 2007, p.140).

In the early stages of the game, players are practising a substantial number of fundamental skills with the game artefacts and tools. By the time they get to the more advanced levels, they are ready for more advanced learning by combining all those skills they already have mastered earlier.

In classroom learning, students usually start with an easy lesson and the difficulty of the lesson increases gradually. However, the classroom learning (i.e. increase in difficulty) is in conflict with the gaming principle (i.e. bottom-up core competencies).

To put the gaming principle into practice, the students should start with a lesson that allows them to learn all the basic and fundamental mathematical and metacognitive skills. Then, these skills will lead them to practise and discover fruitful patterns and generalisations at more advanced level.

> *Learning situations are ordered in the early stages so that earlier cases lead to generalisations that are fruitful for later cases* (Gee, 2007, p.141).

Based on the interview data, mathematics in lower forms (e.g. Form 1 to Form 3) might be lacking in basic and fundamental metacognitive skills (i.e. basic or useful guides for more complicated patterns and generalisations) that are required for problem-solving in Additional Mathematics.

To apply the gaming principle into classroom practice, every example and exercise given to the students (during lower forms) should be designed carefully so that it will lead them into developing every single fundamental cognitive or metacognitive skill in problem-solving. Once the students have mastered all these skills independently at lower forms, they are ready for Additional Mathematics in Form 4 because they could combine all those skills that they already have mastered earlier for advance problem-solving. No doubt that the difficulty of mathematics lesson should be increased gradually but the lesson should be broken down into specific skills so that the learning experience is following a bottom-up approach as in games. In the bottom-up approach, mastering all the basic fundamental cognitive or metacognitive skills is essential in building up a strong foundation of mathematics problem-solving skill.

c. Helping children at home

Studies have shown that parents' participation in their children's homework can increase achievement, and the effect of the involvement will be maximised if parents and teachers work together toward a common goal (Hartog and Brosnan, 1994). However, another study has revealed that the time parents spent helping their children with mathematics homework is not related to their children's mathematics performance (Pezdek *et al.*, 2002). Regardless of the findings, it is important to know parents' involvement in their children's education. The students whose parents are actively involved in their education might excel academically because the parents would understand their children's weaknesses and needs or they could send their children for tuition. In a way, the children might study harder because they feel important and being taken care of.

From my research point of view, if the parents hardly help their children in mathematics, they might be ignorant about their children's actual attitudes and performance in mathematics. In this study, most of the parents (except Parent S and Y) did not help their children with mathematics homework. Several reasons were given: (i) being not proficient in mathematics, (ii) unfamiliar with new syllabus and (iii) different problem-solving method.

i. Not proficient in mathematics

Three parents (E, L and S) mentioned that they were not able to help their children with mathematics homework because they were not proficient in mathematics. For instance, Parent L said,

> *Ha! If you said helping, I can't do it because my mathematics is poor… If saying I help them, I don't know how to do it at all… I taught him until primary 3 because it was simple. When he was in primary four, five and later, it was harder (Translated from BM) (Parent L).*

Although these parents had at least Form 6 level of education, they claimed that they were not proficient in mathematics, especially at secondary school level. The parents were most likely not interested in mathematics. Since they had no interest in mathematics, they might not have the motivation to relearn the subject in order to teach their children.

ii. Unfamiliar with new syllabus

Three parents (A, L and N) mentioned that they could not help their children in mathematics homework because the mathematics syllabus used when they were in school was different from they syllabus used by their children now. For instance, Parent A said,

> *Sometimes if they cannot do it, they cannot solve it, they will ask me. They will bring the books here and 'How to do it?' But sometimes I really cannot help them also because the way, because I am old syllabus… Maths Modern also like that. Quite, quite difficult, different from our years… Now this what HOTS. High Order Thinking Skill (Some words are translated from BM) (Parent A).*

The parents revealed that the mathematical knowledge and skills they had learned previously were not usable for the current new syllabus. Another possibility was that the parents had forgotten the mathematical knowledge learned in the schools because they hardly used mathematics in their daily life or works. This also implied that most of the mathematical knowledge learned in the schools was not applicable and useful in daily living and works.

iii. Different problem-solving method

Parent A also mentioned that she could not help her children with mathematics homework because she had a different problem-solving approach. Parent A said,

> *Yeah that's why when my children said "alaaa mommy, how come you cannot do this one, you are teacher, you are science teacher". I said, it's not because of that, I have my own way… And then the teachers also have their own way (Some words are translated from BM) (Parent A).*

From the parent's point of view, having a different problem-solving method was seen as an obstacle to learning rather than an advantage. The parent wanted her children to follow the *teacher's method* because it was viewed as a safer way to guarantee a good grade in the exam. The role of a teacher was to guide the students to achieve an excellent result.

Although the parents gave different explanations for not helping their children with mathematics homework, one thing in common was that they placed the main teaching responsibilities on school teachers. Another implication was that mathematics problem-solving method was viewed as rigid and alternative method was not encouraged.

In the Asian culture, students are expected to follow the paths outlined by the teachers (Hofstede, 1986). This could explain why parents usually do not encourage their children to explore another problem-solving method that the parents have learned in the past. From the parents' points of view, teachers are someone knowledgeable and highly respectable. So, the students should follow the teacher's way (i.e. rigid). This observation is supported by Hofstede (1986) who has classified Malaysian education system as teacher-centred and teachers play the major role in the success of students' learning. In a way, this shows the trust and confidence that the parents have towards the teachers.

In computer games, however, the problem-solving is flexible (not rigid) because games work on trial and error. Players are given the flexibility of using multiple ways to solve a problem to progress (Gee, 2007). In the responsive gaming environment, the player is gaining the overall feeling of being the controlling party (Egenfeldt-Nielsen, 2005) and the game is responsive to the players' choices (Beck and Wade, 2006; Egenfeldt-Nielsen, 2005). Players have the freedom to be creative in controlling their playing and learning experience. The learning in games is motivating because it satisfies users' psychological needs for autonomy as they are in control of the different pathway in games.

In the classroom, students are not motivated to learn because there is a lack of autonomy. Students are expected to follow the teacher's way of problem-solving and alternative ways are not encouraged. The gaming principles could be put into practice by providing an element of *control*. Learning activities (e.g. role-playing, projects, and group activities) given in the class should allow students to have more *control* over their learning process. Students may construct their knowledge through trial and error. According to constructivism, learners construct knowledge based on their pre-knowledge through the *control* of their learning process (Vos *et al.*, 2011).

d. Tuition

Although some parents said they did not teach their children personally at home for various reasons, they sent their children for tuition. This section would be divided into two major themes: (i) attended tuition class and (ii) never attended tuition class.

i. Attended Tuition Class

The children were sent by their parents to mathematics tuition class so that they could have more practice and improve their learning performance. The parents said,

> *Only Kumon… For me la because they have a very strong foundation (Some words are translated from BM) (Parent A).*

> *I also can't teach him. He has a slight improvement. At least, he has improvement (Translated from BM) (Parent L).*

> *Because preparing for SPM… If she says she needs the help, then she'll go. If unnecessary I don't think so… If she needs. Because only extra exercises during tuition so that will help her (Parent N).*

Although the parents did not mention how they would measure their children's learning outcome, it was most probably determined by the exam marks and grades obtained by their children. Two parents mentioned that she sent her children for tuition because they enjoyed the tuition class.

> *He followed his bother…. It was helpful because the teacher was an expert in mathematics, a Chinese teacher. They liked the teacher. Because the liked the teacher, it was not pressure for them, but they felt more enjoyable (Translated from BM) (Parent S).*

During my first three children, just because they are staying with me, so I send them to tuition. They have a very good teacher that teaches them there… Add Maths and they tend to understand very easily (Student P).

Parent S and P mentioned that the quality of the tuition class teacher motivated her children to attend tuition because the learning experience was pleasant and encouraging. Looking from a different perspective, the parents might perceive that schools failed to provide a positive learning experience that allowed their children to have sufficient practice and improvement. In a way, they perceived that tuition centres could provide a better learning outcome than the schools. The parents might be overly concerned about their children's exam results and considered tuition as something essential to improve their children's performance.

ii. Never Attended Tuition Class

Half of the parents (E, H, P and Y) did not send their children for tuition. Parent H mentioned that she could not see the benefits of sending her children for tuition. Two of the parents said,

No tuition at all… I think what I heard ah last time, some of the Student H's friend ah, the parents send to tuition centre but turns out they're just playing around. They play during school time, right during classes and then they play again with other friends from other schools during tuition (Parent H).

He was never (attend tuition)… Also, he's not interested in going tuition… So they (older siblings) are trying to tell my Student P how to understand Add Maths (Parent P).

Parent H said children go for tuition mainly to play. The parent seemed to overlook peer interaction and playing as essential elements in learning. Parent P mentioned that her son was learning from his older siblings.

It would imply that children like learning among themselves and have learning companions. The parents feel that attending tuition class would allow their children to practise more and obtain a better result. However, it seemed that children enjoy the tuition's learning environment in which they could socialise with other students (most probably from other schools), play and learn together with their siblings. Children have a desire to feel connected to others (relatedness).

Relatedness is one of the innate human psychological needs that is essential for intrinsic motivation. Computer games support relatedness through cooperation (Natvig and Line, 2004), friendship (Chou and Tsai, 2007) and social reinforcement as in MMORPG (Charlton and Danforth, 2007). In games, players are bonded with

the people who share the same gaming experience (Beck and Wade, 2006). Children want to get connected and related to other people and feel the sense of belonging.

In conventional classroom teaching, students are expected to learn on their own (no learning companions) because they will be assessed individually during the exam. Classroom learning is usually perceived to be something serious and playing with friends is not encouraged (e.g. asserted by Parent H). The older generations have a perception that learning must be formal. Thus, the parents are sending their children for tuition with one intention – practise more to get a better result.

7.1.3 Children's Attitudes towards Mathematics

In this section, the parents were asked about their children's attitudes and interest in mathematics and whether they had nurtured the interest in mathematics within their children since young. The parents' responses were divided into two major themes: (a) children's attitudes towards mathematics and (b) building up children's interest since young.

a. Interest in mathematics

Most of the parents mentioned that their children liked mathematics and there were a few reasons for that.

i. Mathematics is simple

According to the parents (H, N), mathematics was simple because it only involved numbers and a lot of drill-and-practice. The parents said,

> *They like Maths very much… They just prefer Maths (compared to BM), because Maths just no sentences and all that, just numbers 1 to 9, 0 to 9 maybe… Student H once said to me (Parent H).*
>
> *The boys (her children), of course, they like maths because mathematics you don't require how to remember things. You just practice and it comes with practice… They don't need to read, right. All they have to do is just do the work… The school homework helps with mathematics practice (Parent N).*

Mathematics was perceived to be simple as it involved only numbers and practice. Furthermore it did not require reading and memorisation. The perception indicated that they did not recognise learning of mathematical problem-solving skills such as reading to understand the problem, visualising by drawing a schematic presentation and other cognitive or metacognitive skills.

ii. Mathematics requires hard work

According to Parent A and S, their children worked hard in mathematics. The parents said,

> *She likes… Because I saw Student A, I know from my observation. Though she said Add Maths very hard, very hard, she still try to do it… Ahh very motivated yeah… Very hardworking (Some words are translated from BM) (Parent A).*

> *From my observation, he is interested. It is proven because he has improvement. For instance, if he doesn't understand mathematics for example plus and minus, or any parts that he is weak in, or example problem-solving, he will work hard in that area to improve his weaknesses. So I believe that he is interested, else he would have given up (Translated from BM) (Parent S).*

The parents (A, S) perceived that their children were interested in mathematics because they worked hard to solve the mathematics problems. However, there was no indication of whether they were *performance-achievement* or *mastery-achievement* oriented.

In this section, most of the parents perceived that their children had an interest in mathematics but the parents were having a misconception that mathematics was a *simple* subject that merely required much *practice* or mechanical calculations. As such, they thought that once the children had recognised the pattern with sufficient practice or homework, they could excel in the exams.

Practice makes perfect is the underlying traditional belief of many Asian culture which is influenced by the examination culture and the syllabus.

> *Through imitation and practice again and again, people will become highly skilled* (Li, 2006, p.130).

Since the parents are most likely educated in the exam-oriented system, they believe that the best learning approach is through practice. Although practice is once thought to be the main approach to learn mathematics in the past, it is now an optional approach. There are many good learning theories to learn mathematics (e.g. constructivism, problem-based and collaborative learning). Nevertheless, many people still believe that routine practice as in behaviourism is the most efficient way to learn mathematics. Given a particular type of mathematics question (stimuli), one then uses the predefined method or formula that matches the question (response). The learners only have to memorise the appropriate response to the observed stimuli.

In computer games, the nature of practice is different. Knowledge in games is usually not explicitly conveyed. For instance, in shooting games, there is no manual given on how to be a good shooter. Players have to discover the knowledge through practice. In games, knowledge and understanding are internalised through continuous practices (Farmer Jr *et al.*, 1992; Kerka, 1997). Practice in games is a form of experiential learning. Knowledge is constructed from user-centred practice and reflection of concrete experience (Fenwick, 2001). The learning is a cyclic process in which cognitive structures are constructed through practice in the game world (Kiili, 2005a). In computer games, knowledge is constructed through the discovery and reflection of the practice.

b. Building up children's interest since young

Studies have shown that children will be more likely to develop enthusiasm in mathematics if the parents show an interest in mathematics around the home (Hartog and Brosnan, 1994). Exposing mathematical concepts at home will establish the idea that mathematics is interesting and more understandable (Hartog and Brosnan, 1994).

The parents were asked later whether they had helped their children to build up interest in mathematics since at their young age. Parents' responses were grouped into three major themes: (i) toys, (ii) books and (iii) storytelling.

i. Toys

Most of the parents (A, N, P, and S) bought toys to help their children. For instance, Parent A, P, and S said,

> *The wooden one, I didn't remember what is it… That one is the geometric shapes… Something like the clock also, I bought it to teach her, time like that (Some words are translated from BM) (Parent A).*
>
> *I see that during that time it was Lego you know. He, he likes to build things… The only thing that I will do is I will buy him the toys, let him fix up the thing. That is how I teach him yeah… To count the thing and like that through toys… Even now my children are still interested in toys… My four boys actually, they are all interested in this Gundam (Parent P).*
>
> *Yes, Lego toys. That could help. I also bought Jigsaw Puzzle (Translated from BM) (Parent S).*

The parents mentioned that they had bought many different types of toys for their children. However, they seemed to be unaware of how these toys could help their children in mathematics.

ii. Books

Three parents (A, N, S) mentioned that they had bought children books for their children. Parent S wanted her children to love reading books, and she said,

> *Since young, the toys of my children are a book… I still remember my eldest when he was 2 years plus, we stayed in Quarters that time. He went downstairs and played with his small lorry. Less than one hour, he went upstairs. He left his toy behind and went upstairs walked straight to his book corner and sat down reading, looking at pictures. Though he couldn't read, he just looked through it. He has addicted to the routine of looking at the book (Translated from BM) (Parent S).*

From the parent's point of view, children's early exposure to books would enable them to be passionate in learning. The parent might want her children to build up a habit of having fun with books instead of toys.

iii. Story-telling

Parent S also mentioned that she used to tell stories to her son since at his very young age. She said,

> *Though they were still small like this, holding them drink milk, I read with the hope that what I read will absorb into them… Every night before we go to bed because we are Christian, I will read Bible story for them (Translated from BM) (Parent S).*

Even though Parent S did not mention how story-telling could help her children in mathematics, she might assume that story-telling may indirectly help her children to develop an interest in reading as well as learning mathematics.

In this section, some parents (A, N, P and S) asserted that they did help their children to build up interest in mathematics since at their young age. This finding had indicated that most of the parents acknowledged the benefits of playful learning and story-telling for young children.

Children learn by playing, but many adults continue to play throughout their lives. For instance, Parent P has mentioned that all her adult sons are fascinated with Gundam. Every adult has an inner child in them, and every individual was once younger than one is now (Berne, 1967). According to the literature, Gundam, LEGO, Jigsaw Puzzle, and story-telling have some benefits for the children's cognitive development.

Gundam plastic model is also known as *GunPla* or *ganpura* (Condry, 2013). It is a model building produced by Bandai, the largest toy company in Japan (Condry, 2013). Blocks for building do encourage children's imagination (Resnick, 2007). According to some online resources (GundamToyShop, 2013; GundamPlanet.com, 2016; cyclopaedia.net, 2013), building the *Gundam* model kits could stimulate and promote blood circulation to the brain and enhance concentration, response rate and memorisation skills.

Playing with LEGO is a form of constructional block play (Wolfgang *et al.*, 2003). LEGO requires the players to build or produce representations of objects with a large numbers of bricks made of plastic with peg and hole connectors (Wolfgang *et al.*, 2003). Completing a LEGO model requires strong spatial abilities and imaginative skills (Wolfgang *et al.*, 2003; Brosnan, 1998; Resnick, 2007). A study has found that LEGO performance among pre-schoolers could predict their mathematics' achievement in middle and high schools level, but not during the elementary school years (Wolfgang *et al.*, 2003). This is because the cognitive structures developed through playing LEGO support learning of abstract mathematics, which usually appears in the later stage of education (e.g. middle or high schools) (Wolfgang *et al.*, 2003). Based on Wolfgang et al.'s finding, LEGO is proven to be a powerful tool to develop imaginative skills required for higher level of mathematics learning.

Jigsaw puzzle is a tiling puzzle that consists of a bulk of unevenly shaped pieces that form a picture when fitted together. Any toy with blocks for building and tiles for making geometric patterns is designed to encourage children's imagination (Resnick, 2007). A study has found that children's frequency of puzzle play could predict their spatial abilities (Levine *et al.*, 2012). Children who could not envision shapes or figures would be struggling to solve a jigsaw puzzle (Björklund, 2012). Another study has also found that jigsaw puzzle task is a reliable tool to test the visuospatial working memory of older people (Richardson and Vecchi, 2002). Based on the above discussion, jigsaw puzzles improve one's imagination.

Other than playing, story-telling is also another important element of one's childhood experience. While listening to a story, people may visualise the story through mental visualisation (Sturm, 1999). Through story-telling, children can develop their imagination skill and creativity because stories stimulate visual memory, and improve imagination and fantasy (Correa, 2002). While listening to a story, some people may merely watch the stories, but some may relate or imagine themselves as characters in the story (Sturm, 1999; Ellis and Brewster, 2014). In a way, stories could help to link the children's real world to the fantasy and imagination (Ellis and Brewster, 2014). People may like to listen to a story because they could indulge in the fantasy world.

Discussion in this section has found out that Gundam, LEGO, jigsaw Puzzle, and story-telling have something in common – develop visualisation, imagination and spatial abilities. These childhood activities help the children to be creative. Young children learn creative thinking through a spiralling cycle - imagine, create, play, share, reflect, and back to Imagine (Resnick, 2007). For instance, the children may imagine what they can do with the LEGO blocks, create a representation of car, play with the car, share their ideas and car with other children, reflect on their experience (e.g. the children may realise that the headlamps are missing) and finally the children may imagine new ideas of where to fix the headlamps. Unfortunately, today's education kills children's creativity. Schools usually train students to be routine workers or like a military school as claimed by a parent (i.e. Parent P). Learning from students' childhood experience, the school pedagogy may consider adopting Resnick's (2007) spiralling cycle into mathematics learning.

7.1.4 Mathematics Teachers

In this section, the parents were asked about the qualities of: (a) existing mathematics teachers and (b) good mathematics teachers. Seeking the parents' points of view was important because the parents might have a different view from the teacher about what constituted a teacher's responsibility.

a. Existing mathematics teachers

From parents' points of view, all their children's mathematics teachers in the schools were satisfactory in terms of their working attitudes and behaviours. Most of the parents (A, H, L, N, P and S) complimented their children's mathematics teachers for having good personalities. Two of the parents said,

> *Very loving, very caring as well… Yes Madam LXXXX (her ex-teacher). I got A1 for my Maths… Yeah, she's very good… Very nice person. Very soft-spoken (Parent H).*

> *You know, when they were in primary, they mention that the teachers were very fierce… "Ah. They are fierce and strict", they said. "That's why I don't like Maths". I said you are making yourself stupid, I said… The teachers are trying to teach you, I said. Not that they are fierce (Parent P).*

The parents claimed that the existing mathematics teachers were lovable and helped their children to improve academic performance. Besides that, the number of students who achieved grade A was also a performance indicator for a good teacher. Parent P supported the teacher for being strict to the students. She was siding the teacher, and this was one of the characteristics of a large power distance society as mentioned in Hofstede (1986). The parents showed trust and confidence towards the teachers. It was surprising to see that most of the parents valued a teacher's good personalities more than the teacher's teaching skills.

b. Good mathematics teachers

In the following section, the parents were asked about the qualities of a good mathematics teacher. The parents' perceptions were important to discover whether the potential use of gaming pedagogy might conflict with the parents' expectations of a good teacher. The parents' responses were classified into two major themes: (i) personalities and (ii) teaching skills.

i. Personalities

Three parents (E, H and S) mentioned that a good mathematics teacher should be patient, caring and being passionate in teaching.

ii. Teaching Skills

Most of the parents (A, E, H, L, N and S) mentioned that a good mathematics teacher should be equipped with good teaching skills: (a) creative, fun and interesting, (b) appropriate teaching approach, (c) interactive teaching and (d) provide more practices.

a. Creative, fun and interesting

Most of the parents (A, H, L, N and S) mentioned that a good mathematics teacher should be creative in providing a fun and interesting learning environment. The parents suggested that changing the classroom environment (e.g. going to computer labs), and using teaching aids and jokes could make the learning more interesting. Suggestions given by the parents might indicate that some mathematics teachers consistently used old-fashioned teaching methods, and the learning experience was demotivating. Students might want to learn, but the approach of instruction discouraged them from learning. The students wanted the teachers to provide interesting examples [refer to Section 6.1.4]. However, from the teachers' points of view, they had tried their best to make the learning interesting [refer to Section 5.3.5].

b. Appropriate teaching approach

Some parents (E, S and Y) mentioned that a good mathematics teacher should use an appropriate teaching approach. One of the parents said,

> *The teacher should not always stick to his/her own method. Instead the teacher should find a method that the student can comprehend and understand on how to solve the mathematics questions… Sometimes, some students could understand faster but sometimes slower (Translated from BM) (Parent E).*

From the parents' points of view, a good teacher should be attentive and able to guide individual student in learning. This might indicate that some students did complain to their parents that some mathematics teachers were teaching too fast and that they failed to catch up with their lessons. This would be further supported from the students [refer to Section 6.1.4].

However, it is difficult to achieve such a personalised learning pace in a conventional classroom teaching that normally has a large number of students in one class. For the teachers, they may not have sufficient time to pay attention to individual student due to time constraint to complete the syllabus and heavy workload in schools. In contrast to computer games, every player is the centre of attention and that the games accommodate their learning pace.

c. Interactive Teaching

A parent suggested to increase students' participation through group discussion. She said,

> *In fact, they should get the children involved… Probably what they can do is giving more work, and more of a group interaction as well… Let them figure out how to solve it, you know. Once they interact they would remember better, rather than doing it on their own (Parent N).*

The parent claimed that students would be actively involved in learning if group discussion was allowed. In fact, group discussion was one of the most commonly used methods to teach mathematics [refer to Section 5.3.2]. However, the students might not find group discussion interesting because none of them suggested group discussion in mathematics learning. The teachers and parents might think that group discussion would arouse the interest of the students to learn but the students might find it boring.

d. Provide more practice

Parent N also suggested to give more practice to the students. She said,

> *Giving more practices. Because Maths comes with practice…. And the teacher has to be more firm on the homework as well… Okay, you're born naturally good with figures, but if you don't put to practice, you cannot grab the methods as well. Maths is all about sitting there and doing it and doing it. You know, repeatedly (Parent N).*

Here, the importance of practice in mathematics was reemphasised. Teachers too, agreed that mathematics would require much practice, but none of the students mentioned that they would want to have more practice. The students might find the practice to be boring.

In this section, only a few parents mentioned that a good mathematics teacher should have good personalities – patient, caring and passionate. Majority of the parents seemed to place a strong emphasis on the teachers' teaching skills – being creative, fun and exciting; making use of the appropriate teaching approach; encouraging interaction and participation, and providing more practice. The parents seemed to give a conflicting view. In an earlier section, they gave compliments to the existing mathematics teachers for having good personalities; but in this section, they idealised a good mathematics teacher as someone with professional teaching skills. It would seem that there was a discrepancy between the reality and expectation. Looking from a different perspective, the parents might be contented with the teachers' good personalities, but urging the teachers to improve their teaching skills.

Most of the highlighted teaching qualities are meant to provide an efficient and motivating learning environment and computer games fit in well for most of the qualities – responsive, creative, fun, interesting, customised learning pace, instant feedback and many practices.

A computer game is a good teacher because it is *responsive* to players' needs. Many children like to play a computer game because it provides a great avenue for them to feel being cared for and important. In every game, the child is the centre of attention (the star); the virtual world is very responsive to the child (the boss); the child can solve many difficult problems (an expert); the child experiences all sorts of crashes, suffering and death (a tough guy); and the child is always the star's role (hero) (Beck and Wade, 2006). Children's innate psychological need for relatedness has made computer games so prominent in their lives. This feature in games satisfies the need for an attentive and passionate teacher (i.e. good personalities).

Computer games are designed with a certain level of complexities that stimulate players' curiosity. Games provide novelties or surprises and the levels and varieties in games are randomised (Malone, 1980). Players' curiosity leads to the desire to play the games and have fun (Denis and Jouvelot, 2005). Playing games are fun because interesting games are designed with a variety of surprises and unpredictable responses. This feature in games satisfies the need for a creative, fun and interesting learning environment.

The computer game is a good teacher because players are *learning* at their own pace. In computer games, players can customise their identities and choose the level of difficulties that match their competencies. Furthermore, players can choose the game they want to play and start at the level they last attempted but failed (Gee, 2007). Players cannot proceed to the next level until they have mastered certain skills and cleared a particular level. This feature in games satisfies the need for appropriate use of teaching approaches that fit the students' learning needs.

Computer games are also responsive and provide instant feedback to the players. Children love to play games because games are responsive to their wishes and even surrealistic wishes (e.g. driving a Ferrari across Europe) (Beck and Wade, 2006). Responsiveness of computer games allows players to learn from the games. The players subconsciously reflect on what they have done and observe the feedback about the success or failure of the action (action-and-reflection) (Gee, 2007). Instant feedback provided by computer games enable players to be active learners and learn-by-doing. This games' feature satisfies the need for more students' interaction and participation in classroom teaching.

In computer games, players get lots and lots of practice. Practice in games is motivating and situated in the learning context. Good computer games involve the players in the fascinating world of action-and-interaction and players can learn deeply in the context of embodied actions (Gee, 2007). The players are focusing on their aspirations or goals in the virtual world, and not focusing on the level of practising skills (Gee, 2007). The practice is engaging because the players are driven by the mission in the games and not driven by the intention to learn or practice. This feature in games satisfies the need for more exercises and practices which are expected to be given to the students in classroom teaching.

7.1.5 Summary

Table 7.2: Parents' Perceptions towards Mathematics Education vs. Computer Games

Mathematics is Important
• Useful in daily life – basic calculation or arithmetic. • For children to further study – university entry requirement. • Many jobs require mathematics.
Misconception of Mathematics
• Mathematics is viewed as a measure of intelligence • Children like mathematics because it is simple and only requires much practice (mechanical calculation).
Build Children's Interest since Young
• Toys (e.g. Gundam, LEGO, Jigsaw puzzle), books and story-telling. • Develop visualisation, imagination and spatial abilities.

Mathematics Education	Computer Games
Children's mathematics performance is satisfactory • Measured by exam result. • Failure is a kind of embarrassment. • Should be prepared for exams.	• Many ways to measure players' performance (e.g. win-loss rate, kill-death ratio and guild level). • Low consequences of failure. • Performance before competence.
Children's difficulties in learning Additional Mathematics • Substantial increase in difficulty from the lower form's mathematics. • Required much practice. • Required metacognitive skills.	• Work on the principle of incremental and bottom-up core competencies. • Players are practising a substantial number of fundamental skills. • Discover fruitful patterns and generalisations at more advanced level.
Unable to help children with homework • Mathematics problem-solving is rigid. • Students are expected to follow the teacher's way of problem-solving and alternative ways are not encouraged.	• Players are given the flexibility of using multiple ways to solve a problem. • Players have the freedom to be creative in controlling their problem-solving strategies.
Tuition in Mathematics • Pros: Good tuition teacher - more practice to get a better result - individual performance in exams • Cons: Too much social interaction - playing with peers.	• Support practice through cooperation, friendship and social reinforcement – guild's performance. • Bonding with the people who share the same gaming experience.

Good mathematics teachers	
• Good personalities - patient, caring and passionate.	• Responsive to players' needs.
• Creative, fun and interesting.	• Provide novelties and surprises - varieties are randomised.
• Appropriate teaching approach.	• Players can customise and choose the level of difficulties that matches their competencies.
• Interactive learning.	• Provide instant feedback.
• More practice.	• Focus on the goals in the games - not focusing on the level of practising skills.

7.2 Technological Experience

To explore the potential use of gaming pedagogy for mathematics learning, it is important to understand parents' technological experience. If parents have no exposure to computer technologies, it could be hard for them to understand and appreciate the potential benefits of gaming pedagogy for mathematics learning.

7.2.1 Computer Usage and Skills

Parents' computer experience is discussed in two sections - possession of different types of computer technologies and frequency of usage.

Table 7.3: Computers Possession and Usage

Parent	A	E	H	L	N	P	S	Y
Desktop	0	1	1	1	1	2	0	1
Laptop	6	2	6	2	1	3	1	2
Tablet	3	0	2	1	4	9	1	1
Smartphone	1	1	1	1	1	1	1	1
Internet	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ICT exposure	Uni	1993	Form 5	2001	Age 18	1980s	2000	2001
Comp. experience (yr)	28	22	18	14	21	35	15	14
Usage frequency	Daily (Work)	Rarely	Rarely	Rarely	Daily (work)	Daily	Rarely (Work)	Rarely
Time spent (each occasion)	6-8 hr	30 min	1-2 hr	5-10 min	3-4 hr	11 hr	2-3 hr	1 hr

Based on Table 7.3, all the parents had at least 14 years of exposure to ICT. Most of the parents, regardless of working and non-working parents, rarely used computers except Parent A, N and P. Two of them (i.e. Parent A and N) were working parents and used computers for 3 to 8 hours per day mainly for work purposes.

Table 7.4: Usage Frequency for Various Computer Activities

Parent	A	E	H	L	N	P	S	Y
Office Application								
Typing documents	1	4	3	3	1	3	2	4
Analyse data	2	4	4	4	1	4	3	4
Prepare presentation slides	2	4	4	4	3	4	3	4
Entertainment								
Playing games	4	4	2	3	4	1	4	4
Watching movie	4	4	1	3	2	1	4	3
Listening to music	4	2	2	3	3	1	2	3
Social networking	1	2	2	3	3	2	4	2
Advanced Usage								
Emails/ Communication	2	4	1	3	1	2	3	2
Using search engines	2	4	1	3	1	1	2	2
Search for medical information	2	3	2	3	2	1	3	2
Search for directions	3	4	2	3	2	4	3	4
Reading news	2	2	1	3	2	1	3	2
Online Shopping	3	4	2	3	3	3	4	3

1-always, 2-sometimes, 3-rarely, 4-never

Based on Table 7.4, Parent A always used a computer to type documents and for social networking, while Parent N always used computers to type documents, analyse data, and communicate through emails and utilise the search engines. Only Parent P always used the computer for personal usage and entertainment for 11 hours per day. Parent P always used computers to play games, watched movies, listened to music, used the search engines, read the news and searched for medical information. Parent P revealed that she used computers to fill up her free time because all her children had grown up.

Certain patterns could be observed from the data in Table 7.4 – non-working parents were more likely to use computers for entertainment purposes (i.e. Parent H and Parent P); working parents were more likely to use computers for office applications (i.e. Parent A and Parent N); parents who constantly used computers for office applications or entertainment were more likely to use computers for advanced usage (Parent H, Parent N and Parent P).

Table 7.5: Technological Expertise

Parent	A	E	H	L	N	P	S	Y
Office Applications Skills								
Typing skill	4	3	1	2	5	5	3	4
Word processing	4	2	1	2	5	5	3	1
Spreadsheet	2	1	1	2	5	5	2	1
Presentation	4	1	1	1	2	2	3	1
Entertainment Skills								
Social networking	1	2	5	5	3	1	1	3
Find/download song/video	1	1	3	3	3	5	1	1
Video sharing via YouTube	1	1	5	2	3	1	1	1
Advanced Skills								
Internet search	4	1	5	5	5	5	3	5
Download/ install software	2	1	3	1	4	1	1	2
Use of electronic gadgets	3	3	5	5	4	5	3	5
Basic computer maintenance	3	1	3	1	1	1	2	2
Basic troubleshooting	3	1	1	1	2	1	1	1

1 would represent novice and 5 would represent expert

Table 7.5 shows the parents' self-reported technological expertise. Neither parents' age nor their occupations had an influence on their technological expertise. This result could be explained by the parents' diverse demographic backgrounds (e.g. age, education level, culture, ethnic origin, occupation, family background, and others) and every parent was unique.

Most of the parents (50% or more) were proficient (i.e. 4 or 5) in typing, using the Internet search engine and electronic gadgets – these skills would seem to be today's basic technological skills. However, most of them were not capable (i.e. 1 or 2) of using word processing, spreadsheet, slide presentation, entertainment skills, download/install software, basic computer maintenance and basic troubleshooting. A follow-up interview with all the parents also revealed that they described their technology proficiency as *basic* and *moderate*.

Based on the definition given by Prensky (2001a), the parents participated in this study are referred as digital immigrants. They have adapted and learned new technologies at some later point in their lives – while studying in the secondary school/university or working. The parents seem to have an attitude of using the computer *when necessary*. Other than using computers for work, only a minority of the parents (e.g. H, P) always use computers for their leisure and personal interest. Parent H is the youngest while Parent P is the eldest parent who have participated in this study. This implies that age does not stop someone from having fun - playing games, watching movies, listening to music and participating in social networking.

Adults might use computers for entertainment purposes with two conditions - personal interest and to fill up their free time. In the absence of either interest or free time, they would fall back on their daily routine responsibilities. As a matter of fact, many mothers, especially the working mothers, are juggling two jobs - housework at home and official work in the office. Most of the parents seem to have neither time nor interest to use the latest computer technologies. Their lack of technological knowledge may suggest that they disapprove the use of computer games for learning. However, the parents seem to have strong confidence that the teachers will do what is the best for the students.

After completing the data analysis for this section, I realised that I should have asked the parents about their leisure time activities to determine whether computers were their companions at leisure time and how much they liked to use computers in comparison to other forms of entertainment. By asking that question, I would have known whether they enjoyed using computers or only viewed computers as a necessity to complete their jobs. Although I managed to obtain their computer usage and expertise in this section, I did not know what they feel about computers – like or dislike.

7.2.2 Smartphone Usage

During the interview, all parents owned a smartphone, and they were asked what they normally do with their mobile phone.

Table 7.6: Usage Frequency of Smartphone

Student	A	E	H	L	N	P	S	Y
Phone communications								
Making phone calls	1	1	1	1	1	1	1	1
Sending SMS	1	1	1	1	2	1	2	1
Using messaging application	1	1	1	1	1	1	1	1
Entertainment								
Playing games	2	3	2	1	1	4	4	2
Taking photo/video	3	2	2	1	2	2	2	1
Watching TV/video	3	4	1	1	2	4	3	1
Using Facebook	4	3	2	1	3	4	4	1
Advanced Usage								
Web browsing	2	3	1	1	1	1	4	1
Checking emails	2	1	1	3	1	1	3	1
Using map/ directions	4	3	2	1	2	4	4	2
Reading news/ sports	2	2	1	1	2	4	2	2

1-always, 2-sometimes, 3-rarely, 4-never

Almost all the parents always used their smartphone for communication purposes. Most of the parents (50% or more) also used their smartphone for web browsing and checking emails. However, only two parents (L, Y) who were also the homemakers always played with their smartphone or used it for entertainment purposes.

Similar to computers, most of the parents only used their smartphone for work and daily routines. The main reason they shifted from a normal mobile phone to a smartphone could be the need for using a messaging application, surfing the Internet and checking emails. Looking at the parents' technological usage, the primary purpose of computers and smartphones was to support serious tasks – not for playing.

They might disagree with the idea of playing with computers if no academic value is involved. For instance, if the children are downloading songs or movies, installing games or programs, creating videos or songs, writing blogs or Internet review, the parents might see those activities as a waste of time because those skills will not help them during the exams in schools.

Having this perception, some Malaysian parents are restricting their children (i.e. below 18) from using computers, smartphones, surfing the Internet and even watching television. The justification given is that these technologies have adverse effects on the children.

For instance, during my pilot interview, two parents gave the following responses.

> *For TV, only children educational programme less than one hour per day is allowed. More than that, it will destroy the child's development for sure. TV is only important for language and nothing else… For computer - totally no. I don't think they need computer.*
>
> *Games cause more distraction than concentration… I don't encourage children to watch TV or play games.*

Both parents are highly educated, and yet they have a perception that learning the use of ICT is not beneficial. Certainly, their children might be lack of media exposure and ICT knowledge as compared to other children.

For instance, during my pilot interview, one of the children was using the type of mobile phone to classify whether a teacher was young or old.

> *My maths teacher, science teacher and computer teacher are so into social media and always with their phone. They use smartphone, so they are young teacher. Okay la… My Tamil teacher is not like that. She has kids.*

She doesn't into social media and her phone also button phone. She is just like my dad. She is old.

Based on the child's justification – a teacher who uses a button phone is old; a teacher who uses a smartphone is young. Parents' beliefs in ICT have a significant impact on the children's mental and social development. Apparently, some parents do not value the importance of implicit or metacognitive skill that can be developed through ICT exposure.

7.2.3 Child's Technological Skills

From the parents' points of view, all their children were very familiar with modern technology, especially computers.

a. Expert in Various Aspects

When the parents were asked about their children's technological skills, all the parents mentioned that their children were expert in various aspects. For instance, two of the parents said,

> *Yes. She knows a lot… I think basic troubleshooting, download and install software, maintenance such as update software and check for virus, internet search, all of this la I think. All of that (Parent H).*

> *He can download, he can print… Most of the things people can do, he also can. For instance, he knows how to search, how to download, take video (Translated from BM) (Parent S).*

All the parents generally made a claim that their children *knew a lot about computer* especially when searching for information on the Internet. The parents' responses could be biased as most of them were not technologically competent. Also, they might not want to embarrass their children by revealing the latter's weaknesses to a stranger.

In a collectivist society, the in-group family will protect the interest of its members and face-consciousness (pride) is strong (Hofstede, 1986). If the parents express a negative opinion of their children, they feel it may reflect on them as a parent, and it makes them to lose the respect of others.

b. Being the Family's IT support

Six parents (A, E, H, L, N and P) also mentioned that their children would solve all the technological problems at home. For instance, Parent L said,

> *Anything related to computers, I always ask him. If I bought a printer, isn't it requires installation to CPU? So I ask him because I can't do it. Even if I don't*

> *know how to switch on a computer, I will ask him too. If download song, I will ask him too. I can't do it (Translated from BM) (Parent L).*

Many parents think that their children are technologically competent because the children have been solving most of the daily technological problems. The parents' dependence on the children could be one of the reasons why most of the parents are not proficient in computers. Children like to take responsibility to be felt important (Beck and Wade, 2006). The children may be happy and feel a sense of achievement for solving their parents' problems.

c. Good learners

Four parents (H, N, S and Y) mentioned that their children were fast learners and could learn independently. For instance, Parent S said,

> *I am surprised, how could they learn so quickly? I don't know; maybe they are IT generation kids… They learn and explore on their own… He is very excellent (Translated from BM) (Parent S).*

Children are always claimed to be good and fast at learning new technologies. This may indicate that children can learn independently outside the school without the help from teachers. In contrast, the parents are seen to be slow learners because they require the presence of a teacher or even a user manual in order to learn confidently. The parents may have grown up in a teacher-centred environment, and they expect guidance from someone to assist them in learning.

In this section, children are perceived to be good in everything related to computers especially for leisure purposes, advanced computer usage and computer maintenance. There is an interesting contradiction here. The parents are proud of the children's achievement and success in IT, but they do not relate those skills to *learning*. The IT skills are seen to be the inborn abilities or the children's talent rather than something that are learned. The students are perceived to be *doing* the digital native practices just because they are young (i.e. born after 1980). The parents are not aware that, children are *learning* to be the digital native in their everyday life.

Though IT skills are seen to be separated from *learning*, the parents do acknowledge the importance of IT skills in helping and supporting their daily lives – the pragmatist view to *survive* in today's world. The parents may not be able link various elements of learning together so the living skill is seen to be disconnected and separated from the formal learning in schools. Many people think that learning only happens at schools in isolation.

All children have the qualities to become independent and fast learners. It is just a matter of whether the given tasks can attract their interest or not. Children may not

be more knowledgeable and intelligent than their parents, but their interest have driven and motivated them to learn beyond the expectations of their parents. The children may not be as good as what the parents thought; the children may just know the basic ICT skills better than the parents. What differentiates the ICT capabilities of the parents and children is that children are willing to *learn* and *relearn*, but not the older generations. That is why many digital immigrants still prefer to stick to their old habits (e.g. reading books instead of reading on their tablet PC; printing instead of reading on a computer screen).

To learn ICT skills, very often someone needs to learn, unlearn and relearn. For example, considering the case where someone started *learning* to operate a computer using the DOS command about 20 years ago. After Windows 3.0 and Windows 3.1 were introduced, he/she had to *relearn* under a different operating system with an entirely different operating procedure. He/she would have to keep on *learning, unlearning* and *relearning* every time a new operating system is released.

In computer games, players always have to *learn* and *relearn* if they want to achieve a new and higher level of skill. In a new game, the player has to rethink and transform routine skills that have been mastered (i.e. skills that have been learned, well-practised and automatic) and then master the new skills through practise again (Gee, 2007). The process of *learn* and *relearn* through adaptation and change are the core competencies in today's fast-changing world.

> *A cycle of automatisation, adaptation, new learning, and new automatisation is a sine qua non of learning for those who want to survive as active thinkers in a fast-changing world that requires the master of every newer semiotic domains* (Gee, 2007, p.67).

Since young, digital native children are playing various forms of digital games such as game boys, video games, mobile games and computer games. Through games, children are well-trained in the cycle of automatisation, adaptation, new learning and new automatisation because most of the digital games challenge different levels of cognitive abilities at various stages of the games. The skill which is developed allows the children to become fast learners through the process of *learn and relearn*.

In contrast, when the parents were young, they played outdoor games with other kids. Their childhood games were Five Stones (i.e. *Batu Seremban* in BM), Jumping Ropes (i.e. *Lompat Getah* in BM), Hopscotch (i.e. *Ketingting* in BM), Catching or Tag or Police-and-Thief, The Eagle Catches the Chicken, Hide-and-Seek, Rock-Paper-Scissors, and marbles. These games mostly challenged one's physical abilities and

sometimes with gradually increased difficulty after each successful attempt. Every generation had different childhood experience because they played different games and trained in various ways - cognitively or physically.

7.2.4 Summary

Table 7.7: Parents' Technological Experience

Computers	Smartphone
• Proficient in typing, use of the Internet search engine and electronic gadgets. • Use the computer when necessary – pragmatist view.	• Usage - communication purposes, web browsing and checking emails. • For work and daily routine.

Working parents	Non-working parents
• Computers for office applications.	• Computers and smartphone for entertainment purpose.

Children's Proficiency in Computer Technologies
• Proud of the children's achievement and success in IT. • IT skills - inborn abilities and not learned.

7.3 Gaming Experience

To explore the potential use of gaming pedagogy for mathematics learning, it is important to understand the parents' gaming experience. If the parents are not playing any form of computer games, they are most likely to have negative perceptions towards game-based learning. For instance, a study has revealed that parents express negative perceptions towards computer games, and they are reluctant to support digital game-based learning because only a minority of them have gaming experience (Bourgonjon *et al.*, 2011).

7.3.1 Gaming Pattern

Parents' gaming experience was explored by examining their playing frequency and types of games played. Two working parents (E, S) were excluded from Table 7.8 because they had never played computer games. Surprisingly, four (H, L, N, P) of the parents were considered active gamers according to the cut-off point of 7 hours per week in the literature (Simons *et al.*, 2014). Overall, it could be seen that parents' favourite type of games was puzzle games and the most popular game played was the *Candy Crush Soda Saga* families. There were two groups of parents: (a) playing puzzle games, (b) playing other types of games except puzzle games.

Table 7.8: Gaming Pattern

Parent	A	H	L	N	P	Y
Playing frequency	Rarely	Daily	Daily	Daily	Daily	Every 2-3 days
Time spent per day	5-10 min	1-2 hr	1 hr	1.5 hr	2 hr	20 min
Gaming devices	• Smartphone	• Computer • Tablet PC • Smartphone	• Smartphone	• Smartphone	• Computer • Smartphone • Video game console	• Smartphone
Favourite games	• Candy Crush • Burger Shop • Unblock Me • Farm Heroes	• Farmville • Baking Life	• Candy Crush Saga • Farm Hero Saga	• Soda Crush • Scramble • Candy Crush	• The Sims • Bowling • Farm Heroes Saga	• Candy Crush • Maze • Bowling • Ant
Favourite types of games	• Puzzle	• Puzzle • Role-Play	• Puzzle	• Puzzle	• Simulation • Sport	• Puzzle
Expertise (1 novice, 5 expert)	3	5	5	5	3	2

a. Playing puzzle games

Four parents (A, L, N and Y) mentioned that they played puzzle games when they were feeling bored. For instance, Parent A and L said,

> *All kids' games… Nolah, not interesting actually for me. For me just to release my boring… Just to get rid of sleepiness (Some words are translated from BM) (Parent A).*

> *Kids games. Those games only need a little time. Wasting time… When I'm waiting for my children, back from tuition… It is not too difficult… Easy and portable. I don't have much time. This short duration (Translated from BM) (Parent L).*

The parents played simple games such as *Candy Crush, Unblock Me, Ant, Scramble* and other puzzle games for a short time (i.e. 5 minutes to 1.5 hours) for various reasons: feel bored; release anxiety; avoid sleepiness; to relax; filling up free time; brain boosting and to challenge themselves. Puzzle games were chosen for their simplicity, short game duration and being conveniently accessible.

The parents do not seem to have an affinity to play games because the puzzle games they have been playing do not require many efforts to learn in comparison to other types of games. For instance, the most popular puzzle game played by the parents, Candy Crush, has simple rules and mechanical, and no storyline. They seem to have no intention to play unless they need some entertainment while resting, waiting or relaxing. The games do not appear to be important to them, and they can live without the games. Adults usually have real life responsibilities and *playing* is defined as outside of ordinary life (Prensky, 2001c). So, as a mother, playing too much may seem to be an improper thing to do.

b. Playing other games

Parent H and P were the exceptional cases. They played other types of computer games other than puzzle games. These two parents said,

> *Maybe watching it growing or expanding, like Baking Life we can expand the restaurant, cooking some. Can cook, but no time limit, like any youngsters game. There's in 15 minutes you have to do this, this. Not stress, very relax la, every mothers know especially the Farmville (Parent H).*
>
> *Just to keep me alive, I can say that. Cause, I have nobody to talk to, things like that, lonely and all that thing. For my husband come back only at night and thing like that. So, just to make myself occupied with all these things (Parent P).*

These two parents spent approximately 2 hours per day playing role-play, simulation and sports games. Parent H was a young mother (i.e. 35 years old), and it might not be surprising that she enjoyed playing computer games. She seemed to enjoy playing games as much as her children. However, it was surprising that Parent P, at the age of 53, played simulation and sports games for 2 hours per day. When she said, "just to keep me alive," it showed that computer games had a strong motivation component of *relatedness.* Through games, the parent had found the value of her life and felt connected to someone even though it was done virtually.

During my data analysis, I realised that I should have asked two of the parents (E and S) why they did not play computer games. I made the mistake by focusing only on the parents who played games. I should have asked the perceptions of the two parents who did not play games – might be negative perception, no interest or busy.

Most of the parents like puzzle games that could be related to their childhood experience of playing board games. Some puzzle games resemble traditional board games and require similar problem-solving skills. Puzzle games usually require logical-mathematical thinking (Becker, 2005), critical thinking, pattern recognition and fast reaction (Anagnostou and Pappa, 2011). In puzzle games as well as traditional board games, people consciously know that they are learning to play the games. When playing games, adults make a distinction between real life and game – some games do not conform to the actual life situation (Corbeil, 1999). This is *reactive learning* as they are aware of it even though it is unplanned (Eraut, 2000, 2004). The conscious mind during gameplay could be one of the reasons why puzzle games are not as addictive as those MMORPG games.

Puzzle games are claimed to be the most monotonous games (Gee, 2008b). This could explain why most of the parents do not find playing computer games as interesting.

As expected, the digital immigrants' frequency and interest to play computer games are minimal. However, age does not stop the digital immigrant from playing. A young digital immigrant (e.g. Parent H) may play computer games due to interest and childhood experience of playing earlier generation of video games. An elder digital immigrant (e.g. Parent P) may play computer games because she has plenty of free time and she wants to find a meaningful purpose in life. However, most of the digital immigrants do not have the intention to play digital games but merely to pass time and to have some fun for a short period.

7.3.2 Good and Bad of Computer Games

When the parents were asked whether playing computer games was something right or wrong for their children, the responses differed. The parents' responses were divided into three broad themes – (a) boys love to play computer games, (b) children's education should be prioritised and (c) subject to types of games.

a. Boys love to play computer games

Three parents (E, H, N) mentioned that their children especially boys were addicted to computer games. For instance, Parent N said,

> *Like my youngest one into racing game. He can stay up because now he can play online with friends. So he can stay up until 1 in the morning and wake up late the next day. So, we stop him during the school days because we know it will drag on… I mean if your child don't have it, then they don't have any topic with their friends. Because this is what people talk about now, right? They will be out of place… Of course we parents say stop it. They still continue. And I can see that especially my second one, he can move about in his sleep. I know he cannot sleep. When he complains to me "I cannot sleep" I say "yeah, yeah, the game is in your head." He says "yeah, it's in my head." (Parent N).*

The parents were complaining that their children were addicted to computer games and the children sacrificed their sleeping time. However, they did not want their children to be left behind by the latest technology such as gaming. The parents seemed to have conflicting views among them. Although gaming was addictive, there were benefits on the other side (e.g. connected to friends and gaming skills). Despite this, most of the parents tended to inflate the disadvantages of gaming and minimise its utilisation.

b. Education should be prioritised

Three parents (A, E, Y) mentioned that children's education should be prioritised. For instance, Parent A and Parent E said,

> *Not good if the game is not related to education (Translated from BM) (Parent E).*

> *Sometimes if always do the homework, always study like that, no any social life, is not good also for me. So sometime, then they rest, OK. Can open tab and then play something. And then after that, you close it and then you continue to study. For me, just to rest the mind… However, during the exam week, all the tabs and laptops will be closed (Some words translated from BM) (Parent A).*

From Parent E's point of view, any activity that was not related to education was considered as not beneficial and not useful. Apparently, the parent might think that playing COTS games was a waste of time. Parent A, however, would allow her children to play computer games if they had completed their homework.

Parents normally set rules and regulations which they want their children to follow, but the children normally will ignore and play whenever they want to, without much thought about their study. There are two different attitudes in life - children live in the present, but parents worry about their children's future.

c. Subject to types of games

Three parents (A, L, S) mentioned that the value of a game depended on its genre. For instance, Parent A and L said,

> *If puzzle games okay. However, if digital games using the console, X-Box for example, sometimes they install violent (games). Those things I told them not to follow – shooting, using the knife… because children are easily influenced… I always worry of the offensive games on the Internet. Dangerous too (Translated from BM) (Parent L).*

> *Depends on the types of games they played. Sometimes, they play shooting and for me, they learn to focus. Though I never played, I looked at them playing. Moreover, computer games help them to think. Other than hand movement, their eyes are looking; they have to think fast… For me, it helps a lot. Most likely hand and mind coordination (Translated from BM) (Parent S).*

Parent S and L had conflicting views on shooting or violent games. Parent S appeared to acknowledge the benefits of learning various gaming skills, but Parent L was concerned of the negative effects brought by violent games. Among all the parents interviewed, only Parent S saw the positive sides of gaming.

In fact, children may teach parents how to become good parents. If the children are responsible and diligent in their study, the parents could willingly let their children play games knowing that their children are matured enough to manage their time. For instance, Parent H and P have mentioned that they allowed their children to play computer games without any restriction. Through the interview, I could feel the trust and confidence that the parents have towards their children. Both Student H and P have been the schools' prefects and they are excellent in their study.

The idea of using gaming to learn is controversial. There is a fine line between the benefits of gaming and game addiction. Banning gaming entirely may be beneficial for children academic performance, but the children may be socially isolated from their friends and they may face the risk of being left behind in technology. Furthermore, preventing children from playing may take away their happy childhood experience, and possibly distort their cognitive development learned from playing. However, opening the door to gaming will also allow exposure to harmful influences including violence, taking away their sleeping time, and risking their health. As parents, they have to be wise and prudent in finding a check and balance between freedom and control in monitoring their children's gaming exposure.

In this section, the parents did not verbally agree or disagree with the pros and cons of playing computer games. However, most of them were quite doubtful and uncertain of the educational benefits of gaming. Most of the parents indirectly expressed their disapproval towards computer games as they said that study must be prioritised; computer games were addictive especially for boys; and some computer games had bad influences.

Most of the parents hardly play various types of games, so their perceptions towards gaming may not be objective as their personal disinterest in games may affect their judgement. The parents' concern is understandable because the good and bad influences of games are very much depended on the types of games.

> *Video games are known to impact not only cognitive function, but many other aspects of behaviour - including social functions - and this impact can be either positive or negative depending on the content of the games* (Green and Seitz, 2015).

Parents' negative perceptions towards computer games may discourage the use of computer games in mathematics learning.

Many people mistakenly consider addiction as simply a disease of *craving* (Sack, 2014). In fact, addiction is a *disease of learning and memory* (Sack, 2014; Love, 2015; BrainU, n.d.; Hyman, 2005), and the dysfunction in the brains' *reward* centre (Love, 2015, 2014).

> *Addiction is a primary, chronic disease of brain reward, motivation, memory and related circuitry* (Love, 2014, p.3).

So addiction is also claimed as a *disease of learning gone wrong* (Lüscher, 2009). An addict's brain learns that doing a certain behaviour (e.g. playing computer games) can lead to *rewarding responses* (e.g. a feeling of satisfaction and sense of achievement) (Love, 2015). *Reward* motivates the repeating behaviour (Love, 2015; Hyman, 2005), and once one is addicted, it is difficult to unlearn the behaviour (BrainU, n.d.). To a certain extent, addictive computer games are great teachers because they teach the players to develop a *disease of learning.*

By learning from computer games, a classroom teaching should be more rewarding (e.g. internal motivation such as satisfaction) rather than just pleasure (e.g. happy and fun). For instance, students might be motivated to learn mathematics because they have a sense of achievement or satisfaction (i.e. rewards) after solving a series of challenging and tough questions.

7.3.3 Metacognitive Skills in Digital Games

In this section, the parents were asked for their opinions on whether someone could learn metacognitive skills through computer games. Even though most of the parents were not positive towards computer games, they had acknowledged the benefits of learning metacognitive skills such as multitasking (Parent H and S), land navigation (Parent S), teamwork (Parent H, N, S and Y), problem-solving (Parent A, H, N, S and Y) and concentration (Parent A, H, N, S and Y).

It was surprising to note the difference in opinions between Parent P and Parent S. Parent P played various types of computer games, but she was not aware of the metacognitive skills learned through computer games. In contrast, Parent S, who had never played computer games, mentioned that her children could learn all the metacognitive skills through computer games. Although Parent S said she did not play games, she recognised the educational values of computer games.

This could imply that parents, whether they play or not play computer games, may appreciate the benefits of gaming pedagogy in mathematics learning. The most important thing is that the parents should be briefed on the purpose of a pedagogy change.

Parent N has highlighted an interesting point that is worth mentioning - most of the current computer games require much thinking skills as opposed to the old generation of computer games that merely focus on simple action skills (i.e. speed and proficiency in pressing the buttons). This might indicate that current computer games require more cognitive and metacognitive skills than physical skills.

> *It (current digital games) does boost their brains, because they have to think. Like shooting game, they have to think which way to go next, you know, and all that. But it's a different skill from what we played last time. Yeah. I don't know how old you are but if you see my age like what do we play when that time like, not much of a thinking skill but more of the hand skill, the leg skill, but not really the brain (laughs) (Parent N).*

During the early development of video games, players developed the capacity to press a few buttons, control a joystick or trackball while playing the arcade games (e.g. Ping Pong and Pac-Man) or the console video game (e.g. Super Mario Brothers). The main focus of these games was on one's speed and capability of pressing game controllers; not much mental abilities were involved.

Nowadays, computer games are becoming more advanced and sophisticated. The games require not only physical skills but also mental abilities – multitasking skill, land navigation skill, teamwork, problem-solving competency and concentration skill. The evolution of video games has changed the physical and mental abilities needed to play the games.

> *Modern video games have evolved into sophisticated experiences that instantiate many principles known by psychologists, neuroscientists, and educators to be fundamental to altering behaviour, producing learning, and promoting brain plasticity* (Green and Seitz, 2015).

Modern computer games require strong analytical abilities, flexibility and adaptability to play the games.

Computer games teach us to adapt to today's fast-changing and sophisticated world. The world is changing faster than ever and the skills learned get obsolete faster and faster. In games, players have to constantly *learn* and *relearn* to adapt to the ever-changing virtual environment. Children can learn technologies faster than their parents because they constantly get to change their strategies when playing computer games. Children enjoy making sense out of constant change. However, the people who resisted constant change could not keep up with the latest

technologies. This could explain why many digital immigrants were not proficient in technologies.

7.3.4 Summary

Table 7.9: Parents' Gaming Experience

Majority Playing Puzzle Games	Minority Playing other Games
• Most popular games played – Candy Crush Soda Saga families. • Reasons for playing – bored, release anxiety, avoid sleepiness, relax, waste time and brain booster.	• Playing games such as Baking Life, Bowling and Farm Heroes Saga. • Reasons for playing - interest and feel connected to someone.

Benefits	Drawbacks
• Learn to focus and think. • Hand and eye coordination. • Children's common topic of discussion. • Learning of metacognitive skills. • Modern computer games require complex skills.	• Game addiction especially in boys. • Education would be neglected. • Violence and offensive content. • Doubtful and uncertain of the educational benefits of gaming.

7.4 The use of computer games to learn mathematics

In this section, it is important to explore parents' perceptions towards educational computer games. Past literature has indicated that the possible negative perceptions of parents are often reported as an obstacle toward the adoption of computer games in classroom settings (Bourgonjon *et al.*, 2011). So, it might be possible that the parents who have exposure to educational computer games would be more supportive and positive towards the use of computer games for mathematics learning.

7.4.1 Good Educational Computer Games

All the parents agreed (i.e. strongly agreed or agreed) that educational computer games should provide training, real life application problems, and problem-solving experience. The parents agreed that educational computer games should resemble the three generations of educational computer games discussed in Egenfeldt-Nielsen (2007) with a stronger emphasis on training and practices. The parents had a similar opinion as the teachers [refer to Section 5.7.2]. However, the students had the least agreement to have training and practices [refer to Section 6.4.3]. For the teachers and parents, the most important element of learning was always training and practices, but for the students, training and practices were less desirable.

7.4.2 Exposure to Educational Computer Games

Only three of the parents (A, L, N) had exposure to educational computer games. They said,

> *My youngest one now, she's using a lot of it I think. She download… Ah alphabet, mathematics. Whatever, colours. Because she's in kindergarten right? Ah so everything, science, shapes… Yeah (interesting)… Yeah. Ah they are using all cartoons (Some of the words are translated from BM) (Parent A).*

> *My children always play Maths Workout Game. This is learning maths such as addition, subtraction, multiplication… Yes la (interesting)… However, they hardly play. I am the one always ask them to play… The questions always look the same, and quite limited (Translated from BM) (Parent L).*

> *Yeah (Scramble), they don't play. Only me. They don't want. Sometimes yeah, my youngest… My youngest would help me (Parent N).*

These parents have highlighted a few issues. Firstly, educational computer games are only designed and suitable for young children (i.e. their youngest children). Secondly, the learning content in educational computer games is explicit and lacks of complexity (i.e. questions looked similar). Thirdly, young children may be attracted to educational computer games, but their interest cannot be sustained because the games are mainly built on drill-and-practice.

Parent N has mentioned that, "They don't play. Only me" and Parent L has mentioned that, "They hardly play." Apparently, edutainments are seen to have little educational and entertainment values. Edutainment is neither entertaining nor educating because children get bored after some time. That is why edutainment is claimed to be the worst type of education (Van Eck, 2006; Charsky, 2010).

7.4.3 Children love to watch kids TV programme

During the interview, I did not ask anything related to social media, but two parents shared their positive opinions on educational TV cartoons. They said,

> *My daughter, she can communicate in English just by watching cartoons… Not yet send her to kindergarten at that time… Like that Mickey Mouse not only cartoon because they also teach us shapes… Shapes and then counting also… Sometimes when she talks to me, she uses some vocabulary that I myself hardly use… That's why I say, "Where did you hear from? How do you know?" She said, "TV"… Sesame street yes. And then High 5 also… She's*

watching it repeatedly (Some of the words are translated from BM) (Parent A).

Last time we had a Science programme on TV, but not Malaysian programme. It is from Australia, and they like it. They like it during primary school, but now no more (Translated from BM) (Parent E).

These parents were indicating that educational cartoons on TV seemed to be more entertaining and educating than educational computer games. It piqued my curiosity when Parent A said that her daughter watched the same cartoons repeatedly, but she enjoyed it and learned her English. There was a certain attraction in modern TV cartoons that could take hold of children's attention despite being surrounded by various forms of digital technologies. It could be the storyline, humour, joy and happiness that were brought along by the cartoons.

Watching cartoons may inspire the children's imagination and creativity. Every time they watch the same cartoon repeatedly, they might discover and learn something new that they did not notice before. Furthermore, children learn by imitation so the repetition reinforces their memorisation and learning. The parents' positive perceptions towards TV cartoons could be related to their childhood experience too. The parents have grown up watching cartoons or TV, so their pleasant experience has shaped their constructive views towards a TV.

In this section, the parents mentioned that their children did play educational computer games, but the games could not retain their interest. Instead, the children seemed to prefer watching educational TV cartoons.

Educational computer games are interactive and yet the passive educational TV programmes are claimed to be more attractive and exciting to the young children. Watching TV is claimed to be a less healthy activity than gaming. TV commercials precisely target TV watchers with unhealthy foods (e.g. fast food, candy, and junk food) and they are more likely to have free hands available to eat those foods (Byrne, 2014). A study has revealed that spending time playing video games rather than watching television improves cognitive skills, self-esteem, and physical activities in the children (Moore, 2013). Video games such as Nintendo Wii, Sony PlayStation Move, and the XBOX Kinect motivate children to exercise and involve in outdoor activities (Moore, 2013). However, viewing television and playing video games are found to increase the subsequent attention problems in childhood (Swing *et al.*, 2010).

From the educational point of view, television viewing is a passive activity while gameplay is an interactive activity that embraces active learning.

Video games, by their very nature, involve predominantly active forms of learning (i.e. making responses and receiving immediate informative feedback), which is typically more effective than passive learning (Green and Seitz, 2015, p.102).

Looking from the educational perspective, children should prefer playing video games to watching TV because children are actively involved in video games. However, the fact is, children prefer watching TV to playing educational computer games. That is the biggest failure of educational computer games nowadays.

7.4.4 Mathematics Learning using Computer Games

It is important for the parents to support the potential use of gaming pedagogy in mathematics learning. Teachers, students and policy makers appear to be influenced by what parents think about the use of computer games in teaching (Bourgonjon *et al.*, 2011).

The parents were asked for the opinion on the potential use of computer games in mathematics learning. Most of the parents expressed their *acceptance* with some concerns.

a. Support the use of computer games

Five parents (E, H, L, N and P) mentioned that they supported the use of computer games in mathematics learning. Two of the parents said,

Yes. If it will take the interest of the children… Because that's what they're interested in… Probably like the, the old kind way of teaching Maths don't interest them anymore and if you have a computer game, that really suits the purpose of learning, I mean the learning methods, yes, why not? Of course if you create a game that will give them interest to Maths, that would be very, very good. (Parent N).

If for study, for their knowledge, it should. But if it's just for the game, for the interest of these kids, I disagree… They learn something out of it… Ah, that's right (not for fun) (Parent P).

The parents were very positive as they mentioned that computer games were something that might motivate children to learn mathematics. The parents seemed to agree that mathematics learning should be made more interesting and fun. When the parents stressed on the *educational benefits* of computer games and not just for *fun*, they might be referring to educational computer games. Thus, the parents might not see or value the educational benefits of COTS games.

b. Combination of old and new methods

All the parents preferred a combination of conventional classroom teaching and the use of computer games. One of the parents said,

> *I think should be both… But if you're talk concentrating on one, that is using board, you shouldn't neglect board. So, to wake them up, you have to let them play the game (laughs) (Parent P).*

A combination of conventional classroom teaching and computer games was thought to be the best teaching approach to game-based learning. Teachers played the role of teaching and supported by the use of computer games. This result was consistent with the teachers' and students' perceptions [refer to Section 6.4.5 and 5.7.4]. It was a positive indication that three parties came into agreement with the use of computer games as a supporting element to the current conventional classroom teaching.

c. Teachers facilitate learning with computer games

Six parents (A, E, H, N, S and Y) asserted the importance of teachers to facilitate learning with computer games. Two of the parents said,

> *There would have to be a teacher with the games… Because children get frustrated very easily. So you leave them with a game, especially a Maths game. Game can be a game. But if a Maths game, you have to make it really interesting. If they will stay on. I mean, not everyone have that patient. Not every children have the interest; some children might just love to see a car crash, a football, not the numbers. So if you don't have a teacher that to push them, or to guide them, then it will be a no-no case (Parent N).*

> *Still need teachers, still need someone to guide them. Ah, I don't trust computer alone. The robot alone (Parent H).*

The presence of a teacher is crucial to facilitate, control, guide and motivate the students to learn using the computer games. Though the presence of teachers is claimed to *facilitate* learning, their presence seems to ensure that students *learn* mathematics instead of just *playing*. In a way, the role of a teacher is to monitor and *force* the students to learn mathematics through computer games. The students are perceived to have no intention to learn without the presence of a teacher.

Looking from the gaming perspective, mathematics computer game is seen to be neither entertaining nor educating. It is not entertaining because children need a teacher to push them to play (i.e. denoted by Parent N); not educating because computer game is just a robot – not a teacher (i.e. referred to by Parent L).

In fact, the parents have no confidence in the sole use of computer games in mathematics learning. If given a choice between learning from teachers and learning from computer games, all the parents are most likely to choose the conventional classroom teaching because they firmly believe that a teacher can provide meaningful and efficient learning.

Teaching is a unique profession that creates the other professions. Teaching is not a simple task that could be learned through reading. Similar to gaming, teaching skill is accumulated through practice situated within the actual classroom environment. The *situated learning* shapes the experience of instruction that is not easily replaceable by a computer-based learning such as educational computer games. The potential use of computer games to learn mathematics could not replace the roles of teachers.

> *Those who proclaim that computers will replace teachers often naively reduce teaching to mere instruction and assessment… Technology will not improve our education system if we marginalise or eliminate teachers… Innovation may lead us to classroom setups and teacher roles that look very different from today, but a human element will always be an essential part of the equation (Arnett, 2013).*

Nevertheless, children are capable of playing, learning and mastering COTS games without the presence of a teacher. A well-designed COTS game is a good teacher. This contradicts the above argument that the teacher is not replaceable.

7.4.5 Summary

Table 7.10: Potential Use of Computer Games to Learn Mathematics

Challenges	Possible Adoptions
• Not much exposure to educational computer games. • The learning contents are explicit and lack complexity (i.e. similar questions). • Only suitable for young children. • Children's interest is not sustainable. • Neither entertaining nor educating. • Children prefer watching TV.	• Good educational computer games – emphasis on training and practices. • Combination of classroom learning and computer games. • Learning with computer games must be facilitated by teachers. • The presence of teachers is to ensure students learn instead of just playing.

7.5 Chapter Summary

In this study, the parents explained mathematics learning and the use of technologies in education from a pragmatic perspective. Mathematics was perceived to be useful, and the extent to which they valued the importance of mathematics for their children's future endeavour (e.g. future study, job and life) had driven them to recognise the usefulness of mathematics. To build up their children's interest in mathematics, the parents had bought story books and toys such as Gundam, LEGO and Jigsaw puzzle for their children since at their young age. The toys and story books could help the children to develop spatial ability.

Furthermore, some parents did help with their children with mathematics homework when the children were studying in primary schools. During the interview, however, all parents revealed that they did not do so anymore. The main reason given was that they were incompetent in higher level of mathematics and they viewed mathematics problem-solving as rigid endeavour. The parents who were strongly influenced by the teacher-centred approach expected their children to follow the *teachers' ways* instead of fostering the children's creativity. In view of that, the parents had high expectations of mathematics teachers - good personalities, creative, fun, interesting, fostered interactive learning, provided more practice and used appropriate teaching approach to suit students' needs.

Other than the teacher-centred approach, some parents also had misconceptions that mathematics achievement was a measurement for intelligence and learning mathematics only required practice. The misconception had made them to believe that by attending more tuition class would be better for their children to have more practice for exams. Apparently, the parents focused on children's academic performance. Most of the parents have indicated their satisfaction towards their children's mathematics performance. In this case, exam grade was the sole performance indicator. For instance, many parents revealed that their children did badly in Additional Mathematics exams. The parents mentioned that there was a substantial increase in difficulty from the lower forms' mathematics to the higher forms' Additional Mathematics. The children were having difficulties in Additional Mathematics because the subject required much practice, cognitive and metacognitive skills.

The parents' pragmatic view was also seen to be applicable to their technological and gaming behaviour. Most of the parents only used computers and smartphones when necessary (i.e. not for fun) to complete their daily routine work. The working parents mostly used computers for office applications whereas the non-working parents used computers for entertainment purposes. However, most of the parents were proficient in typing using computers and the use of the Internet and electronic gadgets such as smartphones. The parents normally used a smartphone for communication purposes, web browsing and checking emails. In gaming aspect, most of the parents played only puzzle games (e.g. Candy Crush Soda Saga) when they were bored. The parents recognised the advantage and disadvantage of computer games but they were mostly concerned about game addiction, violence and offensive content that might affect the children's health and study.

Having a similar experience as the teachers and students, the parents lacked exposure to educational computer games too. The parents perceived that educational computer games were only suitable for young children. Unfortunately, the games were neither educating nor entertaining. Some parents mentioned that TV programmes were even more interesting than educational computer games. From the parents' points of view, a good educational computer game should focus on training and practices. The use of computer games to learn mathematics was only deemed to be necessary if it had educational benefits. Although they tended to agree with the use of computer games in learning mathematics, they felt that the combination of conventional classroom teaching and computer games could help the children in understanding the subject matter better. The presence of teachers was important to ensure that students were learning and not just playing. For the parents, playing was not appropriate in learning of mathematics.

In this study, the parents do not seem to concern themselves much about how mathematics is taught in schools. They are worried much more about the underlying problems in Malaysian education system as a whole, i.e. using BM (instead of English) to teach Science and Mathematics. The parents tend to look at education from a wider macro perspective. They look at the big picture of society and suggest how schools contribute important functions for society. School education is expected to equip children with society's skills and knowledge. For example, the parents argue that mathematics is useful in daily life, which is a popular view - whether it is true is a different matter. Surprisingly, the parents do not think that 21st century skills (e.g. technology or multitasking skills) are those skills that should be acquired in schools. Those skills are perceived to be merely entertainment skills rather than educational skills. Here, the parents seem to be trapped in the past, relating to society's skills and knowledge during their own childhood rather than in today's fast-paced digital world. Thus, it is not astonishing that the parents in this study do not see the necessity of using DGBL to learn mathematics.

Their concerns, however, may need to be addressed so they feel comfortable in giving schools and teachers their support. The data in this chapter suggests educators need to be wary of not pushing the parents too far away from their zone of comfort. The parents seem to shape their beliefs from their past learning experience in schools.

They strongly believe that teachers bear the full responsibility in their children's education. For the parents, there are no unmotivated or weak students, only inflexible or boring teachers. Instead of blaming their children for not being motivated to learn, or blaming themselves for not inculcating this motivation into their children, they are putting the responsibility on the shoulders of teachers who allow their children to be unmotivated to learn. The parents believe that if teachers want students to change their learning attitudes, the teachers must first change their teaching approaches. The parents want teachers to be the agents of change.

Chapter 8: A-Chronological Findings: Gaming in Mathematics Learning

8.0 Introduction

At the initial stage of this study, I wanted to explore the feasibility of educational and COTS games as a way to enhance mathematics pedagogy. I believed naively that students would like to play computer games to learn mathematics, and teachers and parents would appreciate the benefits and embody learning principles embedded in the games. My prediction was proven wrong. Data analysis in chapter 5 to 7 has shown that students would still prefer guidance from teachers as in conventional classroom teaching; teachers were less likely to change their teaching practices for various constraints in schools; and parents did not think that pedagogical change was required. In this instance, the idea of using computer games to learn mathematics had come to a dead end; it was fundamentally too far to travel.

After an in-depth analysis of the findings, I had discovered a new finding. Though the physical deployment of computer games in schools was not feasible [See Section 8.2.3], the participants did acknowledge the metacognitive skills and good learning principles in gaming, e.g. multitasking, teamwork, instant feedback and process-oriented. Consequently, I tried to look at how these metacognitive skills and good learning principles could be pushed into a mathematics classroom. I made a comparison between existing mathematics classroom and gaming context in Section 8.3.2 and Section 8.4. Then, a new pedagogy was derived in the conclusion [See Section 8.5]. It should be noted that the main contribution of this study is to explore how good gaming principles (pedagogy) could be used to teach mathematics, and not what could be learned from playing computer games.

There are three approaches of digital game-based learning to integrate computer games into learning (Van Eck, 2006).

1. The use of *educational computer games.*
2. *Commercial off-the-shelf (COTS) games* are used for educational purposes.
3. Students are taught on how to develop the games.

The first two approaches will be discussed further in this chapter, but the third approach is considered beyond the scope of this study. The third approach is built on game development and it is normally used to teach Computer Science students

(Denner *et al.*, 2012; Carbonaro *et al.*, 2010; Yang and Chang, 2013; Vos *et al.*, 2011). This approach is deemed to be not appropriate for mathematics pedagogy if teachers are not proficient in game design and development.

In this chapter, three major sections will be discussed as depicted in Figure 8.1.

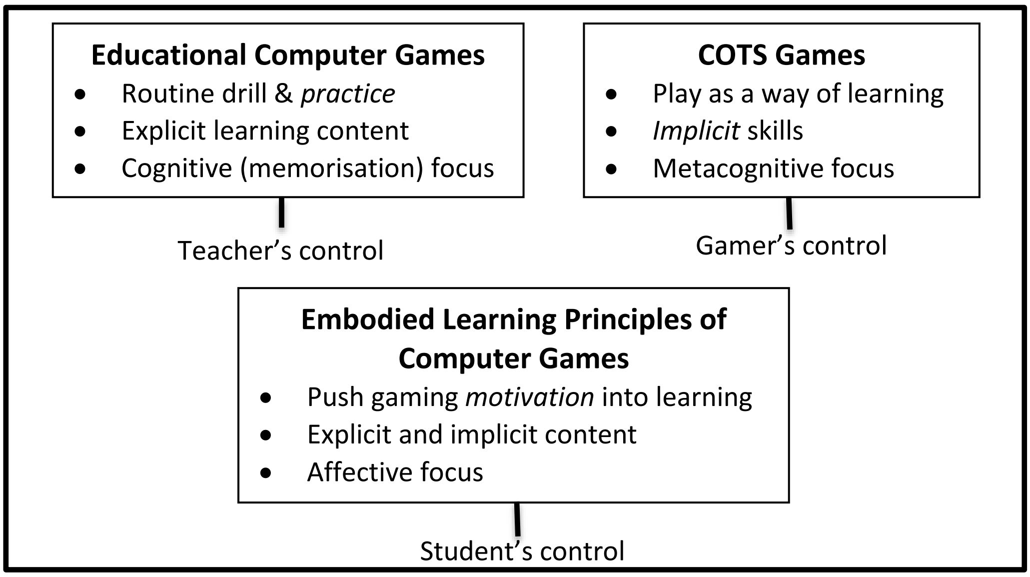

Figure 8.1: Approaches to Gaming Pedagogy

The first section is a discussion on the use of educational computer games, which is mainly referring to edutainments that are built on routine drill-and-practice. In edutainments, the learning content is delivered explicitly and learners are trained to memorise the stimulus and responses through a series of practices. Teachers can control students' learning because the learning pathway or outcome is fixed and predefined.

The second section is a discussion on the use of COTS games for learning purposes. The main idea of this approach is to recognise learning of implicit or metacognitive skills through gameplay. In this approach, gamers control the gaming experience as the games are responsive to the gamers' requests and interactions.

In the third section, I will be looking at another possibility - the use of embodied learning principles of computer games to teach mathematics. This approach may not employ any computer games, but look at what we could learn from good COTS games and then adopt the games' learning principles into the classroom teaching. The main focus is to look at what is the *motivation* behind the gameplay and how this *motivation* could be pushed into the classroom instruction. The learning content may be explicit or implicit, but most importantly, students are actively and emotionally involved in learning.

However, before embarking on further discussion of approaches to gaming pedagogy, it is important to understand the existing mathematics pedagogy in schools. Throughout the discussion in this chapter, not only qualitative data and students' quantitative data are used as a source of evidence, other literature is used to converge on a set of understandings of strengths and weaknesses in mathematics learning and computer games. Although the data collected through the interview and questionnaire are self-reporting, it is important to address what the students, teachers and parents have said because the data appear to be what they strongly feel and believe in.

8.1 Mathematics Pedagogy

In East Asian countries, routine practice is the mainstream pedagogy in mathematics teaching (Li, 2006). This study yields a similar finding. The teachers strongly believe that practice is the best way to learn mathematics because drill-and-practice can effectively improve students' academic performance. They even urge the parents to monitor their child's academic performance closely, and to be ready to tighten the child's routine practice at home if needed. As expected, parents do agree with the notion of practice too. They send their children for tuition to have more practice and they strongly believe that a good teacher should give more homework. Students are influenced by the practice artifice too. They may think that practice is the only way to learn mathematics because that is what they have been told in schools.

Apparently, the drill-and-practice is designed around an exam-oriented system. The parents measure their child's performance based on marks or grades; the students are learning for the sake of exams; teachers are rushing to complete the syllabus and drilling the students to prepare for exams. Worse still, some exams only focus on the final answers and not workings or calculations. This method of assessment ignores students' strategies and reasoning to derive the answers. Mathematics in this sense is portrayed as tedious, monotonous route to follow and a lot of problems to clear (Romberg and Kaput, 1999). The drill-and-practice approach to mathematics learning is a controversial issue. There is a debate of whether mathematics should be taught using *drill-and-practice* or with an *understanding* or *creativity* (Davis, 1990).

8.1.1 Drill-and-practice

Students normally learn arithmetic through rote learning whereby they are told what to do and how to do, and then followed by substantial amount of *drill-and-practice* (Davis, 1990). This approach is grounded on the assumption that people can become experts through imitation and practice repeatedly (Li, 2006). The primary focus of drill-and-practice is to memorise a routine algorithm (Davis, 1990). In this case, students do learn mathematics, but they learn to memorise a collection of procedures that are useful for certain purposes (Romberg and Kaput, 1999). It is similar to learning to match the right collection of procedures to a specific problem without looking at the reasoning behind the procedures.

The drill-and-practice approach is a deeply rooted traditional way of teaching mathematics. Teachers will demonstrate or explain a concept, and students are expected to memorise facts and to practise procedures until they have mastered the concept (Romberg and Kaput, 1999). In a conventional classroom teaching, a lesson is normally divided into three segments – recall previous lesson; teach new lesson with some examples and students are working on similar problems in the class; homework is given to reinforce the practice (Romberg and Kaput, 1999). This study yields a similar finding. In particular, a teacher will begin a lesson by giving some examples and then followed by more homework and routine practice. Homework given in schools is normally taken from a textbook. Students can learn from textbooks in two ways - learning from examples and *learning by doing* (Simon, 1980). A mathematics textbook usually comes with a set of routine exercises at the end of each topic. However, these exercises are very unlikely to involve problem-solving because no novelty or creativity is involved (Orton, 2004). Here, *learning by doing* merely means routine practice.

Routine practice involves the deployment of a set of routine that does not require creativity, guesswork or discovery (Romberg and Kaput, 1999). It is an effective way to foster retention in the memory (Orton 2004). Nevertheless, routine practice can be performed without a human being. In other words, tools such as calculators or computers can be used to solve the routine problem and learners only have to know how to operate the tools. Here, mathematics is perceived as a fixed and static body of knowledge because it involves only the mechanistic manipulation of numbers, algebraic symbols and proving of geometric deductions (Romberg and Kaput, 1999). This belief has determined the teaching approach used, and led to some misconceptions of mathematics. For instance, mathematics is perceived to be simple because it involves only numbers from 0 to 9 and only requires constant practice; no other skills are required [refer to Section 6.1.2 and 7.1.3]. The misconception has indirectly confined the mathematical concepts and skills that can be learned through the traditional way of mathematics teaching, i.e. drill-and-practice. This approach might be useful to solve routine problems, but not non-routine problems.

> *A routine problem is a problem that can be solved either by substituting special data into a formerly solved general problem, or by following step by step* (Polya, 1945, pp.171–172).

In this study, for instance, students were trained to solve routine problems, and this could be one of the reasons why some students reported difficulty in learning HOTS.

8.1.2 Understanding and Creativity

Mathematics is not simply a body of knowledge, it is also a creative activity that involves both process and product (Orton, 2004). A creative approach is necessary because mathematics is too complex to be learned merely through rote or routine procedures that are dull, demotivating and not helping students to develop their analytical thinking skills (Davis, 1990). Problem-solving is not a routine process because each problem should have a certain level of novelty that requires learners to be creative (Orton, 2004). If learners can easily solve a mathematics question using rote algorithms or routine process, then the problem does not exist or the problem is routine.

The most famous approach to problem-solving is Polya's (1945) four-step process and it provides a general guideline on how to proceed in solving problems. In this study, most of the teachers adopted this approach in teaching mathematics problem-solving. Nonetheless, students were reported to be weak in cognitive and metacognitive skills such as analysing, applying, monitoring, controlling and planning [refer to Section 5.2.3]. The students also claimed to be struggling to master HOTS because they failed to recognise meaningful pattern from pieces of information to build connections and think strategically [refer to Section 6.1.3]. This finding could imply that teaching Polya's (1945) four steps to problem-solving is inadequate to develop understanding and creativity in learning mathematics.

Many mathematics problems do not automatically lead to a solution by applying the Polya's (1945) routine for problem-solving (Orton, 2004). When students do not understand a particular lesson, they will learn the routine problem-solving as an isolation skill that cannot be applied or extended to new and unfamiliar problems (Carpenter and Lehrer, 1999; Polya, 1945). Thus, one of the major difficulties faced by the students is to transfer knowledge learned to solve a new problem. Knowledge transfer is hard when students could not relate what they have learned to a bigger picture.

> *Conventional academic and folk theory assumes that arithmetic is learned in school in the normative fashion in which it is taught, and is then literally carried away from school to be applied at will in any situation that calls for calculation* (Lave, 1988, p.4).

Even if teachers are aware of this problem, they have to spend most of the time re-teaching and providing routine practice because the school is exam-oriented. Routine practice seems to be the easiest and fastest way to improve exam performance.

In this section, the existing mathematics pedagogy in schools has been discussed. In the following sections, three approaches to gaming pedagogy will be examined. There are two possible pathways of gaming pedagogy, whether to (1) push the existing mathematics pedagogy into computer games or (2) draw a new mathematics pedagogy out of computer games.

8.2 Educational computer games

Many people equate educational computer games to *edutainments*. Having this conception in mind, the majority of the research participants in this study believe that the combination of conventional classroom teaching and edutainments is the best teaching approach. The teachers may consider adopting an edutainment provided it is only an additional teaching aid to the conventional classroom teaching. The students and parents believe that edutainment is useful but the learning process is incomplete without a teacher. This could explain why the quantitative data has revealed that students do not strongly support the use of edutainment in formal education.

There are three generations of educational computer games (Egenfeldt-Nielsen, 2007), but only the first generation of edutainments will be the focus of discussion. This is because most of the research participants in this study have only been exposed to edutainments, for instance, *MathWorkout, 2048, Typing versus Zombies, Scrabble, Keyboard Shark, Scramble* and games designed by *UNESCO* and *mathisfun.com*. These games are characterised as edutainment because they offer extrinsic motivation (e.g. score), straightforward content delivery (e.g. spelling, mathematical and typing skills are made explicit), more to training than learning (e.g. need more drilling to be perfect), simple gameplay (e.g. mostly are simple puzzle games) and linear progression (e.g. lack of alternatives to wonder around) (Egenfeldt-Nielsen, 2007; Denis and Jouvelot, 2005). Only two mathematics computer games have been highlighted during the interview, *MathWorkout* and *2048* (excluding those designed by *UNESCO* and *mathisfun.com*). These two games are reviewed briefly as follows.

8.2.1 Examples

a. Math Workout

Math Workout is a mathematics puzzle game designed with a set of training exercises and drills. It tests a player's basic arithmetic calculations within a limited time and the player has to answer the question quickly.

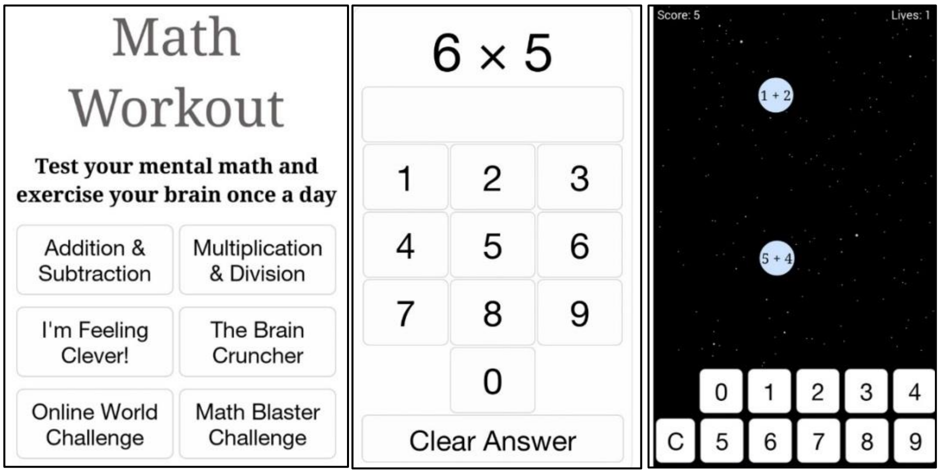

Figure 8.2: Maths Workout game (Copyright ©2016, Workout Games Ltd)

Based on my observation, this game is obviously a mathematics edutainment because the learning content is conveyed explicitly. The main challenge of the game is to achieve high score (i.e. external motivation) within a limited time frame. Although the game comes with minimal sound effects to make the gameplay more fun and interesting, it is essentially a monotonous game as a player can only follow a pre-defined path (e.g. question 1 to 20 in a linear sequence). After playing the game several times, the questions would repeat and that no new insights are gained.

b. 2048

2048 is a puzzle game that can be played online and available for free download. The goal of the game is to get a single square to be *2048*. If two of the same numbers are next to each other, they will collide while moving and merge into a number by adding the two numbers together. When playing the game, players can move the cursor or swipe left, right, up and down to collide numbers with equal values.

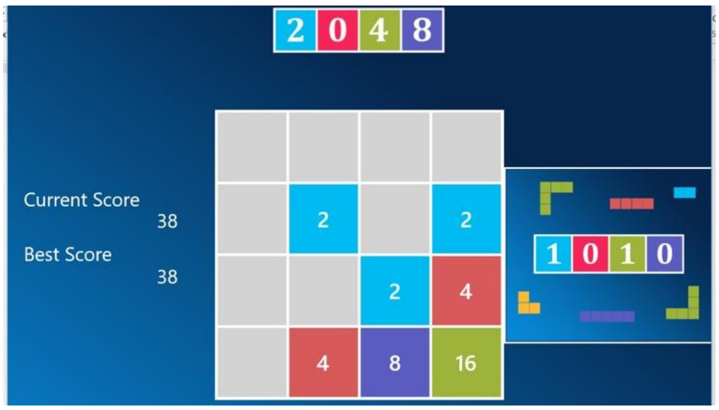

Figure 8.3: 2048 game (Copyright ©2016, Martin Freitag)

This puzzle game looks simple but it is challenging. It requires a high level of mathematical and logical thinking skill. Even though the game is tough, it is less motivating compared to other COTS games such as MMORPGs. The game lacks interactivity, complexity (e.g. graphic, sound, animation) and involves no collaboration. The game has a certain level of difficulty but it may not appear to be fun or interesting enough for children to start playing.

8.2.2 Behaviourism

Edutainments like *Maths Workout* and *2048* are mainly built on behaviourism learning theory in which learning of skills and content is achieved through reinforcement of training and practices. The sequencing of learning materials is important in behaviourism, whether it is *programmed learning* or *hierarchy learning* (Orton, 2004).

The *Maths Workout* game is an example of *programmed learning* because the mathematics questions are presented in a sequence of stimuli that require a user's response. The basic form of programmed learning is linear without deviation from a predetermined sequence, and user moves to the next question while receiving feedback about their response to the previous question (Orton, 2004). Users are typically forced to move along a predefined path.

In contrast, the *2048* game resembles a *hierarchy learning*. Hierarchy learning is like a pyramid, whereby the base and middle stages are leading to the ultimate objective on top (Orton, 2004). In the game, the bottom level of 2 is replaced by 4, 8, 16 and progressively adding up until it reaches 2048. If a player does not identify correctly the base line or omits some stages in the pyramid, the player may lose the game. For instance, to form a number 16, a user has to plan in a proper sequence (see Figure 8.4). Insufficient or missing of 2, 4 or 8 cannot form a number 16. In hierarchy learning, one needs to check whether the objectives for each level in the hierarchy have been attained before moving on to the next level (Orton, 2004). In this game, users are implicitly forming a hierarchy in their mind to make sure that each level is achievable.

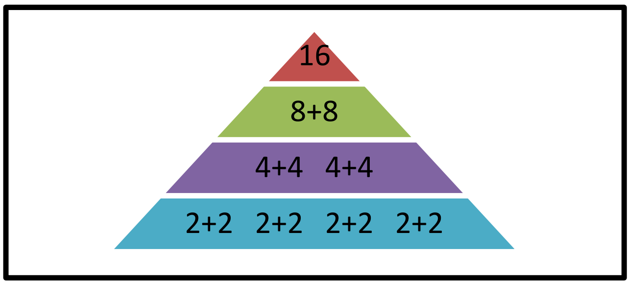

Figure 8.4: Hierarchy Learning in 2048 Game

Math Workout and *2048* generally have two different gaming structures, but the sequencing and progression of the gaming content are carefully designed. The objective of the games is pre-defined and it determines the sequencing of the materials to be learned. Before a user starts playing, the learning outcomes are somehow anticipated. In other words, if these games are used in a classroom teaching, the learning content is delivered explicitly and teachers have control over the learning outcomes. This could be a reason why some teachers prefer computer games for behaviourist learning. For instance, a teacher has used computer games to teach mathematics. Based on my observation, those games [refer to Section 4.4.2] fit well into *programmed learning*.

8.2.3 Challenges and Controversial

Educational computer games built on *drill-and-practice* (i.e. edutainments) fit well into the teachers' teaching philosophies who believe in practice makes perfect. The teachers are not drawing a new teaching strategy out of gaming. In fact, they are pushing their existing teaching approach (i.e. drill-and-practice) into the games. The teachers essentially do not change their teaching approach to suit the gaming context, but to use the games to fit their existing teaching approach. The use of educational computer games to learn mathematics is merely replicating the existing *drill-and-practice* pedagogy. In reality, most of the teachers only *pragmatically accommodate* technologies into their existing working style (Selwyn, 2011). This practice is obviously seen amongst the teachers in using the modern technologies such as computers and smartphones.

The second concern to adopting educational computer games is the teachers' reluctance to learn new technologies; unlike their students who always find computer games exciting. For instance, most of the teachers hardly use computer technologies except for office applications. They typically justify the use of educational computer games as inappropriate due to time constraint, mismatch to the topics learned, difference in assessment method and insufficient computer facilities in schools. Although these are reasonable justifications, it could also imply that the teachers are not willing to change the existing teaching approach. In the collectivist society as in Malaysia, the young students are expected to learn, but not the teachers (Hofstede, 1986). Sometimes, it is the pride of the teachers that has refrained them from learning. Most of the teachers (67%) interviewed in this study were Chinese even though their ethnicity was not captured due to ethical and anonymity concern. In the Chinese culture, a teacher has the knowledge authority (i.e. teacher is the only source of right answers) and *face (i.e. pride)* is extremely important for the teachers (Liu and Feng, 2015). It is a common view that teachers should know everything and they tend to maintain their face. Many teachers might be unwilling to try new teaching technologies for fear that they might lose face in front of their students as it may reveal their incompetency in handling the new technologies. To overcome the cross-cultural situation, the teachers should be taught both *how to learn* and *how to teach* (Hofstede, 1986). To avoid losing face, the teachers might be more agreeable to the third approach of gaming pedagogy – the use of embodied learning principles of computer games.

The third concern is that the learning principle behind an educational computer game might clash with what the teachers are trying to do. Since they always think that mathematics learning is all about *drill-and-practice*, they may deliberately choose edutainments that fit their teaching philosophy or try to structure other types of educational computer games (e.g. second or third generations) around classroom practice. The teachers think that games are only meant to give more mathematics exercises, not for students to explore, test, reflect and construct new knowledge. The teachers may think that this is what it means by teaching with educational computer games because they have given a practice in a slightly different way. On the other end, students can only expect to receive another form of *drill-and practice* (i.e. digital format) that is merely replicating the pen-and-paper exercise and nothing interesting. Again, the students' learning experience is still the same because the teachers are using the same teaching approach.

The fourth concern is that students are not interested to play educational computer games because the games are monotonous and boring. They prefer playing COTS games that are fun, challenging and interesting. Rationally, students would not play educational computer games because they want to learn mathematics. They play COTS games because they want to have fun. The idea of learning mathematics with computer games seems to be not practical because the students are not even motivated to start playing educational computer games in the first place. Even if they play, the engagement towards the games is not sustainable. The existing educational computer games available in the market are even claimed to be less appealing than children TV programmes.

Doing a drastic change to the existing teaching approach that is built on *drill-and-practice* may not be a wise decision. Over the past few decades, teachers have been comfortably adopting this approach, and successfully produced many talented people and experts around the world. If teachers are urged to adopt any form of digital technologies in teaching, they are most likely to push their existing pedagogy into the technologies and reproduce it in a different platform (e.g. online drill-and-practice). Conversely, if the teachers are urged to make a complete pedagogical change, they may resist due to new and unfamiliar ways of teaching. Hence, the use of educational computer games in this study is seemed to be not feasible.

8.3 COTS games

COTS games are the usual commercial games available in the market. COTS games are mainly designed for leisure and entertainment purposes. The use of COTS games in teaching and learning is cost effective because they are ready-made. However, it requires careful evaluation and a matching of the learning content to the game content (Van Eck, 2006). This approach cannot be implemented without sufficient gaming experience and proper lesson plan because the knowledge and skills are embedded implicitly inside the games. For instance, someone could learn mental rotation in *Tetris* (De Lisi and Wolford, 2002) and quadratic equations in *Angry Birds* (Avraamidou *et al.*, 2015).

This raises a question: do we need educational computer games or COTS games that educate children? In educational computer games, the knowledge and skills (i.e. learning content) are explicit to the teachers, so they may prefer this way of learning. As for COTS games that educate children, the knowledge and skills are not explicit because the learning content is embedded implicitly in the games. Teachers may refuse to use COTS games (e.g. Candy Crush, FIFA, etc.) for teaching because these games are perceived to be not academically related. For instance, a teacher has mentioned that COTS games should not be used for teaching and learning because the games are not appropriate [refer to Section 5.7.2]. From her point of view, only educational computer games that provide questions and answering are useful and beneficial for learning. Another teacher also has a similar view [refer to Section 5.3.3]. Apparently, teachers would prefer educational computer games to COTS games. Educators tend to support overt telling (i.e. educational computer games) instead of immersion in practice (i.e. COTS games), and this issue has not been resolved over the years (Gee, 2007).

Although COTS games would seem to have less educational benefits, some teachers do acknowledge learning of multitasking, land navigation, teamwork, problem-solving and concentration skills. However, it does not internalise sufficiently for it to impact upon practice. The teachers could be influenced by their personal prejudice towards games as most of them are more concerned about the destructive effects brought by game addiction. Nevertheless, most of the students acknowledge the benefits brought by gaming. People who like to play COTS games tend to relate gaming to positive outcomes and vice versa.

In this study, most of the teachers and parents played only puzzle games, but the students played all genres of games. The teachers' and parents' favourite game was *Candy Crush*. For the students, males' favourite game was *FIFA* and females' favourite game was *The Sims*. In the following sections, these games would be briefly reviewed.

8.3.1 Examples

a. Candy Crush

Candy Crush is a match-three simple puzzle game that can be played on mobile devices and computers. If the matching is a combination of 4 or 5 in a certain arrangement, special candies will be created. When players reach higher levels, the difficulty of the game increases with some challenges like icing, chocolate, candy bombs, and other blockers. *Candy Crush* is a simple but addictive game. According to the teachers, they like to play *Candy Crush Saga* because it helps them to think and they enjoy the competition and satisfaction gained from playing the game. *Candy Crush* is seemed to incorporate structural, social, cognitive, and emotional design elements (Varonis and Varonis, 2015). *Candy Crush* is claimed to be highly addictive for several reasons: candies are associated to people's sweet childhood memories and happiness; unexpected reward in the game is motivating; pleasant frustration; competition with friends on the Facebook; level reached shown on the Facebook is a self-esteem booster; happiness for mastering a certain skill (Radwan, n.d.).

b. FIFA

FIFA is a football or a soccer computer game. The player can choose to compete with the default team or a seasonal team. Compared to the *Soccer* video game in 1980s, *FIFA* is so much improved with the graphics, animations, interactivity and virtual reality that it could simulate the actual FIFA tournament. The game incorporates *agents* that closely resemble actual soccer players like *Lionel Messi, Cristiano Ronaldo, Luis Suarez* and other popular soccer players. In *FIFA*, the player has to manage their team by assigning a soccer player with certain skills to a proper position (e.g. defender, skipper, striker, winger, captain, midfielder and goal keeper) and any fatigue player has to be replaced. The player can learn to decide if keeping a good tired player in the field or let a less skilled player with more energy to play. Through the games, the player can learn football strategies and rules. For instance, two students who loved to play *FIFA* mentioned that they learned new knowledge, thinking skills and spatial abilities in the sports game [refer to Section 6.3.6]. Soccer is the most popular sport and the biggest global sports in terms of number of fans (Robert, n.d.; SportsBiggestGlobal, n.d.). This could explain why male students loved to play soccer computer games the most.

c. The Sims

The Sims is a life simulation computer game series. The player can control the day-to-day lives of a virtual character or a Sim. This is an open-ended game and the player is free to decide for himself or herself what constitutes a life. The player can do whatever to make him or her happy, build up a career, do housework, go to a nice place and build a relationship. The player will need to make his or her Sim successful in certain ways (e.g. get promoted, get a job done, set up a family) by fulfilling the Sim's need to sleep, cook, eat, socialise with other Sims and so forth, just like in real life. Through this game, players are learning new skills and forming complex relationships in virtual realities (Vitelli, 2014).

Simulation games can help to develop certain domain knowledge (Martinovic *et al.*, 2014) and metacognitive skills such as land navigation and problem-solving skills (Cherenkova and Alexandrov, 2013). Spatial abilities required in land navigation (Cuqlock-Knopp and Whitaker, 1993; Self and Golledge, 2000) are the essential skills for learning of diagrams and graphs in mathematics. Furthermore, some simulation games would mimic mathematics problems, for example, estimate cooking time, calculate items sold and estimate the cost of items.

8.3.2 Learning of Metacognition

During the early development of video games, the gameplay focus was mainly placed on the speed and capability to press the game controllers and that not much mental abilities were involved. Nowadays, a children's game like *Yu-Gi-Oh* – a card game played by children as young as seven involves complex language, vocabulary, and thinking skills (Gee, 2008b). Computer games teach us to adapt to today's fast-changing and sophisticated world because computer games are complex and require multiple metacognitive skills such as confidence in reasonable risk taking, ability to multitask, leadership, teamwork, visualisation, problem-solving and decision-making.

Metacognitive knowledge is an awareness about what one knows such as strategies, knowledge, processes, techniques and ideas (Biryukov, 2004; Ozsoy and Ataman, 2009). Metacognitive knowledge is neither explicit nor implicit because it is a combination of both (Sun and Mathews, 2003; Frith, 2012). Explicit metacognition is easily interpretable; has a clear conceptual meaning; is accessible and can be manipulated (Sun and Mathews, 2003). It enables people to reflect on and justify their behaviour and the learning is deliberate (Frith, 2012). Explicit metacognition has a clear meaning and is learned consciously. Implicit metacognition, however, means a process that is not directly reportable or consciously accessible such as feeling-of-knowing (Sun and Mathews, 2003); rapid, automatic and without awareness (Frith, 2012); without knowing they have the knowledge and it is not represented as factual (Dienes and Perner, 2002). Implicit metacognition is learned without awareness so one may not know of its existence.

Metacognitive skills can be acquired in two ways – top-down and bottom-up direction. In a top-down assimilation, explicit metacognitive skills can be taught and learned, and the processes are gradually assimilated into implicit skills (Sun and Mathews, 2003). In a bottom-up direction, implicit metacognitive skills are learned through trial and error, and then explicit rules and strategies are acquired (Sun and Mathews, 2003). In schools, students are taught or verbally told to learn metacognitive skills, but students are learning metacognitive skills naturally in computer games. Schools seem to focus on the top-down approach, while computer games engage both approaches.

The combination of bottom-up and top-down approaches to learning of metacognitive skills (as in computer games) seems to be more enjoyable and effective. In this study, most of the students value the benefits of playing computer games and have reported learning of metacognitive skills through the gameplay. Nevertheless, they have been struggling to master metacognitive skills in schools. To learn the desirable metacognitive skills in schools, the bottom-up approach should be considered in which the focus should be placed on learning by doing or trial and error as in computer games.

Bottom-up approach is an implicit learning in which implicit metacognitive skills are learned unconsciously and unplanned. In contrast to the top-down approach, explicit metacognitive skills are learned consciously, whether planned or unplanned (i.e. deliberate or reactive learning). People usually play computer games to have fun so the learning is usually unplanned and metacognitive skills are learned consciously or unconsciously (i.e. reactive or implicit learning). Nevertheless, sometimes people may deliberately learn a computer game after a few unsuccessful attempts.

Conscious learning of metacognitive skills such as deliberate or reactive learning tends to be less engaging and addictive. For instance, the teachers and parents do not show strong affinity to computer games because they are consciously aware that they are learning to solve puzzle games. On the other hand, role-play, fighting, shooting and other game genres might be more engaging and addictive because the learning is implicit. For instance, a few parents have mentioned that their sons are addicted to play racing games [refer to Section 7.3.2]. The games that are addictive tend to indulge players in unconscious and unplanned learning. Eventually, the learning of metacognitive skills turns out to be more natural and enjoyable.

Metacognitive skills such as multitasking, land navigation, teamwork, problem-solving and concentration skills can be learned through COTS games (Cherenkova and Alexandrov, 2013). The following sections will discuss the metacognitive skills and how these skills are applicable to mathematics learning.

a. Multitasking

Multitasking is the capability of doing more than one task at the same time. In today's technological world, multitasking behaviour has become ubiquitous (Anguera *et al.*, 2013), especially among the young generations. For instance, all the students have mentioned that they are capable of multitasking. They mostly listen to song while doing homework. Furthermore, they also play game, listen to stories or watch movie while doing homework; chat with friends online while playing games or watching movie on a computer. Multitasking seems to be part of their lives.

Most of the students also claimed that they learn multitasking in computer games. For example, in *The Sims*, a Sim has to entertain to multiple requests from other Sims simultaneously. In *FIFA*, a player has to check for offside line and nearby players while drifting the ball. It is evident that most of the students perform multitasking in their daily life, but only some students perform or learn multitasking in computer games.

There are few possibilities. Firstly, the students may not aware that they have performed multitasking in games because the skill is implicitly learned. For instance, a student (i.e. Student P) who liked to play strategy and role-playing games (i.e. games that require multitasking skill) claimed the absence of multitasking in the games. Secondly, the students may play simple games with minimal multitasking tasks. For instance, a student (i.e. Student N) who liked to play *Crossy Road* claimed that she did not learn multitasking in games. Thirdly, it is most likely that their multitasking skill in daily life is not transferable into games. Regardless of the response, all the students are convinced that they can do multitasking and one of the tasks is usually related to the use of technologies (e.g. playing games, listening to song and watching movies).

Past studies (Appelman, 2007; Anguera *et al.*, 2013; Zelinski and Reyes, 2009) have shown that playing multitasking computer games enhances mental cognition. For instance, a study found that training on a multitasking video game called *NeuroRacer* improved older adults' (e.g. 79 years old) cognitive ability (Anguera *et al.*, 2013; BBC, 2015). Multitasking skill can be enhanced by playing certain game genres such as role-playing, strategy and MMORPG (Cherenkova and Alexandrov, 2013; Zelinski and Reyes, 2009). Males and females do like to play multitasking computer games.

In this study, qualitative data has shown that all the male students like to play strategy games, whereas all the female students like to play role-playing games. Apparently, males and females may like different mode of multitasking. In real-time strategy games, the action (e.g. action of the enemy, amount of time) continues while the player is making a decision and this creates a *time pressured multitasking* (Zelinski and Reyes, 2009). As in role-play games, a player has to perform *multitasking with a memory load* by managing multiple characters simultaneously to defeat the enemy (Zelinski and Reyes, 2009).

Males' preference for *time pressured multitasking* and females' preference for *multitasking with a memory load* could explain why FIFA and The Sims were the favourite games among the male and female students respectively. While playing FIFA, a student mentioned that he had to make a decision on how to drift a ball while other players continued to move around and other actions continued (e.g. action of the opponents and amount of time). In *The Sims*, a student mentioned that she had to handle multiple requests from the other Sims in which she had to load her memory with multiple requests, jobs and tasks simultaneously. The finding in this study had indicated that students were capable of multitasking.

Learning Mathematics in Classrooms: In schools, however, students are not encouraged to use multitasking to solve mathematics problem. Students are taught to follow a predefined step-by-step problem-solving process according to Polya's (1945) four-step method. Some students ignored the instruction and a teacher mentioned earlier that,

> *They think that they can combine everything into one. They want to be fast… They want to find the simplest. Actually I want them to step by step.*

This statement has indicated that students are trying to apply multitasking skill into mathematics problem-solving, which unfortunately, is unsuccessful and does not work out. In a past study, a student has complained of having to *power down* in school (Prensky, 2001a). This could be a reason why students get bored in the school because their abilities are underused.

b. Land Navigation

Land navigation skill is the capability of using compass, map and sense of direction. Most of the students have mentioned that they could learn land navigation skill through computer games. For example, in *Persona 4*, a player has to refer to a map to get out from a place. In *Grand Theft Auto*, a player has to use a Global Positioning System (GPS) when driving a car. Many genres require certain level of land navigation skills, such as strategy, simulation, action, adventure and driving games (Cherenkova and Alexandrov, 2013). Explicit land navigation skills (e.g. use of map and compass) could be transferred to real life applications. For instance, a student mentioned earlier that,

> *In the game I feel I'm expert at it. I understand map… Too bad I don't have Geography now in Form 4. If I do, if they happen to ask anything about Africa, then I can answer it.*

Based on the student's description, the land navigation skills learned through computer games has enriched her geographical knowledge. On the surface, land navigation skill may seem insignificant in mathematics other than topics related to angles elevation and depression. In fact, land navigation skill requires spatial abilities (Cuqlock-Knopp and Whitaker, 1993; Self and Golledge, 2000).

Spatial ability can be developed through puzzle (De Lisi and Wolford, 2002; Zelinski and Reyes, 2009), action (Paul, 2013; West *et al.*, 2015; BBC, 2015) and simulation games (Mitchell and Savill-Smith, 2004). Expert gamers can mentally rotate objects more efficiently (Boot *et al.*, 2008). Spatial abilities or imaginative skills are important in playing computer games. The game's world is transparent, so players have to understand the *meta-map* to show the directions of other players, enemies, resources and goals (Beck and Wade, 2006). Nevertheless, females are less likely to enjoy game-play situations that involved 3-dimensional rotation (Lucas and Sherry, 2004). This could explain why females normally have less interest in playing computer games than their male counterparts.

Learning Mathematics in Classrooms: Spatial ability is important in mathematics learning (Wells, 2012; Guay and McDaniel, 1977). To help students to develop spatial abilities, some teachers have used PowerPoint, animation or courseware to show diagrams and graphs when teaching mathematics. The use of computer technology to support learning of abstract concepts is essential as some students have weak imaginative skill and spatial ability. Gender differences in spatial ability have been highlighted by the teachers. Female students are claimed to be weak in spatial ability and this has been documented in many past literature (Self and Golledge, 2000). Although sex differences in spatial ability are well documented, they are poorly understood (Kaufman, 2007).

People who like to play puzzle, action and simulation games should have better spatial abilities (De Lisi and Wolford, 2002; Zelinski and Reyes, 2009; Paul, 2013; Mitchell and Savill-Smith, 2004; BBC, 2015). However, qualitative data collected shows that female students regardless of having strong or weak spatial ability like to play action, puzzle, racing and role-play games. The only difference is that female students with strong spatial ability like to play strategy games too. Strategy games are strongly favoured by the male students. Since males generally have better spatial ability than females (Paul, 2013), it is most likely that strategy games require strong imaginative skill to play. This finding opens for the possibility of future research to experiment students' spatial abilities in relation to the games they played. Another possibility is that the female students may not play computer games long enough to develop spatial ability. Improvements in spatial skills persist over time and require training (Paul, 2013).

c. Teamwork

Teamwork is the capability of working collaboratively with a group of people. Most of the students agreed that they could learn teamwork through computer games. The students seem to enjoy collaboration and teamwork because they are helping each other not to get killed and to complete a common mission. Some students mentioned earlier that,

> *We help our teammate not to get shot, not to get killed.*
>
> *My brother will ambush them in two ways like, me from the front and my brother from the back door.*

From the students' conversation, teamwork in games has fostered positive experience and bonding among the players. Through games, the students are socialising and interacting with their peers. The students can offer and receive help in games and they can help each other to succeed. Furthermore, every player may have different responsibility. For instance, a student mentioned earlier that in *Little Big Planet*,

> *Two players need to push two buttons at the same time. And the third needs to climb the stairs… then the fourth person needs to go down.*

Every player has a different role to play and this makes them feel special and important. They need to trust and support each other to complete a mission. Young people prefer multiplayer games (Gee, 2007) and they work better through teamwork (Prensky, 2001a, 2001b). In games, other players can encourage a player's thinking and reflect on their metacognitive knowledge (Gee, 2007). It is most likely that computer games will be the next generation of social network.

Learning Mathematics in Classrooms: To encourage teamwork among the students, the teachers did use classroom activities such as group discussion and project. The teachers perceived that group discussion was effective in motivating students to learn mathematics. However, none of the students suggested their preference for these two activities. Teamwork in the classroom is different from the gaming context. Teamwork is not allowed during exams, so students cannot help each other to succeed. Most of the time, homework given is also expected to be completed individually. Sometimes, offering help or asking for help may constitute cheating.

In a game, a guild's achievement is broadcasted but students' exam performance is individually assessed and is private and confidential. There are no group exams in schools. In a game, every player has a different role in a guild, such as a tank, support, healer or damage to do a quest. Each player is important with a different role to play. However, in classroom activities such as a group discussion, every student normally has one common task – solve the problem. The students have no special and unique role to be recognised as important. Young generation do like to feel important (Beck and Wade, 2006), so conventional classroom activities (i.e. group discussion and project) may not excite them to learn.

d. Problem-solving

Problem-solving is a process of finding solutions to difficult or complex issues. Most of the students recognised learning of problem-solving skills in games. For instance, a student mentioned earlier that,

> *I play the CSI games, something that related to forensic and investigation… Usually we need to find the clue. Maybe we need to make a very accurate*

> *decision…Our solution affects our life in the game whether we succeed or not succeed.*

The student said that she learned how to analyse (i.e. find the clue) and solve a problem (i.e. make a very accurate decision) in games. The decision made involves risk of succeeding or failing the games, but there are no fatal consequences of failing. Players can always try an alternative problem-solving strategy in another *life* and the learning appeared to be very natural and flexible. Players are active problem solvers that persist in exploring, testing hypothesis, taking a risk and seeing mistakes as opportunities for reflection, learning and progress (Gee, 2007). Problem-solving in games seems to focus more on bottom-up approach. Players are free to use various ways to explore and learn the games. Good computer games do not restrict players to a pre-defined pathway.

Nevertheless, problem-solving in games is sometimes not real. A student mentioned earlier that,

> *Most of the problem-solving in games is very exaggerated. It doesn't really apply in real life… they don't apply physics or knowledge of physics.*

In games, players are solving different types of problems that may look logical, but it may not happen that way in real life. Everything in games is pseudo-reality, but it is interesting and fun. In other words, children may play a game, but they cannot learn physics or mathematics. Although the game world is not real, computer games are good for practice (Gee, 2007) because the game world is logical, not inexplicable and a lot simpler than reality (Beck and Wade, 2006). In real life, many incidents and events are unpredictable, unexpected and unexplainable. In games, there is always an answer and ending. Players are learning the process of problem-solving and thinking in a logical way.

There are certain gaming economics that can be learned through gameplay even though they may not be practical in reality. For instance, in *World of Warcraft* a player can learn the gaming economics, which is based on supply-and-demand. If fewer people are playing the game during week days, the price of things will drop. The player can buy those things on weekdays and put them for sale during the weekend to earn profit.

Learning Mathematics in Classrooms: Learning of problem-solving skills in the classroom follows top-down assimilation because a step-by-step problem-solving skill and HOTS are taught explicitly. A sufficient amount of drill-and-practice is expected to gradually assimilate into implicit skills. The teachers strongly believe that routine practice is important to develop problem-solving skills. Nevertheless, students may find it boring because they are passively absorbing the problem-solving rules and algorithm without actual understanding. For instance, a student mentioned that mathematics was interesting but it was not taught in a fun way. Two students also stressed the importance of understanding to retain their interest to learn [refer to Section 6.1.2].

In classroom learning, students usually have no opportunity to test different problem-solving strategies to enable active learning and understanding of cause-and-effect as in computer games. Students are not encouraged to take risk by using alternate problem-solving strategies other than the one that is taught by the teachers. Trial and error approach is a risky approach that might lead to failing an exam. To be safe, students are encouraged to follow teachers' ways. In Asian culture, it is a norm that students should follow the path outlined by the teachers (Hofstede, 1986). This could be a reason why a parent labelled teaching in schools as being a *military style*.

There is a common understanding that problem-solving skill in mathematics is useful for everyday life, and it influences many students, teachers and parents when they are dealing with numbers and calculations. For instance, many parents have made the above claim in the interview of this study. However, if the statement above is true, they would not have disclosed later that their incompetency in mathematics was due to not having the opportunity to use their mathematics skills in this everyday life activities and at their workplace. The fact is that mathematics taught in schools are not used in daily life and even for work. The same thing applies to computer games; many problems in computer games are not applicable to real life.

> *Many educated people believe that mathematics does not make sense in the real world because it is a game of arbitrary rules made up by talented but slightly crazy mathematicians* (Wong, 2002, p.4).

Sometimes, it is not the product and content knowledge that matters, but what can be learned through the process (e.g. implicit skills). Both computer games and mathematics could train players to solve problems in a logical and systematic way.

e. Concentration

Concentration is the power of focusing all your attention. Most of the students do agree to learning concentration skill while playing computer games. They have mentioned that they have to pay full concentration during gameplay, else they will lose the game. However, long hours of gameplay may affect their concentration in study. A student said,

> *Playing games is very different from studying. So, the sudden change will not immediately apply concentration to study after game.*

The negative effects brought by computer games have been reported in many news media (The Star, 2014a, 2014b; Hew and Loke, 2013; Stanley, 2013; Yeoh, 2013). A study has also reported that students who spend more time on digital technologies are more vulnerable to psychological disturbances (Zulkefly and Baharudin, 2009). Nevertheless, students in this study valued the benefits of gaming. For instance, a student mentioned earlier that,

> *Playing games helps me to think fast, helps my eyes coordination, such as I can learn to spot thing fast. I can know the difference by seeing those thing, I know the difference.*

The student mentioned that concentration in games had helped him to learn visuospatial attention. In games, information is available in numerous modalities including visual, background song, animation, sound effect and texts. Players have to learn to focus or divert their attention to certain elements in games. For example, action video-games usually require players to attend to different multiple objects within complex visual environments (Latham *et al.*, 2013). This example is similar to *multitasking with a memory load* as discussed earlier.

Some studies have also indicated that multitasking with digital technologies could be harmful to children (Paul and Gelish, 2011). However, it should not be assumed that children who are capable of multitasking cannot concentrate (Brown, 2000). Perhaps most of the past studies have reported enhancements in visuospatial attention among computer game players (Latham *et al.*, 2013; Boot *et al.*, 2008; BBC, 2015; West *et al.*, 2015).

Mathematics Classroom Learning: Mathematics is learned through texts or diagrams in books. One may assume that having less multimedia elements (e.g. sound, animation, and video) will allow students to pay more attention in the class. Nevertheless, most of the students do enjoy listening to song, playing game, listening to stories or watching movie while doing their homework. It seems to be a norm as past studies have also found that students would frequently use ICTs at the same time while they are doing schoolwork (Junco and Cotten, 2012). This implies that students prefer learning with multiple sensory modalities.

Looking from a different perspective, students always perform other tasks while doing their homework because they feel bored. A student said,

> *I'm listening to music while typing school work, so that I don't easily get bored… While waiting for the thing I am searching for to load, I do my school work so that I don't waste time.*

Based on the student's explanation, multitasking is helping and motivating him to concentrate in his study. Since schoolwork is considered to be an unpleasant experience and is boring, students need an entertainment to motivate and lighten their mood so that they can continue paying attention to their study. Nevertheless, multitasking while studying will overload their ability to process information and engage in deeper learning (Junco and Cotten, 2012). It is an interesting issue of whether multitasking can help to improve or decrease the attention span of learning.

This section discusses metacognitive skills that can be learned through COTS games. Apparently, the metacognitive skills have no direct and explicit connection with mathematics learning content. Mathematics teachers may not see the underlying metacognitive skills that are embedded in the games. Furthermore, every player may experience and learn different metacognitive skills while playing certain COTS games. In the next section, the third gaming pedagogy is considered - the use of embodied learning principles of computer games.

8.4 Embodied Learning Principles of Computer Games

Good computer games are motivating and engaging. Quantitative data showed that 88% of the students loved to play computer games and 95% of them perceived computer games as fun and enjoyable. There are a few good learning principles in computer games that can be embraced in mathematics learning. The learning principles will be discussed in the following sections.

8.4.1 Process-Oriented

A good computer game works on the principle of *playful learning*. Playing is a form of imitation and exploration that enables learning to take place almost inadvertently (Corbeil, 1999). If learners are engaged in *playful learning*, they can learn effectively because they enjoy the *process* of playing. For instance, the students have mentioned that they enjoy playing computer games because they like the challenges, thrills and excitements of gameplay in which they could involve in role-playing, teamwork and competition. The gameplay has been an emotional roller coaster for the players that may turn a boring situation into one that is fun. Since the students enjoy the *process* of gameplay, they acknowledge the many benefits of computer games such as learning of sports rules, language, world map and metacognitive skills. Apparently, the students enjoy the *process* of playing computer games so they are engaged in *playful learning*. Playing computer games is not only *product-oriented* (i.e. win the games) but also *process-oriented* (i.e. fun and enjoyable).

A computer game is fun and enjoyable because it stimulates players' curiosity. Fun is the *desire* and *pleasure* that comes from curiosity, challenge, control, problem-solving, competition and achievement (Denis and Jouvelot, 2005; Amory *et al.*, 1999). Curiosity and playfulness are human nature (Stafford, 2012). Since young, children play to learn or learn to play because they are curious of their surroundings. If children are curious, they will continue to explore and discover. The learning is formed naturally and effortlessly. Likewise in computer games, adults explore and discover the virtual worlds due to curiosity. The virtual worlds are fictitious so it is even more exciting and mysterious because it is something different from the usual life. Through gameplay, adults can experience the challenge, excitement and achievement which they have felt previously when they were children. Curiosity is human's natural passion for learning.

In this study, students' attitudes towards computer games and mathematics learning are similar in the sense that both are *process-oriented*. When the students were asked about mathematics learning and gaming experience, none of the students emphasised that they studied mathematics and played computer games because they wanted to obtain a grade A and win a game respectively. In fact, they were talking about the instant feeling and experience while playing and learning. Apparently, children live in the present.

Learning Mathematics in Classrooms: Adults, however, have the conception of the future (Bell, 2011). Teachers and parents are obviously *product-oriented* because the whole education system is designed around exams and getting the answers right. Students study under exam pressure and the learning is not fun, but stressful. The traditional perspective about mathematics has led to a teaching approach that emphasises on speed and answers rather than processes (Anderson, 1996). In fact, the focus of learning (i.e. product or process) is determined by the objective of the problems. A *product-oriented* problem concentrates on getting the answer to solve a problem, but a *process-oriented* problem concentrates on the efforts of getting the answer by using certain algorithms (Kennedy *et al.*, 2007). Learning from gaming pedagogy, the practice in mathematics should be *process-oriented* in which mathematics is taught to foster understanding.

The current mathematics education lacks emphasis in understanding the *process* of problem-solving. For instance, a student mentioned that her teacher hardly provided rationale behind the use of certain mathematics technique [refer to Section 6.1.4]. Apparently, teachers play a major role in fostering students' understanding.

> *The most challenging tasks can be taught so that students simply follow routines, and the most basic computational skills can be taught to foster*

> *understanding of fundamental mathematical concepts* (Carpenter and Lehrer, 1999, p.24).

A challenging question can be a routine problem when students only have to substitute data into a formerly solved and known problem or by following a step-by-step procedure (Polya, 1945). Conversely, a simple question could be a non-routine problem when there is no sample example or step-by-step algorithm provided, and students are free to use any method and to be creative. Mathematics problems alone could not determine whether the learning will be *process* or *product-oriented*. The teachers are the ones planning a lesson and determine whether to engage students to complete a task (i.e. *product-oriented*) or to foster an understanding (i.e. *process-oriented*).

Unfortunately, many teachers are trying to make their curriculum shorter and simpler for the students to achieve good grades. Teachers' primary concern is not to keep learners engaged, but to *trap* them physically in a classroom or by their goals to disseminate all the learning materials (Prensky, 2002). Sadly, there are very few teachers who acknowledge the significance of leveraging student' interest and passion (Resnick, 2004).

Nowadays, the use of calculators has also changed how students learn mathematics. In the past, students performed manual or mental calculations (i.e. *process-oriented*) with no help from calculators. In today's classroom, a calculator is an essential tool in teaching and learning of mathematics, but it has sparked some controversies. For instance, some teachers have mentioned that the use of calculator have diminished students' logical skills and ability to perform mental calculations [refer to Section 5.1.4 and 5.8.2]. In fact, the use of calculators does not mean that all mathematics problems can be solved and there is no necessity to learn the basic facts and algorithms (Kennedy *et al.*, 2007). A calculator is merely a tool. Teachers should guide students to use the calculator in an appropriate way (e.g. free students from tedious computations) to eliminate the over-reliance on the calculator to solve every mathematics problem. If the objective of a mathematics lesson is to learn the algorithm of calculations (i.e. *process-oriented*) then the use of manual pen-and-paper exercise might be more beneficial. However, manual exercise is useless if students do not understand the reasoning behind the algorithm.

8.4.2 Learning by Doing

In computer games, knowledge is constructed through experiential learning whereby players learn by doing.

> *Learning is a cycle of probing the world (doing something); reflecting in and on this action and, on this basis, forming a hypothesis; reprobing the world to test this hypothesis; and then accepting or rethinking the hypothesis* (Gee, 2007, p.105)

The learning is a cyclic process as the knowledge and understanding are constructed and internalised through continuous practice in the game world (Farmer Jr *et al.*, 1992; Kerka, 1997; Kiili, 2005a). Since the knowledge is embedded implicitly in games, players have to discover it through practice. For instance, to master a simple game like *Angry Bird*, a player has to constantly practise and there is no way to master the game just by reading a manual, walkthrough or a cheat log on the Internet.

Experiential learning is also constructed through trial and error. When playing a new computer game, basic cognitive and metacognitive skills are learned through trial and error, and the skills are gradually transformed into explicit rules, strategies and knowledge.

> *Good video games concentrate in the early parts of the game an ample number of the most fundamental or basic artefacts, skills, and tools the player needs to learn* (Gee, 2007, pp.139–140).

Good computer games not only provide a sequence of challenges and problems in a sensible manner, but that the difficulty in games should increase gradually to support cognitive processes so that players can progressively construct complex strategies (Bottino *et al.*, 2007). They also offer substantial number of opportunities for practice through trial and error to allow players to master each fundamental skill before they proceed to more advanced levels that require them to combine various skills mastered earlier.

Learning Mathematics in Classrooms: The existing classroom learning is strongly built on drill-and-practice. Drill-and-practice approach is beneficial and useful for people with memory impairment (Svoboda *et al.*, 2012) but not for the young and healthy students. Learning is not purely a mechanical process so it should be designed to suit the students' developmental level (Vygotsky, 1978). Students do need practice in mathematics but not mechanically memorise the facts, rules, algorithms and skills (Li, 2006). Alternatively, students should be encouraged to learn by doing or through trial and error from various classroom activities. This would enable experiential learning.

The teachers did try to foster experiential learning in schools. For instance, some teachers have given statistics projects that require students to collect, analyse and present data collected like actual researchers [refer to Section 5.3.2]. In this case, students are learning by doing, and this is a form of experiential learning. Unfortunately, not all mathematics topics could be learned by doing. Computer games, however, eliminate this limitation. For instance, to learn the angle of elevation together with mass and string tension, students could play Angry Bird. Angry Bird is a study of mathematics and mechanics that is related to a parabolic throw. In the game, players can use a slingshot to launch birds at the pigs that are stationed in various structures. During gameplay, players can manipulate the angle of elevation, mass and string tension to experiment how the pigs could be destroyed on the playing field. Apparently, computer games provide a great avenue for trial and error and visualisation of abstract concepts.

To foster experiential learning in mathematics education, the flow of the learning content is crucial too. According to the teachers, the existing mathematics curriculum is not designed in a sensible manner [refer to Section 5.8.4]. In primary education, students are learning basic arithmetic operations, whole numbers, percentage, fractions, decimal numbers and ratio. They are then followed up in secondary education with topics related to algebraic expression, algebraic factions, linear equations, polygons, transformation and others. This is a layer-cake structure because the design of each topic is primarily to meet the prerequisites of the next topics (Romberg and Kaput, 1999). Learning from the gaming pedagogy, each mathematics topic should be designed carefully so that students could learn and practice each fundamental skill at the early stage. Then, these fundamental skills could be combined for more advanced learning in the future.

8.4.3 Instant Feedback

Computer games provide instant feedback on how well a player is doing and this is an area in which the conventional classroom teaching is lacking. The instant feedback in computer games makes the practice exciting and it is an ongoing success (Gee, 2007). Players have a feeling that they are progressing because they are learning and discovering something new continuously. The instant feedback given in computer games helps to stimulate curiosity and consequently allows for greater motivation to learn. An instant feedback is a form of affirmation and support given to the players leading them to the final goals. Without an instant feedback, players would not know whether they are on the right track. They may then have a lack of confidence and courage to move on. Instant feedback comes in various modes, but they are generally classified into rewards and punishments.

In computer games, feedback or reward of progress is often ongoing. Players are rewarded in multiple facets, such as accumulating scores, virtual currencies, or triumphant sound effects after making a correct choice or action. However, the real rewards are the satisfaction and sense of achievement when coming to the solution of a challenge and then progressing to the next more challenging level. When players receive a rewarding feedback, the actions used to achieve the reward are reinforced and this prompts the players to seek future opportunities to repeat the actions. Even if the players fail to progress in the games, they are rewarded in other aspects. For instance, the students have mentioned that computer games help them to release stress, relieve boredom, gain knowledge, socialise and improve spatial ability. A player may not win a game, but he or she is rewarded for having some fun and making friends. Every gameplay is a new and unique experience so it is rewarding too because it is exciting. Motivational elements such as interest, self-efficacy and attributions are required for successful problem-solving in academic (Mayer, 1998).

Making mistakes in computer games is not a dreadful punishment because there is no serious consequence of failing. Instead of being demotivating, the failure in games is having as much fun as successful in games. A fun learning should create relaxation and motivation to enable learners to put forth effort without resentment (Prensky, 2001c). Games provide a safe environment for players to make mistakes, obtain feedback on how they are doing, and motivate them to keep trying despite failures. The instant feedback gives players the opportunity to correct a mistake to ensure that they are on the right path. The mistake is corrected before they continue playing because game is not a lockstep. If players are not making any mistake in a game, then there is no point of playing the game because it is no more challenging. A computer game without challenge is no longer interesting and fun.

Computer game is a good example of how players can learn from mistakes. Players learn far more from losing than they learn from winning. When they win, they celebrate the victories and learn very little. However, when they lose, they reflect, analyse, compare, investigate and plan a new strategy. Losers make far more mistakes so they get more feedback. The losers do not fail at all, but rather they have successfully found *what do not work*. That kind of healthy attitude toward mistakes enables players to learn to win more often in the more advance levels in the game.

Learning Mathematics in Classrooms: In schools, given 20 to 50 students in a class, it is almost impossible to expect personal guidance from a teacher to provide instant feedback to every student. In the conventional classroom teaching, students normally receive feedback of their academic performance during exams. In an exam-oriented system, students are rewarded for the *product* (i.e. marks and grade), but not during the *process* of learning. Learning from the gaming context, students would be rewarded during the process of learning. For instance, a teacher has mentioned that she uses compliments as a way to motivate her students to learn mathematics [refer to Section 5.3.5]. Other than compliments, students can be rewarded through recognition and attention spent on them. As mentioned earlier, children live in the present so the instant experience is more important for them. Students want to feel that the time spent on learning is worthwhile and they gain something out of it. The teachers have also characterised the current young generation of students as needing information easily and quickly without much thought. Thus, students cannot bear tedious long hours of learning without ongoing rewards.

In schools, failing an exam is an embarrassment and dreadful punishment. Mistakes are not welcomed and exam performance is taken seriously because reassessment is usually not permitted. Learning from the gaming context, school exams should work on the principle of *learning from mistakes*. Mistakes should not be treated as failures and students should be given an unlimited number of attempts to achieve a passing score or higher. Students are expected to make some errors in judgement and the mistakes are welcomed as part of the learning process. The students should not feel the shame of failing instead the shame is only in not having tried.

One of the main reasons students dislike mathematics is making careless mistakes in a long calculation or series of steps [refer to Section 6.1.3 and 5.2.1]. Mathematics problem-solving is a lockstep because one minor mistake may lead to the final wrong answer. During the process of calculation, no instant feedback is provided (as in computer games) to notify and get the mistake corrected. The lockstep procedure in this context means a fixed order whereby someone is not able to return to the previous step once he or she has moved to the next step. Learning from the gaming context, instant feedback would be provided at every step of calculation so that mistakes can be corrected instantly. However, it should be mindful that there is no instant feedback provided during exams. Thus, students should also develop skills in spotting their own mistakes.

8.4.4 Stories

Stories play a significant role in the growth and development of children. Some parents mentioned that they bought storybooks for their children since they are at very young age [refer to Section 7.1.3]. The parents seem to recognise the importance of reading storybooks as part of their children's mental and emotional health development. Stories are putting people in touch with their inner child. Many children (so do adults) enjoy reading storybooks and listening to stories. The characters in the stories become vivid like their friends and they may even imagine themselves as though they are the characters (e.g. being a hero or princess) in the stories. Stories can be realistic or unbelievably fantastical, but people usually invest time in a compelling story. Reading storybooks has been part of many people's childhood experience and they continue this hobby even after they have grown up. Besides that, many people watch movies and play computer games for the realistic or fascinating storyline too.

Nowadays, many computer games have added on element of wonder and fascination into their stories. For instance, two students have mentioned that they are attracted to play role-playing and action-adventure games because the games come with great stories [refer to Section 6.3.4]. Students' favourite games such as *Far Cry, Grand Theft Auto, Hunting 101, Leaf 4 Dead, House of the Dead, Defence of the Ancients 2, Call of Duty* and *Resistance Fall of Man* are built on a storyline. The latest *Far Cry Primal* is designed around the story of Takkar who starts as a hunter and progressively becomes the leader of a tribe (Erfanian, 2016); *Resistance Fall of Man* delivers around the story of the Chimaera that has overrun Russia and all of Europe (IGN, 2006) and *House of the Dead III* is a horror game in which the players have to encounter horrific zombies while they uncover new secrets as they travel different routes and advance the storyline (IGN, n.d.).

When playing a story-driven game, players are motivated to prolong their *lives* to gratify their curiosity and interest in the game.

> *A game is an ongoing series of complementary ulterior transactions progressing to a well-defined, predictable outcome* (Berne, 1967, p.19).

Players are looking forward to see the progress of the story because they are writing their own story to achieve the mission in the game. While going through the storyline, the game characters may become like their virtual friends and the story allows the players to develop creative imagination.

Learning Mathematics in Classrooms: Storytelling is an educational strategy that could be used to teach mathematics. The best thing about a story is to connect information in an impressive form, and it forms the listener's emotional state about the information being communicated (Zazkis and Liljedahl, 2009). Stories of Karl Friendrich Gauss, Archimedes and many more could be used in mathematics teaching (Balakrishnan, 2008; Zazkis and Liljedahl, 2009). Storytelling is a way to let students get a sense of reality in a way that connects with them. In a study that applied storytelling within the contexts of mathematical problem-solving and ICT integration (e.g. PowerPoint, Movie Maker, and others), they concluded that storytelling was effective in developing the pedagogical, technical and content knowledge (Starcic *et al.*, 2015). They explained further that the use of storytelling in teaching mathematics was motivating because stories were realistic expressions of the children's lived experience and built on their imagination (Starcic *et al.*, 2015).

A student mentioned that it was fun and exciting to learn mathematics when his teacher told stories and made jokes [refer to section 6.1.4]. The teacher was telling the story of his friend who wanted to be an engineer. Stories and jokes could make learning fun and interesting because students might feel connected to the stories. Some students also mentioned that they liked to learn with interesting mathematics examples. Hence, one way of doing it is through storytelling. The data collected indicates that storytelling could be an interesting and untapped way to teach mathematics. Peter and Allen (2008) have suggested mathematics teachers to tell their own stories instead of other people's stories.

> *Without designing the stories that we are telling through our teaching, we are leaving the experience of mathematics void of compelling purpose and cultural context, turning mathematics into a flaccid copy of someone else's story. The story is there but we don't know what it is* (Appelbaum and Allen, 2008, p.235).

Regardless of telling someone's story (e.g. Karl Friendrich Gauss) or telling teachers' own stories, mathematics learning that integrates storytelling would introduce a new approach to mathematics pedagogy. Through storytelling, students can imagine themselves as the characters in the storyline and may find the learning more meaningful because they are solving their *own* problems.

8.4.5 Imaginary Play

Imaginary play, fantasy play or *pretend play* includes the process of role-playing, script knowledge, creativity, social conversation and negotiation (Bergen, 2002). During *imaginary play*,

> *they use objects in ways that are inconsistent with their intended purpose, attribute items with properties they do not have, and act as someone they are not* (Nielsen, 2015, p.870).

Imaginary play is the best activity for children to learn (KiddyCharts, 2016; Paley, 2009). Children like to pretend, and they can learn various abilities such as cognitive, social, language and communication skills through *imaginary play* (KiddyCharts, 2016). Cognitive strategies such as cooperative planning, negotiation, problem-solving, and goal seeking are exhibited during the pretence (Bergen, 2002). They know they are pretending, and it requires them to imagine they are someone else (e.g. actions or thoughts).

Role-playing games exhibit the process of *imaginary play* because players can interact with other players, role-play and think of new ideas. Consequently, the gaming experience is subjective because it relies on participants' interactions with the environment and the responses of other players (Feinstein *et al.*, 2002). In role-playing games, players have to pretend, act and play like children.

In general, playing computer games is an imaginary situation or abstract thought because they are governed by a set of rules (Vygotsky, 1978). Most of the rules in computer games are abstract. Hence, players have to interact with the gaming environment in accordance to their common sense understanding or theory of mind.

> *The term theory of mind refers to a kind of common sense understanding of the world that involves… a range of mental states, such as thoughts, beliefs, and desires* (Nielsen, 2015).

People's behaviour is driven by their perception, belief, imagination and meaning towards the situation and sometimes it may be contrary to how it really is (Vygotsky, 1978; Nielsen, 2015). The theory of mind is essentially developed by the ability of *imaginary play* (Lillard, 2001; Nielsen, 2015). In a game, the players' success or failure may depend on their theory of mind, whether they have the right or wrong understanding of the game's world and rules.

Learning Mathematics in Classrooms: Similarly, mathematical concepts are also governed by a set of rules that require imagination and common sense understanding. For instance, a teacher has mentioned that mathematics requires students to visualise the rotation of the earth and existence of latitude and longitude [refer to section 5.2.4]. Mathematics is an abstract concept. For some students, mathematics may not be easily understood or acceptable because they do not have the spatial ability to imagine the abstract concept.

In schools, the learning environment is normally very formal and serious. Today's schooling system is well-organised, rigid and confined in a classroom teaching environment. It has taken away that absolute thrill of learning through exploration and imitation which they have enjoyed when they were young children. There is no *imaginary play* or role-playing in schools. Students are learning and being themselves. They are not role-playing or hiding behind the game characters. So, if they make any mistake during learning, they have to bear serious consequences – failing an exam, being expelled from schools or facing social embarrassment. In a classroom learning environment, the objective is to get everything right. In computer games, however, players have no fear of failure and less social embarrassment because they are interacting with computers. The failure may not link directly to them but to the games' characters. Furthermore, the players know that they are playing and pretending. So, there is no serious consequences of making mistakes.

Learning from the gaming context, role-playing activity can be adopted in mathematics classroom learning. For instance, a student has mentioned that a teacher can act and role-play the inverse function to make learning more interesting and memorable [refer to section 6.5.2]. The use of role-playing to teach mathematics have been discussed in some past studies (Williams, 2011; Kilgour *et al.*, 2015). Students may enjoy the process of role-play because it is a form of playful learning.

8.4.6 Social Interaction

Computer games are entirely social for the young generation (Gee, 2007). Children enjoy more when playing computer games with their friends than playing alone or with a computer (Shahid *et al.*, 2014). The students have also mentioned that they like to play certain types of computer games because they enjoy the collaboration and interactions with their friends or siblings in the games [refer to section 6.3.4]. For instance, in a role-playing game, each player has to create a character to interact with the fictional world and with other players. In the creation of a character, the player may choose the character's features and attributes, and each character has unique strengths and weaknesses. Like human being, no one character is perfect. Therefore, players have to build up their interpersonal skill because no character can survive without cooperating with others (Squire, 2003; Feinstein *et al.*, 2002). Nowadays, many multiplayer games such as MMORPGs are addictive and engaging due to the social interactions. Social interactions in computer games can be in the form of virtual behaviour, in-game interaction, interpersonal communication and group relationships through the creation of guilds.

Other than computer games, the current young generation also uses various types of computer technologies to engage in social interaction. For instance, the students spent approximately 2.82 hours per day communicated with others (e.g. texting, calling or online chatting), and spent approximately 1.6 hours per day on Facebook. Apparently, modern technologies have altered the nature of social interactions especially amongst the young generation. Teenagers are more likely than adults to use computers and they might form *electronic friendships* with computers instead of real friendships with humans beings (Subrahmanyam *et al.*, 2001). In fact, the teenagers who spend a lot of time on a computer or the Internet are not addicted to the technology, but they are engaged with their friends (Perle, 2014). Similarly, teenagers who constantly communicate online (e.g. playing games, email, Facebook, Skype, etc.) are not antisocial, but rather they are preparing themselves with the essential communication skills required for their future adulthood at work (Perle, 2014) – a future which will be potentially very different to the present day in which adults live.

Learning Mathematics in Classrooms: In schools, students are expected to learn mathematics without peer interaction because learning is regarded as an individual obligation. However, children do like to learn together with their peers. For instance, the parents have mentioned that children like to attend tuition classes because they want to play and learn together with their friends or siblings [refer to Section 7.1.2]. The contact and experience with peers give them the joy, meaning and purpose of learning.

Throughout childhood, peer interaction is essential for the development of cognitive, social and communication skills (Bruce and Hansso, 2011; Ostrosky and Meadan, 2010). Young children play with other children to make friends, use social skills to ask for or share their toys, and role-play or act during pretend play. There are many skills that can be learned best through peer interactions without too much involvement from adults (Bruce and Hansso, 2011). For instance, peer interaction such as pair work can greatly benefit students' understanding of mathematical concepts (Zorfass and Brann, 2014). To promote peer interaction in learning, teachers should plan classroom activities carefully. Teachers should determine the appropriate number of students per group, identify which students should be grouped together, model effective ways of interaction, provide students with relevant learning materials, and provide appropriate guideline and timeframe (Zorfass and Brann, 2014; Ostrosky and Meadan, 2010). During peer interaction, students are expected to share knowledge, take turns, ask and offer assistance to their peers to learn.

8.4.7 Learn and Relearn

A computer game is a good example for transfer of learning. Skills (e.g. working memory and attention span) improved through playing the game are transferable into the real world (BBC, 2015). Sometimes, players will realise that basic skills learned in a game is transferable within the game itself, to other games or other genres. For instance, a student who loved to play *FIFA, NBA* and *WWE* mentioned that he could learn sports rules in those games [refer to Section 6.3.5]. The student may come to realise that certain teamwork and playing strategy in *FIFA* is also applicable to *NBA*.

Knowledge transfer in computer games is not merely a simple transfer (Egenfeldt-Nielsen, 2005). According to constructivism, knowledge is not passively received but actively constructed through interaction with their environments.

> *The function of cognition is adaptive and serves the organisation of the experiential world* (Glasersfeld, 1989, p.162).

In games, players have to actively engage and construct their knowledge through the artefacts in the game world (Egenfeldt-Nielsen, 2005). Knowledge is acquired through trial and error, and the learning process is managed through control over the game character (Vos *et al.*, 2011). Once the player has integrated new knowledge into his or her existing mental model, the knowledge is easily transferable between contexts (Egenfeldt-Nielsen, 2005).

To enable transfer of knowledge, players always have to *learn* and *relearn*. If a player wants to achieve a new and higher level of skill to reach a higher level of difficulty, or in a new game, the player has to rethink and transform the *routinised* mastery (i.e. skills that have been learned, well-practiced and automatic) and then master the new skills through practice again (Gee, 2007). A cycle of *automatisation, adaptation, new learning,* and *new automatisation* allows learning transfer in games (Gee, 2007). Players who constantly practise and go through the cycle would gradually develop spontaneous *automatisation* (i.e. learn) and *adaptation* (i.e. relearn) skills.

Since young, digital native children are playing various types of digital games such as video games, arcade games and computer games. Through games, children are well-trained in the cycle of *automatisation, adaptation, new learning* and *new automatisation* because most of the digital games challenge different levels of cognitive abilities at the various stages of the games. The skill developed allows the children to be fast learners to *learn and relearn*.

Learning Mathematics in Classrooms: In this study, many teachers have claimed that students are not capable in transferring and applying knowledge learned to solve non-routine problems [refer to Section 5.1.1 and 5.2.3]. Although HOTS has been taught in schools in recent years, students do not seem to be able to solve non-routine problems especially in Additional Mathematics. One of the possibilities could be the late introduction of HOTS in schools. Many students only first heard of or exposed to HOTS during secondary education, and it was deemed to be too late.

On the other hand, students have been trained to transfer learning in computer games since young. Learning from the gaming context, students should not only be taught to solve mathematics problems, they should be taught of how to *learn and relearn* to enable knowledge and skill transfer. Transfer is only possible if students learn and understand the current problem-solving methods and then they can relearn in a new situation. The finding in this study has indicated that the students have the potential to *learn and relearn* using various computer technologies. Essentially, they have gone through the cycle of *automatisation, adaptation, new learning,* and *new automatisation*, spontaneously and effortlessly. Similarly, students can develop the process of *learn* and *relearn* in mathematics but it should have started when they were young. If students have learned to relearn mathematics since young, it would be easier for them to assimilate new knowledge.

This section has discussed the third option to gaming pedagogy that tends to be more viable and acceptable by the students, teachers and parents. In the context of this study, the use of computer games whether educational or COTS games is not feasible given the practical constraints of time, expertise and resources available in schools. Students do appreciate the advantages brought by computer games (e.g. educational or COTS), but they feel more comfortable learning with the presence of a teacher. Furthermore, teachers and parents prefer conventional classroom learning to computerised delivery as they typically see computer games as just *playing devices*, a *health hazard* and a *waste of time*.

8.5 Conclusion

A computer game is a good teacher – fun, motivating and engaging. To push the gaming pedagogy into a classroom, making a drastic change to the current teaching approach may not be appropriate. It requires a series of adjustment to the current practice – design of the mathematics problem, learning attitude and classroom activities.

Mathematics definitely requires practice, and not merely relies on memorisation of meaningless routine algorithms. Firstly, a *mathematics problem* should be challenging and non-routine (i.e. requires novelty and creativity), but it must be attainable with persistent efforts. Students should be given an opportunity to learn by doing (i.e. bottom-up approach), and actively testing the cause-and-effect of different approaches so that HOTS skills can be learned through the learning process. Secondly, during the *process of problem-solving*, instant feedback should be provided to prompt students to continue learning. The feedback could be an intrinsic reward (e.g. praise, helps and recognitions) or indication of mistakes made in a constructive way. Thirdly, the knowledge and learning skills should be *transferable*. Students should be taught how to *learn-and-relearn.* Teachers should design their lesson plans carefully to enable learning to be built on students' prior knowledge whether through the process of assimilation or accommodation.

Other than the design of the mathematics problem, *learning attitude* towards mathematics is also crucial. During the process of learning, students should be allowed to attempt endlessly until they succeed without the fear and stress of failing or making a mistake. Mistake should be seen as a way to learn rather than a roadblock. In games, a child makes many mistakes while learning, but eventually they master what they are trying to do – no stress, no dreadful punishment and just keep on trying. However, it is hard for adults or even the education nowadays to accept mistakes. We all make mistakes and if we did not make them, we would never learn anything. The same rule should apply to mathematics education. Learning is about discovery and actually there are untold blessings hidden within every mistake.

Learning from the gaming principles, some *classroom activities* can be introduced such as story-telling, role-playing, collaborative learning and the use of visual aids. Teachers can use story-telling as part of the mathematics lesson, either telling their own story or story of others. Children do like to play and learn together with their friends. Thus, students could be asked to work in a group to role-play different characters of a story related to mathematics. For instance, a student may act as a car dealer, bank officer, mathematics professor or researcher. Acting or role-playing requires imagination and common understanding of what the character should be doing. Other than role-playing, students may be given a task to work in a group. In the group work, every student should be given a unique responsibility so that they could help each other to succeed a goal and the achievement of the group should be recognised.

Chapter 9: Conclusion and Future Research

9.0 Introduction

The purpose of this chapter is to summarise the main findings and to present the main conclusions drawn from the results of this study. Then, recommendations for the future studies are discussed at the end of this chapter.

In Malaysia, as in elsewhere within asian region, mathematics has been taught using traditional didactic method. It is primarily in the form of face-to-face lectures, chalk and talk, drill-and-practice and repetition of instructions (Bragg, 2003). Many students find traditional methods of mathematics instruction dull, boring and irrelevant (Chang, 2009; Wilkinson *et al.*, 2001; Sedighian, K., & Sedighian, 1996; Venkateshwar Rao, 2016; Jablonka, 2013). Nevertheless, students are easily engaged in playing computer games (Chang, 2009; Offenholley, 2011).

The findings from these previous studies had triggered my interest to explore the potential use of gaming pedagogy to learn mathematics. The success of computer games in capturing hours and hours of gamers' attention had sparked my interest to identify the design strategies and intrinsic motivations in games that encouraged players to learn and go through successively more challenging goals and tasks in the games, voluntarily and effectively. Based on the advantages presented by computer games, the following research question was raised:

> *How mathematics pedagogy could be influenced by an understanding of children's engagement with computer games?*

To answer the research question, two case studies were conducted at two secondary schools in Sarawak involving students, teachers and parents. Operational research questions that I derived from this research question had been used to govern the research process of this study. These were:

1. What were teachers', students' and parents' perceptions towards mathematics education?
2. What were teachers', students' and parents' technological experiences?
3. What were teachers', students' and parents' gaming experiences?
4. What were teachers', students' and parents' perceptions of the use of educational computer games to learn mathematics?

5. How did children learn through computer games? What transfer issues were there?

To seek the answers for the above questions, the literature on mathematics learning, motivation, digital game-based learning, educational gaming model, playful learning and learning theories in computer games were reviewed. A mixed methods approach using survey and interview was used to grasp an understanding of the above operational research questions. Convergent parallel design was employed to collect and analyse the quantitative and qualitative data.

9.1 Summary of Major Findings

9.1.1 What were teachers', students' and parents' perceptions towards mathematics education?

Teachers

a. ***Limitation of the education system:*** From the teachers' points of view, students' poor performance in mathematics was partly due to the design of the Malaysian education system that placed strong emphasis on exams rather than learning of HOTS and metacognitive skills to solve non-routine problems. The education system had somewhat shaped or constrained the teaching strategy (i.e. drill for exams), which had resulted in a setback for mathematics learning.
b. ***Conventional methods of instruction:*** The main pedagogy used to teach mathematics was the traditional classroom teaching – chalk and talk, routine practice and occasional use of group discussions. These approaches were claimed to be the best and effective ways to teach mathematics. The teachers wanted to control what and how students learned (i.e. teacher-centred).
c. ***Approach to problem-solving:*** Polya's (1945) four steps of problem-solving method was taught in the class – understand a problem, devise a plan, carry out the plan, and reflection. Students were expected to follow a step-by-step predefined strategy laid down by the teachers. Nevertheless, some students disregarded the instruction as they wanted to get things done fast and easy.
d. ***Students' negative attitudes:*** Most of the students were claimed to be not confident and had no interest in learning mathematics. They were not motivated to attempt challenging questions, could not apply the knowledge learned, and were weak in cognitive and metacognitive skills. In addition to that, female students were weak in spatial ability and male students were hard to discipline themselves to do extra practices.

Students

a. ***Mathematics was fun:*** From the students' points of view, mathematics was fun and interesting because it was challenging and hard (i.e. hard fun). The students liked to solve challenging questions provided they could grasp and understand the problems.
b. ***Effective teacher:*** The main criterion of a good mathematics teacher was patience. A teacher was expected to help and guide every individual student, and being attentive to students' various learning styles and needs. Furthermore, the students wanted an interesting and meaningful mathematics lesson, and to be actively involved in learning.
c. ***Learning difficulties:*** Three learning difficulties among the students were revealed - long calculation, spatial ability and HOTS. Male students found it tough and tedious to perform long calculation because they were prone to careless mistakes (i.e. lockstep). Female students found it tough to visualise abstract concepts (i.e. spatial ability). Both male and female students revealed their worries and difficulties in learning HOTS.

Parents

a. ***Mathematics was useful:*** From the parents' pragmatic point of view, mathematics was important because it was useful to get into a university or to get a job. They wanted to ensure that their children left school with good exam grades (i.e. exam-oriented).
b. ***Conventional methods of instruction:*** Traditional classroom teaching was thought to be the best teaching approach. The parents wanted their children to listen and follow *teachers' ways* to learn mathematics. However, the parents would prefer if the teachers could foster an interactive, fun and interesting learning environment.
c. ***Routine practice was important:*** Many parents believed that the best way to learn mathematics was to do a lot of practices. In view of that, they sent their children for tuition and urged teachers to give more homework.

In this study, the students revealed that they liked mathematics, but the teachers labelled them as having a lack of interest and motivation to learn mathematics. It could be the existing teaching approach (i.e. top down, step-by-step and not flexible) that disinterested the students to learn. Most of the students could not apply the knowledge learned (i.e. no *learning transfer* and lack of HOTS), lacked of discipline (i.e. no *instant feedback* to indicate right or wrong calculation) and had weak spatial ability. Essentially, many students were lacking in *metacognitive* skills and *affective* dimension of mathematics learning.

In mathematics education, three parties had come into an agreement that teachers played a significant role in teaching. Even so, the students and parents urged the teachers to use more creativity and innovation in teaching and learning (e.g. *stories*), and give a partial control to students so that they could learn actively and effectively (e.g. *learning by doing*). The instant experience was important for the students (i.e. *process-oriented*), but the teachers were pressured to complete syllabus and drill students for exams (i.e. product-oriented). The teachers' teaching approaches were driven by their responsibility to disseminate knowledge and produce high-achieving students. In fact, this was also to fulfil the parents' expectations who wanted their children to perform well in exams for better future career prospects (i.e. pragmatic perspective). The differences in expectations among the groups of respondents were inevitable because they have diverse roles and responsibilities.

9.1.2 What were teachers', students' and parents' technological experiences?

Teachers

Pragmatic accommodation of technology for work: In the technological aspect, male and female teachers used computers differently. The male teachers were more proficient and had more interest in computer technologies, and used them for work, entertainment and some advanced usage. As for the female teachers, they mostly used computers for work purposes. The teachers' technological usage was basically built up pragmatic accommodation of technology into their existing modes of working.

Students

Digital native characters: The students were characterised as digital natives because they grew up in an environment surrounded by computer technologies and they were proficient in using these technologies in many aspects of their lives - communication, entertainment, office applications and many advanced usages. They used computers on personal initiative and always used computers to surf the Internet, listen to songs, communicate with people, play games and get connected to social media. All these involved using the latest technologies.

Parents

Pragmatic perspective: As for the parents, they used computers and smartphones to complete their daily routine work. The working parents normally used computers for work and non-working parents used computers for entertainment. They were proficient in general basic skills such as typing, surfing the Internet, and checking emails. For the parents, technological skills were something that they had to learn to survive in the fast-changing world, therefore technological skills were picked up due to necessity.

The teachers mainly used computers for work (i.e. pragmatic accommodation); the students used computers in every aspect of their lives and the parents used computers only if necessary. If computer games were to be introduced in schools, the teachers would most likely accommodate the games to fit into their existing teaching style – to drill students for exams. The students might not find it exciting because they wanted something new and interesting such as the latest augmented reality games. The parents who had pragmatic perspective would most likely think that the use of computer games to learn mathematics was not necessary at all.

9.1.3 What were teachers', students' and parents' gaming experiences?

Teachers

a. ***Male teachers played more than female teachers:*** The male teachers played a variety of computer games, whereas female teachers either did not play or played only puzzle games.
b. ***Male teachers were more positive towards computer games:*** The male teachers saw many benefits of gaming especially in learning of various metacognitive skills, but female teachers were more concerned with the possible drawbacks brought by computer games such as game addiction, health hazard and violence.

Students

a. ***Male and female students played computer games:*** Both male and female students played various types of computer games. However, male students were inclined to spend more time playing computer games.
b. ***Male and female students favoured different types of games:*** The male students preferred strategy and sports games, and their favourite computer and Facebook games were *FIFA* and *Clash of Clans*. Female students liked to play puzzle and simulation games, and their favourite computer and Facebook games were *The Sims* and *Candy Crush* respectively.
c. ***Students liked role-play games:*** The students liked to fantasise themselves as the virtual characters (e.g. hero and expert) for having various special capabilities and doing many things that they could not do in real life.
d. ***Motivating and beneficial:*** The students enjoyed the challenge, thrill, excitement, competition and collaboration in games. They also reported many benefits of gameplay from the cognitive, metacognitive and affective aspects.

Parents

a. ***Not useful:*** From the parents' points of view, playing computer games was presumed to be not useful. Most of the parents played only simple mobile apps or puzzle games when they felt bored as a leisure activity.
b. ***Negative effects of computer games:*** Similar to the female teachers, most of the parents reported the disadvantages of computer games over the advantages specifically in game addiction, violence and offensive content.

Most of the teachers and parents had no interest and they were not positive towards computer games. If computer games were to be introduced in schools, the teachers would most likely use only puzzle games. They might not see the educational benefits of other types of games such as strategy, role-play, sports or simulation games that the students liked. The teachers might be influenced by their personal fear and prejudice towards computer games. The students, however, liked to play various types of computer games, and recognised many benefits of gameplay. Thus, it was conjectured that the students would be more positive towards the use of educational computer games in learning mathematics.

9.1.4 What were teachers', students' and parents' perceptions towards the use of educational games to learn mathematics?

All respondents

a. ***Neither educating nor entertaining:*** Most of the teachers and parents had never been exposed to educational computer games. Some students who had ever played educational computer games, found the games monotonous, not exciting, with no storyline and lacked complexities. Some parents also revealed that educational computer games were only suitable for children but the games were neither educating nor entertaining.
b. ***Combination of classroom teaching and computer games:*** All respondents (i.e. teachers, students and parents) recommended a combination of classroom teaching and computer games as the best approach to DGBL. Computer games could be used as a supplementary (i.e. optional) activity to the conventional classroom teaching, mainly for more drill-and-practice.

Teachers and Parents

For training and practices: The teachers and parents believed that good educational computer games should provide training and practices.

Students

a. ***Learning from problem-solving:*** The students believed that good educational computer games should allow them to learn from problem-solving and mistakes in the games.
b. ***Positive but optional:*** They were happy with the use computer games, but it was optional. The presence of teachers was more crucial.

Teachers

Obstacles of implementation: Although most of the teachers did not put off the idea of educational computer games, they raised their concerns for time constraint, insufficient of computer facilities, incompatibility of exams format, and inappropriate use for topics learned.

Even though the combination of classroom teaching and computer games was regarded as the best out of all methods of implementation, the difference in expectation could pose a bigger challenge. The teachers and parents wanted to engage students to do more practice with edutainment (i.e. behaviourist learning), but the students expected an active involvement as in COTS games to regulate and construct knowledge (i.e. experiential learning). The difference in expectation could be one of the obstacles to the deployment of educational computer games. Furthermore, the use of computer games in schools might not be feasible given the reality constraints (e.g. time, facilities and syllabus) and absence of positivity among the teachers.

9.1.5 How did children learn through computer games? What transfer issues were there?

In the existing mathematics education as discussed in Section 9.1.1, it is understandable that the learning is (a) exam-oriented and predominantly product-oriented, (b) passive and focused on routine practice (i.e. repetition of stimulus and responses), involving (c) no instant feedback, having (d) no story or imaginary play, (e) teacher-centred and lacks peers' interaction, (f) where the knowledge is not easily transferable and that (g) HOTS is taught formally. Children, however, learned differently in computer games – (a) process-oriented, (b) learn by doing, (c) instant feedback is provided, (d) involve in stories and imaginary play, (e) engage in social interaction, (f) learn and relearn, and (g) metacognitive skills are learned informally.

a. Process-oriented

Computer games are process-oriented and engage players in *playful learning* that is *pleasantly frustrating*. It is also termed as *hard fun*. Learning in computer games is frustrating (i.e. hard, mistake and failure) but life-enhancing (e.g. fun, thrilling and exciting) (Gee, 2007). Fun is a kind of *pleasure* that comes from curiosity, challenge, control, problem-solving, competition and achievement (Denis and Jouvelot, 2005; Amory *et al.*, 1999). All these motivational elements drive players to replay the game numerous times. Curiosity and playfulness are human nature (Stafford, 2012). Furthermore, most the addictive computer games are built on competitions and that victory is a pride of players or team members.

b. Learning by doing

In computer games, players are active learners because they learn by doing (i.e. experiential learning) or learn by *trial and error*. Knowledge is constructed through continuous practice of discovery and reflection of concrete gameplay experience in the game world (Fenwick, 2001; Kiili, 2005a; Gee, 2007). Learning is a cycle of probing the world by experimenting something; feedback will be observed for reflecting on the action; forming a hypothesis to result in better generation of solutions; re-probing the world to test this hypothesis; and then accepting or rethinking the hypothesis by taking the constraints and resources into consideration (Gee, 2007; Kiili, 2005b). Children learn best through trial and error (Beck and Wade, 2006). Thus, the practice in games fit well into their learning approach.

c. Instant feedback

Ongoing instant feedback in computer games is important because games work on the principle of *performance before competence*. The instant feedback allows players to subconsciously reflect on what they have done and observe the feedback about the success or failure of the action (Gee, 2007). Instant feedback regardless of *reward* or *punishment* provides an affirmation, motivation, clue and direction leading the players towards a final goal. In order to learn, players have to make mistakes and be given limitless opportunities to reattempt. Making mistakes in computer games is not a lockstep because the mistakes are always corrected before the games progress.

d. Stories and Imaginary Play

Nowadays, many computer games are built on compelling stories and related to imaginary play. The best thing about stories is to connect information in an impressive way, and form people's emotional state about the characters in the stories (Zazkis and Liljedahl, 2009). Stories help people to link the real world to fantasy and imagination (Ellis and Brewster, 2014). In computer games, the imaginary situation is governed by a set of rules (Vygotsky, 1978) so players have to interact with the virtual world in accordance to their common understanding. In other words, the stories in computer games help to connect players to the virtual games' world or even the virtual characters.

e. Social Interaction

In computer games, players are self-learning or learning through interactions with other players. Social interactions in computer games can be in the form of virtual behaviour, in-game interaction, interpersonal communication and group relationships through the creation of guilds. In games, a player's experience is subjective and unique because it relies on the player's interactions with the environment and other players (Feinstein *et al.*, 2002). Children enjoy playing computer games with their friends than playing alone (Shahid *et al.*, 2014). Thus, children who spend a lot of time on computer games are not only addicted to the games, but also engaged with their friends.

f. Learn and relearn

In computer games, the basic skills in a game are transferable within the game itself, to other games or other genres. Knowledge is not transferable if someone cannot *learn and relearn*. To transfer learning in games, player can rethink and transform the routinised mastery, and then master the new skills through practice again (Gee, 2007). A cycle of *automatisation, adaptation, new learning,* and *new automatisation* allows learning transfer in games (Gee, 2007). Players who constantly practise and go through the cycle would gradually develop spontaneous *automatisation* (i.e. learn) and *adaptation* (i.e. relearn) skills.

g. Learning of metacognitive skills

Metacognitive skills such as multitasking, land navigation, teamwork, problem-solving and concentration skills can be learned through gameplay (Cherenkova and Alexandrov, 2013). In this study, most of the students have also reported learning of these metacognitive skills.

Multitasking

There are two types of multitasking that can be learned through computer games - *time pressured multitasking* and *multitasking with a memory load*. In a *time pressured multitasking,* the actions in games continue while the player is making a decision (Zelinski and Reyes, 2009). In a *multitasking with a memory load*, the player has to manage multiple characters simultaneously while achieving his or her goal (Zelinski and Reyes, 2009). Multitasking is a common behaviour among the digital natives.

Land Navigation

In computer games, players can learn land navigation skills such as the use of compass, map, direction, geographical locations and sense of direction. These land navigation skills require spatial ability (Cuqlock-Knopp and Whitaker, 1993; Self and Golledge, 2000). The game's world is transparent, so players have to visualise the directions of other players, resources, enemies and goals

(Beck and Wade, 2006). Playing computer games could enhance one's spatial ability (De Lisi and Wolford, 2002; Mitchell and Savill-Smith, 2004). Thus, females who are known to be weak in spatial skill are urged to play more action or simulation games (Mitchell and Savill-Smith, 2004; Paul, 2013).

Teamwork

In computer games, players are learning teamwork skill because they are helping each other to succeed by offering and receiving assistance. In some games, players can ask for extra life, ticket or assistance from other players. This could explain why children like to play multiplayer games (Gee, 2007; Prensky, 2001a, 2001b). For instance in role-playing games, like human being, no one character is perfect as each character has unique strengths and weaknesses. Thus, players have to build their interpersonal skill because no character can survive without cooperating with others (Squire, 2003; Feinstein *et al.*, 2002). For example, each player may have a different role in a guild, such as a tank, support, healer or damage to do a quest. None of the role can be eliminated.

Problem-solving

In computer games, players are active problem solvers. The process of problem-solving follows a bottom-up approach. Players are not restricted to a predefined pathway so they are free to use numerous ways to explore the games. Although the game world is pseudo-reality, computer games provide a good environment for players to practise because the games are responsive (Gee, 2007). Furthermore, the game world is logical, not inexplicable and a lot simpler than reality (Beck and Wade, 2006). In games, there is always an answer or ending. Although problem-solving in games may not be practical in reality, there are certain gaming economics that can be learned through computer games.

Concentration

In computer games, information is presented in numerous modalities but players are learning to focus or divert their attention to certain elements. For example, action video-games usually require players to attend to different multiple objects within complex visual environments (Latham *et al.*, 2013). This is similar to the *multitasking with a memory load* (Latham *et al.*, 2013; Zelinski and Reyes, 2009). However, it should not be assumed that children who are capable of multitasking cannot concentrate (Brown, 2000). Perhaps most of the past studies have reported enhancements in visuospatial attention among computer game players (Latham *et al.*, 2013; West *et al.*, 2015; BBC, 2015).

In this section, computer games are motivating because they satisfy humans' innate psychological needs – *competence, relatedness* and *autonomy*. Players feel *competent* because every challenge is achievable though it is tough (i.e. hard fun or pleasantly frustrating), instant feedback is provided to indicate success or failure, learning is easily transferable (i.e. learn and relearn) and opportunities are given to demonstrate their capability of using multitasking, land navigation, spatial ability and concentration skills. Players also feel connected to other players (*relatedness*) through collaboration, interactions (e.g. offer and receive help), role-playing, virtual behaviour, group relationship, and imaginary play in a story. Lastly, players can self-organise and feel independent (*autonomy*) because the games facilitate self-learning. Players are active problem solvers that learn by doing (i.e. continuous discovery and reflection), free to use various ways to explore the games (i.e. bottom up), work on trial and error, and are given power to make unlimited attempts to learn from mistakes.

Apparently, there are many good learning principles that can be learned through computer games. It should be noted that gaming knowledge and skills cannot be learned or mastered merely through reading a book or manual, watching a game tutorial, or being taught by someone. The knowledge and skills are usually embedded implicitly in the games. Thus, continuous practice situated within the gaming context is required to construct the meaning of the knowledge. There is no way to experience all the good pedagogy in computer games without someone playing the games. This is the major difference between the informal learning in computer games and the formal education in schools.

9.1.6 How could mathematics pedagogy be influenced by an understanding of children's engagement with computer games?

Learning from the gaming principles in good computer games, the following mathematics pedagogy is proposed.

a. ***Pleasantly frustrating (process-oriented):*** A *mathematics problem* should be challenging and non-routine (i.e. requires novelty and creativity), but it must be attainable with persistent efforts. There should be a balance between the challenge and support so that the learning experience is hard and frustrating, but fun and pleasant at the same time.
b. ***Trial and error (learning by doing):*** Students should be given the control of their learning environment such as what, when and how to learn. Students should be given the freedom to experiment and reflect on the cause-and-effect of different approaches in relation to problem-solving. Knowledge and skills are gradually internalised through continuous practice.

c. ***Prompt for right or wrong move (instant feedback):*** Students need continuous and immediate help in every step of problem-solving. Errors should be instantly notified when students are making wrong moves. Mistakes should not be seen as failures to learn, but as the lessons that need to be learned to avoid the same mistakes.
d. ***Storytelling and role-playing (stories/imaginary play):*** The use of storytelling to teach mathematics is motivating because stories are realistic expressions of the children's experience and built on their imaginations (Starcic *et al.*, 2015). The stories could be fairy tale, fiction, history or teachers' real life experience. Students not only can listen and imagine the scene in the stories, they can also create and play out the stories (i.e. role-playing).
e. ***Collaborative learning and competition (social interaction/teamwork):*** Sometimes, students may find it easier to learn and understand from peer interaction than teacher's explanation. Collaborative learning can foster social interaction and reflective thinking. Each student should be given a unique role in a group so that they feel recognised and have a sense of belonging to learn and work towards a common goal. The task given to each group should be challenging, built on competition, and requires complex skills.
f. ***Learning transfer (learn and relearn):*** To enable learning transfer in mathematics, students should be taught how to *learn and relearn* by going through the process of *automatisation, adaptation, new learning and new automatisation* as in computer games. However, learning transfer should be taught since young because metacognitive skills are developed over time.
g. ***Bottom-up basic skills (problem-solving):*** Mathematics learning should start with the basic skills that lead to learning of more advance patterns or algorithms. At the fundamental level, every cognitive and metacognitive skill should be identified and learned exclusively so that the mastered skills can be combined to solve more advance and complicated problems.
h. ***Use of visual aid (spatial/land navigation):*** Other than pictures, visual aids such as PowerPoint, animations, courseware or even computer games could be used to demonstrate abstract concepts in mathematics.

This section discusses how mathematics pedagogy can be influenced by an understanding of children's engagement with computer games in various aspects – cognitive (e.g. bottom-up basic skills), metacognitive (e.g. the use of visual aid) and affective (e.g. collaborative learning). The proposed *mathematics pedagogy* is applicable to the process of problem-solving and classroom activities. The process of problem-solving in mathematics should be pleasantly frustrating, enabled trial and error, worked on bottom-up basic skills, prompted for right or wrong move and enabled learning transfer. For classroom learning, teachers may consider some activities such as story-telling, role-playing, collaborative learning, competitions and the use of visual aids.

Other than making the pedagogical change, the positive *attitudes* among the teachers and students are crucial too. A mistake should be seen as a way to learn rather than a roadblock. Students should not be afraid of making mistakes; failures should not be penalised dreadfully. Students should be allowed to keep on trying and learn until they have succeeded. As a matter of fact, it is hard for education nowadays to accept mistakes. Learning is about discovery. There are untold blessings hidden within every mistake.

9.2 Theoretical Implications

The respondents of this study devoted unequal attention and prominence to the various aspects of mathematics learning and the potential use of gaming pedagogy to learn mathematics. The teachers gave the most attention to the exams, syllabus completion, practice, and they would only consider the use of edutainments in teaching mathematics. Meanwhile, the parents regarded the usefulness and practical aspects to be the most fundamental reasons to study mathematics, and the use of computer games to learn mathematics was considered to be trivial. The students would like to have fun and interesting learning environment, but they did not show any interest towards educational computer games. These three groups of respondents were also found to have dissimilar attitudes towards computer technologies and COTS games. The existence of controversy is an inevitable part of any educational research. The question should be how to deal with it in such a way as to produce the best possible outcomes for all the parties concerned.

In this study, two possible pedagogical changes were studied: (1) the direct or informal learning of mathematics through computer games and (2) the learning of mathematics through the embodied learning principles of computer games. In the first option, two approaches to DGBL were considered – direct learning through educational computer games and informal learning through COTS games. Each of these pedagogical changes was considered for its practicability of implementation in the context of this study.

In past studies, the use of educational computer games to learn mathematics has suggested positive learning outcomes that are fun, motivating, engaging, and effective for learning of various problem-solving skills (Bragg, 2003; Çankaya and Karamete, 2009; Ke and Grabowski, 2007; Ke, 2008a; Núñez Castellar *et al.*, 2014; Rosas *et al.*, 2003). However, it is noted in this study that such benefits are not likely applicable for most of the students have described the games as monotonous, not motivating and lack complexities. The teachers would prefer using educational computer games (e.g.

edutainments) for teaching but this approach merely replicates the existing drill-and-practice pedagogy – same pedagogy and same students' learning experience. Apparently the learning is not fun and interesting as what the students expect.

The students, however, have indicated the fun and interesting experience of playing COTS games. COTS games are engaging and addictive (The Star, 2014b, 2014a; Stanley, 2013; Hew and Loke, 2013; Yeoh, 2013). This type of games has been used in formal classroom teaching in some past studies (Hayes, 2006; Dickey, 2011; De Lisi and Wolford, 2002). Nevertheless, it is noted in this study that the teachers and parents do not think COTS games are educational. Most of the teachers and parents are not proficient in gaming and could not appreciate the benefits brought by COTS games. In this case, this approach to DGBL is deemed to be not feasible too.

Furthermore, the use of computer games to learn mathematics in the first option, whether educational computer games or COTS games, is deemed to be impractical due to the lack of infrastructural facilities especially in the rural areas and low level of computer literacy amongst school teachers. In this study, the teachers have illustrated the problem of rushing to complete syllabus ahead of time to allow more time to drill students for examinations. The use of computer games therefore does not necessarily offer a practical pathway out of the conventional classroom teaching. Teachers may need to sacrifice some time to learn how to operate, play and prepare lessons using computer games. Furthermore, the students, teachers and parents have a common view that the use of computer games to learn mathematics is optional and not important.

Given all the above practical concerns, the use of computer games has taken something of a back seat. However, there are other definite concerns. The most pressing of these is whether changing the entire mathematics pedagogy to adopt the computer games is the best use of a DGBL. My data (briefly depicted in Figure 9.1) and the current literature reveal that it is not a practical suggestion – at least in my fieldwork context.

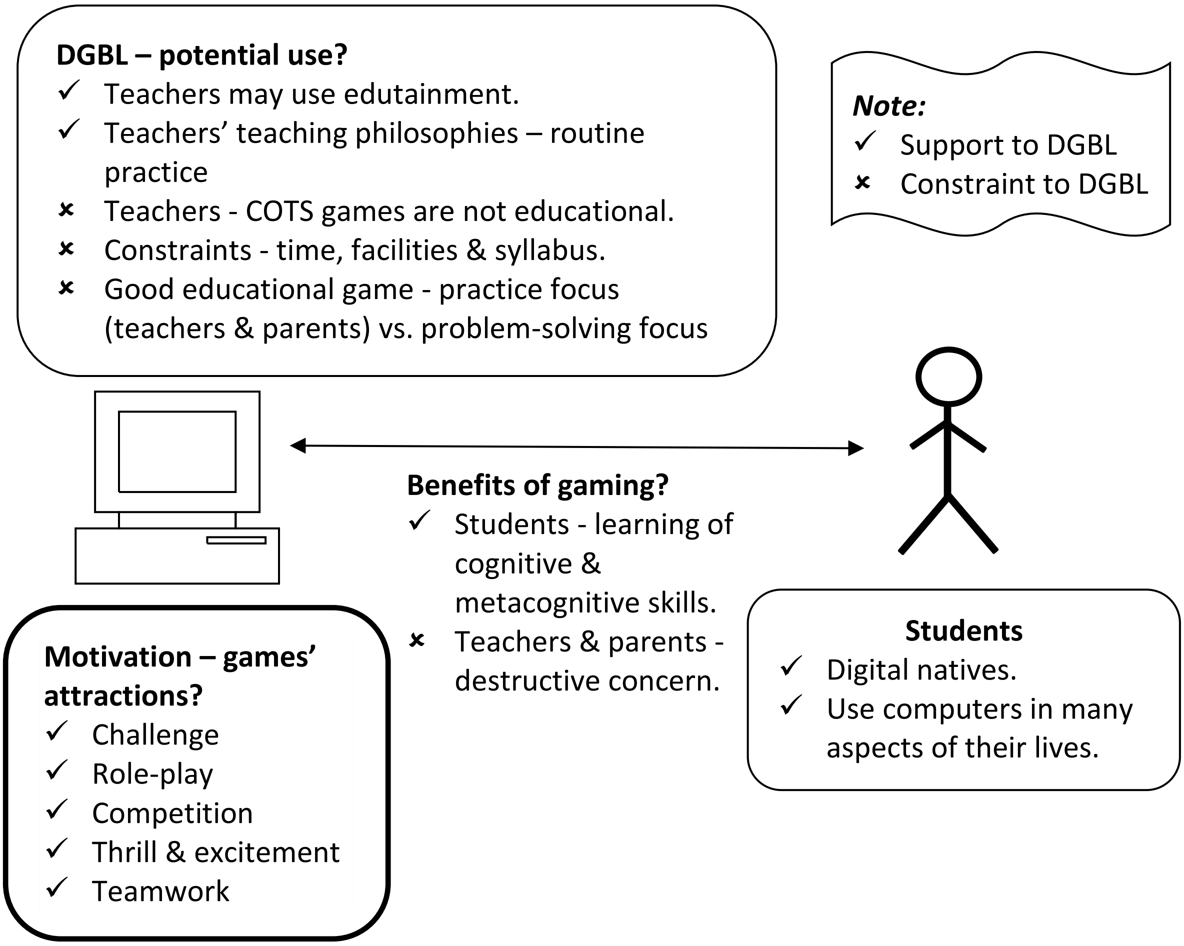

Figure 9.1: Main Findings of this Study

In this study, an alternative option is considered - (2) learning of mathematics through the embodied learning principles of computer games. The learning principles in good computer games are the best theories of learning in cognitive science and even better than the schools (Gee, 2007). Learning in computer games is characterised by:

- *process-oriented* - pleasantly frustrating (Gee, 2007); hard fun (Papert, 1998); fun, curiosity, challenge, control, problem-solving, competition and achievement (Denis and Jouvelot, 2005; Amory *et al.*, 1999; Stafford, 2012).
- *learning by doing* - on-going success (Gee, 2007); a cycle of discovery and reflection (Fenwick, 2001; Kiili, 2005a; Gee, 2007); trial and error (Beck and Wade, 2006); knowledge is internalised through practice (Farmer Jr *et al.*, 1992; Kerka, 1997; Kiili, 2005a); progressively construct complex strategies (Bottino *et al.*, 2007).
- *instant feedback* - performance before competence (Gee, 2007); limitless trial and error (Vos *et al.*, 2011; Beck and Wade, 2006); control and responsiveness (Beck and Wade, 2006); reflect on success or failure (Gee, 2007).

- *Stories and imaginary play* - works on stories (Feinstein *et al.*, 2002); governed by a set of rules (Vygotsky, 1978); theory of mind (Lillard, 2001; Nielsen, 2015).
- *social interaction* - interpersonal skill and cooperation (Squire, 2003; Feinstein *et al.*, 2002; Shahid *et al.*, 2014; Natvig and Line, 2004); friendship (Chou and Tsai, 2007) and social reinforcement as in MMORPG (Charlton and Danforth, 2007).
- *learn and relearn* - learning transfer (Gee, 2007); spontaneous automatisation and adaptation (Gee, 2007); knowledge construction and self-regulation (Vos *et al.*, 2011); integration of new knowledge into existing mental model (Egenfeldt-Nielsen, 2005).
- *Development of various metacognitive skills* – multitasking, land navigation, teamwork, problem-solving, concentration (Zelinski and Reyes, 2009; Latham *et al.*, 2013; Gee, 2007; Beck and Wade, 2006; Prensky, 2001a; Cherenkova and Alexandrov, 2013).

Learning from the embodied learning principles of computer games does not mean that all the teachers and students need to run out and start playing computer games. Mathematics pedagogy can be improved by looking at how children play games and what theory of learning in good computer games tells us. It is noted from this study that all respondents would still prefer teachers teaching in a classroom. Nevertheless, partial control could be given to students.

Many past studies have reported the benefits of DGBL (educational or COTS) in learning mathematics. However, the findings of this study do not support the idea fully. It is most likely that DGBL may only offer solutions to certain group of learners. Given the various concerns and views identified in this study, the use of learning principles in computer games is deemed to be more feasible.

Contribution to Knowledge

In this thesis I examined the *principles and practices* with computer games and extracted these into a classroom pedagogy that did not push teachers too far. This is a significant contribution of my work. I focus on the *principles and practices* with computer games instead of going after the technology. Nowadays, many new teaching innovations are linked to computer technologies because people use electronic gadgets and the Internet in their everyday lives. Many technology innovations have been blindly introduced in schools without considering the costs and benefits (e.g. PPSMI courseware), and the appropriate underlying pedagogy and learning outcomes in long term.

In the education industry, keeping up to date with technology is a great challenge – the change often fails to accommodate the old generations of teachers. More technology may cause these old digital immigrants' voices to go unheard, and might contribute to more work stress and worse still leading to early retirements. My stand in this thesis is, we do acknowledge the change of current generation of students, but at the same time, we should not forget totally some goodness of old teaching practices in schools, e.g. personal face-to-face communication. We should not devalue the rich teaching experience possessed by these old generations of teachers and make them feel worthless with certain technology enforcement. Any teaching innovations should improve instead of worsen the existing good teaching practices. The old should be valued for accumulated knowledge, on the basis of which come expertise in teaching.

In this thesis, I have explored mathematics pedagogy from a wider perspective in which I am looking at the underlying learning principles instead of just the technology as a learning tool. Most of the people do not see how gaming is applicable to different contexts in mathematics classroom - computer games are usually regarded as a waste of time. It should be noted that, I am not anti-technology or oppose to the use of DGBL, but teachers should be clear of the underlying pedagogy and learning principles. My main argument in this thesis is that, mathematics pedagogy should be improved in three major aspects:

1. *Process of problem-solving* – Mathematics problems should be challenging but attainable so that it is pleasantly frustrating; enable trial and error to encourage creative thinking and understanding; work on bottom-up basic skills to enable active learning; provide instant feedback to enable reflection and on-going success; and allow learning of how to relearn to enable learning transfer.
2. *Classroom activities* - story-telling and role-playing activities to enable students feel connected to the mathematics problems; competition to build up strong team spirit; collaborative learning to enable students feel connected to others; and the use of visual aids to help students to visualise abstract concepts in mathematics.
3. *Learning attitude* – a failure should be seen as an opportunity to learn something new and difficult. A failure is a success of discovering *what does not work*. Students should always be allowed to learn from mistakes and try again.

Hence, a more practical mathematics pedagogy is drawn out from the good learning principles of computer games to enhance teaching without over committing teachers, especially the older generations of teachers. This approach to mathematics teaching is more practical in the sense that teachers can continue with classroom teaching but gradually make slight changes to their lesson plan to experiment the effectiveness of each pedagogical change. Teachers can keep modifying their teaching style until they got the response they want - attentive learning. It would be more feasible rather than doing a drastic change (i.e. use computer games) that may result in a culture shock, resistance, wastage of resources (e.g. cost, time and training) and risking students' examination results for an unproven technology. A recent study has found that students who play computer games almost every day do perform better in mathematics, but there is no evidence to prove that computer games are the cause of the improvement (Gibbs, 2016).

It should be noted that this approach to mathematics teaching does not totally disregard the use of technology but accepts that technology could be used to support teaching whenever it is deemed to be necessary. This mathematics pedagogy offers more flexibilities in deploying a technology, e.g. the use of role-playing and story-telling activities may employ computer games too. In this case, the use of technology is optional and depends on the purpose of learning. This study has proposed a mathematics pedagogy that is more flexible and suits the teachers' teaching preferences whilst at the same time recognising the students' learning preferences.

Although this study is conducted at Miri Sarawak, the findings of this study could be generalised to some similar cases in Malaysia. No doubt all cases have their variability, differences and specificities, yet there is also a degree of uniformity across human interactions, e.g. the participants interviewed in this study are greatly influenced by a *Confusion* heritage. Their views and perceptions might be common among the Asian society. Furthermore, there will be commonality in school and teachers who follow their professional training (e.g. Malaysian teachers' training colleges), and government policies (e.g. HOTS, PPSMI). Thus, most of the Malaysian teachers may have the same concerns and views towards DGBL.

Here, I am not trying to argue that my pedagogy is perfect without any limitation. My work has laid down the fundamental principles and practices from a gaming perspective, and they should be further experimented in the actual classroom settings. As a matter of fact, students may not be able to accept this new pedagogy. Here, I am going to share a real classroom situation (consent given by Mr David - pseudonym).

Mr David has been teaching for more than 20 years, and he has a unique way to inspire students to learn independently. He always encourages his students to try, discuss and explore all tutorial questions before the solutions are discussed. He would normally ask a few students to show the calculations on the white board, and he would then explain the right or wrong steps of the solutions. Through students' solutions, he would provide feedback indicating the right ways (calculation) to solve the tutorial questions. Nevertheless, recently, he has received a few formal complaints from the students claiming that "*solutions are not provided*".

From the gaming perspective, Mr David is doing the right thing. He encourages students in (1) trial and error to enable creative thinking and understanding; (2) work on bottom-up basic skills to enable active learning; (3) provide feedback to enable reflection of what does and does not work. Apparently, the students want a fast and easy approach – obtain solutions without putting in much efforts. That could be the way how they were trained in schools since young because teachers are always perceived to be the source of knowledge and solutions. To avoid further complaint, Mr David could just distribute tutorial solutions to all students without them learning anything, but they could just memorise the teacher's solutions. The students may not know what is best for them. In this instance, Mr David may need to explain his good intention and purpose behind his teaching approach. He could explain how children learn to play a computer game (e.g. active learning, try-and-error to discover new knowledge), and he is using the same approach to teach in the class. Sometimes, students need to be informed of the pedagogy change because they may not understand what is expected from them. Apparently, students' support is one of the key success of any policy change.

9.3 Limitations and Recommendations for Future Studies

This study has raised a number of issues and limitations that might provide a basis for future studies. The limitations identified in this study as well as issues raised during data analysis are proper grounds for future research. To generate effective and achievable mathematics teaching strategies build on gaming pedagogy, there is a need for more case studies at the local level to allow further understanding of local context.

1. The sample of this study has drawn from two secondary schools in Miri Sarawak. These schools are high performance schools located in the town areas. That is the constraint in this study as other private and regular secondary schools have turned down their participations. For future studies, more case studies should be conducted in other types of schools in Sarawak especially in the rural areas to understand the local context that may have lower computer literacy and exposure to ICT.
2. During data analysis, I have come to realise that my study tends to focus only on respondents who have experience of playing computer games. This study has not explored why people do not like to play computer games. Future studies should explore the reasons behind the absence of positivity towards computer games as a way to inform the other facets of good learning theory that might be lacking in the gaming pedagogy.

3. Another issue has surfaced during data analysis whereby I tend to assume all respondents use and know about computer technologies. For future studies, a more objective investigation should be conducted to explore what the respondents feel and think about computer technologies especially computer games. Their perceptions could shape their attitudes towards the acceptance of these technologies whether as a learning companion, necessity, need or optional tool.
4. One of the results of this study has revealed that female students who like to play strategy games have good spatial ability. This finding opens for the possibility of future research to experiment female students' spatial abilities in relation to the games they play, especially strategy games.
5. Lastly, another limitation of this study is the time constraint during data collection due to the bureaucracy involved in administering a legal research. In future studies, application for data collection should be extended to one or two years as a preparation for any delay or setback in the whole process of application.

Throughout this study, I have faced many obstacles and challenges that have helped to refine my research strategies and these are the invaluable research experience that could not be obtained through reading a research book. As in computer games, I am learning by doing, learning from mistakes, and the learning is situated within the actual research setting. The meaning of every interaction and experience during data collection is unique and attached to the context of this study. There is nothing more valuable and contented than constructing my own research skills and knowledge through trial and error, and continuous practice - discovery and reflection of concrete experience in the actual research setting.

9.4 Final remark

In spite of what is often reported about the benefits of educational computer games and the use of COTS games for educational purpose in theoretical debates, the use of DGBL in practice has only offered some solutions to certain groups of learners. The benefits of employing the embodied learning principles of computer games into mathematics pedagogy have been seen to be more comprehensive and sustainable in the long-term.

This PhD work has given me an invaluable experience that cannot be gained elsewhere.

- **Research:** I learned how to conduct qualitative and mixed methods research from the design of a study, data collection, data analysis to the final interpretation.

- **Personally:** I have learned to be a better and more effective person. I have learned how to work tirelessly under great time pressure – dividing my time between PhD study and my teaching/administrative responsibility in the university. During the process, I had to wrestle with many difficulties that were beyond my control. It really tested my determination, research skill and problem-solving skill.
- **Academically:** The findings of this study have greatly benefited my personal teaching career because it has helped me to think of the possible change in my own ways of teaching. Though I am not teaching mathematics, some of the good gaming pedagogies can be applied into the modules that I am currently teaching, e.g. C programming, MATLAB. Moreover, this study has helped me to better understand my digital native students.

Finally, I strongly believe that the findings of this thesis can provide interesting insights to mathematics educators as well as educators in general. I myself have been inspired and motivated by the findings of this study.

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Appendices

Appendix A: Interview Questions

Interview Questions for Mathematics Teachers

Section 1: Background

- How old are you? _________
- What is your completed highest level of education?
- Could you tell me about your teaching experience? How many years have you been teaching mathematics? Which levels of students did you teach? What mathematics subjects do you teach at the moment?

Section 2: Mathematics Teaching Experience

- Recently, Malaysian students showed poor rankings and average scores in both Trends in International Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA). What do you think about this?
- How do you describe your students' attitudes towards mathematics? Is there any difference between male and female students in their attitude towards mathematics? What are the strategies used by your students to solve mathematics problem step by step – do they use any strategy such as analyse the problem, calculate the answer and then check for problem solution? How would you describe your students' ability in solving mathematics problems? How would you describe their understanding or analytical thinking skill?
- Tell me about the approaches you used to teach mathematics. Do you use group discussion, games, etc.? Have you ever used computer technologies such as the Internet or any software to teach mathematics in the classroom? I*f "Yes"*, could you explain briefly? How was the learning outcome – fun, interesting, effective, etc.? Why do you think that it is (not) fun/ interesting/ effective, etc.? How do you motivate your students to learn, do you use any "tricks" to make the lesson easier and fun for the students?

Section 3: Computer

- Do you have computer at home? *If "Yes"*, how many *(read a-c)*?
    a) Desktop Computer
    b) Laptop/Notebook
    c) Tablet PC (e.g. IPad, Galaxy Tab)

  If "No", where do you have access to computer? Is it at *(read a-c)*?
    a) the school
    b) friends' house
    c) cyber cafe

d) Or any other places? ___________

- Do you have internet access on your computer?
  - o Yes
  - o No
  - o Others:__________________
- How often do you use a computer? Choose one of the following options.
  - o Daily
  - o Every 2–3 days
  - o Once a week
  - o 2–3 times per month
  - o Once a month
  - o Rarely
  - o Others:______
- On each occasion, how many hours per day do you spend on the computer? _______
- What do you normally use a computer for? Based on the following activities, tell me your frequency of use – always, sometimes, rarely or never.

	always	sometimes	rarely	never
Typing documents	○	○	○	○
Analyse data	○	○	○	○
Prepare presentation slides	○	○	○	○
Playing games	○	○	○	○
Doing your school work	○	○	○	○
Watching movie	○	○	○	○
Listening to music	○	○	○	○
Emails/ Communication	○	○	○	○
Using search engines (e.g. Google)	○	○	○	○
Social networking (e.g. Facebook)	○	○	○	○
Searching for medical information	○	○	○	○
Searching for directions (e.g. Google Map)	○	○	○	○
Reading news	○	○	○	○
Online Shopping	○	○	○	○
Others:_____________	○	○	○	○

Section 4: Cell Phone/ Smartphone

- Do you own a smartphone? *If "No"*, do you own a cell phone? _________ *(If "Yes" for smartphone, continue; otherwise skip to the next section)*
- What do you normally use your smartphone for? Based on the following activities, tell me your frequency of use – always, sometimes, rarely or never.

	always	sometimes	rarely	never
Making phone calls	O	O	O	O
Sending SMS	O	O	O	O
Using messaging application (e.g. WhatsApp, WeChat)	O	O	O	O
Playing games	O	O	O	O
Taking photo/video	O	O	O	O
Watching TV/video	O	O	O	O
Web browsing/ surf the Internet	O	O	O	O
Checking emails	O	O	O	O
Using Facebook	O	O	O	O
Using map/ directions	O	O	O	O
Reading news/ sports	O	O	O	O
Others:_______________	O	O	O	O

Section 5: Technology Skill

- Do you consider yourself knowing a lot about modern technology, especially computers?
- Based on the following technology skills, how you would rate yourself in a rating of 1 to 5 (1 would represent novice and 5 would represent expert).

Typing skill	
Word processing (e.g. Ms Word)	
Spreadsheet (e.g. Ms Excel)	
Presentation (e.g. Ms PowerPoint)	
Internet search (e.g. Google)	
Social networking (e.g. Facebook, Twitter)	
Find and download song/video	
Download and install software	
Video sharing via YouTube	
Use of electronic gadgets such as smartphone and tablet PC (e.g. IPad)	
Basic computer maintenance such as update software and check for virus	
Basic troubleshooting for Operating System, Wi-Fi and network	
Others:	

- Do you think your students knowing a lot about modern technology, especially computers? What do you think your students are good at? What do you think your students are weak at?
- How would you rate your technology skill compared to your students - you are better than your students, your students are better than you, you and your students are equally good or weak, or others? Is there a generation gap between you and your students?

Section 6: Digital Natives

- Can you recall the first time you used computer and the Internet?
- Multitasking means doing more than one task at the same time. For example, you may listen to a song while doing your work. Do you do multitasking? Can you give me some examples? Do you believe that multitasking make you better or worse at the tasks you are doing?

Section 7: Gaming Experience

- Digital games are electronic games such as video games or computer games. Have you ever play digital games? ____________ *(If "No", skip to the next section; otherwise continue)*
- How often do you play digital game? Choose one of the following options.
    - Daily
    - Every 2–3 days
    - Once a week
    - 2–3 times per month
    - Once a month
    - Rarely
- On each occasion, how many hours per day do you spend on playing digital game? ___________
- What devices do you use to play digital game? Choose one or more from the following options.
    - Computer
    - Tablet PC
    - Smartphone
    - Video game console
    - Others:_______________
- What are your favourite digital games? What makes the digital games so interesting?
- Generally, what are your favourite types of digital games? Choose one or more from the following options. Why do you love ______ games?
    - Simulation (i.e. recreate the reality, e.g. The Sims)
    - Racing (i.e. drive a vehicle or participate in a race, e.g. Need for speed: the run)
    - Fighting (i.e. focus on close-combat fighting, unarmed or using melee weapons, e.g. Street Fighter)
    - Strategy (i.e. focus on thinking and decision making, e.g. Warcraft)
    - Puzzle (i.e. focus on logical and conceptual challenges, e.g. Tetris, Zuma Deluxe)
    - Shooting (i.e. most commonly used with guns or arrows, e.g. Call for Duty, Counter-Strike)
    - Role-play (i.e. play a role in a story line, e.g. Final fantasy, Diablo II)

    - Sport (i.e. control of individual athletes, e.g. FIFA 2013)
    - Action-adventure (i.e. quick reflexes and interact with the environment, e.g. GTA)
- How do rate yourself in terms of gaming expertise in a rating of 1 to 5 for (read a - b)? *[1 would represent very weak and 5 represent very professional]*
    - your favourite type of game
    - other types of game
- What do you do when you start to play a new digital game? Choose one or more from of the following options.
    - Trial and error
    - Read game instructions
    - Observe someone else
    - Watch game tutorial
    - Find a cheat or walkthrough on the Internet
    - Other strategies:____________________
- Do you think playing digital game is good or bad for the students? Could you explain in more detail?
- In digital game, do you think you could learn (read a - e) skill?
    a) Multitasking (i.e. handle more than one task at the same time)
    b) land navigation (i.e. use of compass, map and direction)
    c) team work (i.e. working collaboratively with a group of people)
    d) problem-solving (i.e. finding solutions to difficult or complex issues)
    e) concentration (i.e. power of focusing all your attention)
- *If "Yes"*, could you give an example of digital game in which you have learned (read a-e)?

Section 8: Educational Computer Game

- Educational computer games are digital games designed for educational purposes, for example computer games used to learn mathematics, spelling, science and many more. Could you name a few educational computer games that you know? Do you find them entertaining? Do you find them useful?
- Based on your understanding, what is a good educational computer game? (Choose one of the following options - strongly agree, agree or undecided)
    - Educational computer game should provide training and practices.
    - Educational computer game should allow learning from problem-solving experience.
    - Educational computer game should provide real life application problems.
- Would you recommend the use of computer games to learn mathematics in the classroom? Between classroom teaching and mathematics computer game, which would be the better option to teach mathematics? How do you see your school in the near future, would technology replace classrooms?

- What do you think about the use of computer games to teach other subjects such as Science, Biology, Chemistry, language, etc.?
- What are the challenges that you foresee if mathematics computer games are going to be used for teaching in your school?
- As a mathematics teacher, what are your suggestions and advice for the:
    - students who want to succeed in mathematics?
    - parents who want to help their child to succeed in mathematics?
    - policy makers to have more effective mathematics teaching environment?

Note: Interview questions in Sections 3, 4, 6 and 7 are the same for all participants.

Interview Questions for Students

Section 1: Background

- How old are you? __________
- What is your race or ethnic background? ___________
- What is your stream of study - science or art stream? _____________
- Where did you study during your primary school education? Where did you study during your secondary school education from Form 1 until now?
- Where do you stay at the moment - in the hostel or with your family? If you stay in the hostel, how often do you go back home? How long do you stay at home?
- Where were you born? Where did you grow up?
- Now, where is your family staying?
- What are your parents' occupations?
- How many siblings do you have? What are their occupations?
- What do you do during your free time?
- What do you want to be when you grow up?

Section 2: Mathematics Learning Experience

- What do you think of mathematics?
- How confident are you in mathematics? Normally, what is your result or grade in mathematics? What are your strengths in mathematics? What topics are you good at in mathematics?
- Have you ever struggled in a mathematics exam? What do you find most challenging about mathematics? In your opinion, what are the most difficult topics in mathematics? Do you go for any tuition classes?
- What are the qualities of a good mathematics teacher?
- How does your mathematics teacher teach in the classroom – using blackboard, chalk and talk or using computer? What is the language of communication in the class? What about the textbook?

Section 5: Technology Skill

[Same as teacher's interview questions except questions 16 and 17 are replaced by the following questions]

- Do you think your parents are technology savvy, how would you rate your technology skill compared to your parents? Choose one of the following options.
    - I am better than my parents
    - My father is the best
    - My mother is the best
    - All of us are equally good
    - All of us are equally not good
    - Others:_________
- Do you think your teachers are technology savvy, how would you rate your technology skill compared to your teachers? Choose one of the following options.
    - I am better than my teachers
    - My teachers are better than I am
    - We are equally good
    - We are equally not good
    - Others:___________

Section 8: Educational Computer Game

[Same as teacher's interview questions except questions 31-34 are replaced by the following questions]

- Have you ever learned mathematics using a computer at home? Have you ever learned mathematics from the Internet? How would you describe your learning experience – fun, interesting, helpful or useful?
- Imagine that one day your mathematics teacher is using computer game to teach in the classroom, how would you feel? Could you explain the reason behind this? Would you support the school to use computer game to teach other subjects as Science, English, etc.?
- Imagine that there are three mathematics teachers in your school, Teacher A, Teacher B and Teacher C. Teacher A teaches using blackboard, chalk and talk. Teacher B teaches using blackboard, chalk and talk and then let the students to play mathematics computer game as an exercise. Teacher C teaches using mathematics computer game; no blackboard and no chalk and talk. Which teacher do you like best? Could you explain the reason behind this?
- In your opinion, how can we make mathematics class more interesting?

Interview Questions for Parents

Section 1: Background

- What is your occupation? What do you do as a/an _____?
- What is your highest level of education completed?
- How old are you?
- How many children do you have? How old are they?

Section 2: Views on Mathematics

- What do you think of mathematics?
- How would you describe your child's mathematics performance? Did you help your child with his/her mathematics homework? Do you send your child for mathematics tuition or any special training?
- How would you describe your child's attitude towards mathematics – whether they like or dislike maths? Did you help your child to build an interest in mathematics since his/her young age? What did you do?
- How would you describe your child's mathematics teacher in the school? In your opinion, what are the qualities of a good mathematics teacher? Do you think mathematics teacher should use computer to teach in the class?

Section 5: Technology Skill

[same as teacher's interview questions except questions 16 and 17 are replaced by the following questions]

- Do you think your child knowing a lot about modern technology, especially computers? What do you think your child is good at? What do you think your child is weak at?
- How would you rate your technology skill compared to your child - you are better than your child, your child is better than you, you and your child are equally good or weak, or others? Is there a generation gap between you and your child?

Section 8: Educational Computer Game

[same as teacher's interview questions except questions 31-34 are replaced by the following questions]

- Would you recommend the use of computer games to learn mathematics in school? Between classroom teaching and mathematics computer game, which would be the better option to teach mathematics? How do you see schools in the near future, would technology replace classrooms?
- As a parent, what is your expectation from the school education system? Do you have any suggestion for the school?

Appendix B: Survey Questionnaire

(A) DEMOGRAPHIC INFORMATION

GENDER *
Mark only one oval.
- Male
- Female

STUDY STREAM *
Mark only one oval.
- Arts
- Science
- Others

TYPE OF STUDENTS: *
Mark only one oval.
- Day scholar (staying at home/outside of the school)
- Boarder (staying in the hostel)

ETHNIC GROUPS *
Mark only one oval.
- Malay
- Chinese
- Iban
- Melanau
- Bidayuh
- Kenyah
- Kayan
- Lun Bawang
- Kelabit
- Penan
- Bisaya
- Berawan
- Others:_______

HOMETOWN *
Mark only one oval.
- Miri
- Kuching
- Samarahan
- Sri Aman
- Betong
- Sarikei
- Sibu
- Mukah
- Bintulu
- Kapit
- Limbang
- Others:_________

PLACE OF RESIDENCE*
Mark only one oval.
- Town area
- Rural area

AMBITION
Mark only one oval.
- Engineer
- Medical Doctor
- Pharmacist
- Teacher/Lecturer
- Accountant
- Entrepreneur
- Others:________

(B) TECHNOLOGY ACCESSIBILITY AND USAGE

Do you have ACCESS to the following technologies at HOME? (Not including your access at school) * *Mark only one oval per row.*

	Unrestricted Access (Can access any time)	Limited Access (Not that convenient)	No Access	Not Sure
Desktop computer	○	○	○	○
Video game console	○	○	○	○
Laptop/Notebook	○	○	○	○
Tablet PC (e.g. iPad)	○	○	○	○
MP3 player (e.g. iPod)	○	○	○	○
Portable DVD viewer	○	○	○	○
Digital/video camera	○	○	○	○
Regular cell phone (e.g. Nokia 101)	○	○	○	○
Smart phone (e.g. iPhone)	○	○	○	○
Broadband Internet at home (e.g. Unifi, Streamyx)	○	○	○	○
Mobile access to the Internet (e.g. Maxis, Digi Internet plan, etc.)	○	○	○	○

On average, how many HOURS PER DAY do you spend on each of the following activities? * *Fill in number of hours.*

Surf Internet (non-academic)	
Phone call/ message	
Facebook	
Play digital game (e.g. video or computer game)	
Watch TV	
Listen to music	
Doing homework	
Self-studying	
Physical Activity/ Sport	
Sleeping	

(C) DIGITAL NATIVE CHARACTERISTICS

What is your attitude towards TECHNOLOGY USAGE? * *Mark only one oval per row.*

	Strongly Disagree ←			Not Sure			→ Agree Strongly
I use the internet everyday	○	○	○	○	○	○	○
I use computers for many things in my daily life	○	○	○	○	○	○	○
When I need to know something, I search the internet first	○	○	○	○	○	○	○
I use the computer for leisure every day	○	○	○	○	○	○	○
I keep in contact with my friends through the computer every day	○	○	○	○	○	○	○
I am able to surf the internet and perform another activity comfortably	○	○	○	○	○	○	○
I can check email and chat online at the same time	○	○	○	○	○	○	○
When using the internet for my work, I am able to listen to music as well	○	○	○	○	○	○	○
I am able to communicate with my friends and do my work at the same time	○	○	○	○	○	○	○
I am able to use more than one application on the computer at the same time	○	○	○	○	○	○	○
I can chat on the phone with a friend and message another at the same time	○	○	○	○	○	○	○
I use pictures more than words when I wish to explain something	○	○	○	○	○	○	○
I use a lot of graphics and icons when I send messages	○	○	○	○	○	○	○
I prefer to receive messages with graphics and icons	○	○	○	○	○	○	○
I use pictures to express my feelings better	○	○	○	○	○	○	○
I use smiley faces a lot in my messages	○	○	○	○	○	○	○
I wish to be rewarded for everything I do	○	○	○	○	○	○	○
I expect quick access to information when I need it	○	○	○	○	○	○	○
When I send out an email, I expect a quick reply	○	○	○	○	○	○	○
I expect the websites that I visit regularly to be constantly updated	○	○	○	○	○	○	○
When I study, I prefer to learn those that I can use quickly first	○	○	○	○	○	○	○

(D) DIGITAL GAME PLAY

Have you ever played video/computer game? *
Mark only one oval.
- O Yes
- O No *Skip to section E.*

How LONG have you been playing video/computer games? *
Mark only one oval.
- O less than 1 year
- O 1 to 2 year
- O to 5 years
- O to 10 years
- O or more years

How OFTEN do you currently play video/computer games? *
Mark only one oval.
- O Several times a day
- O Once a day
- O Several times a week
- O Once a week
- O Once/twice a month
- O Every few months
- O Once/twice a year

How GOOD are you in playing video/computer game? *
Mark only one oval.
- O Beginner
- O Intermediate
- O Expert

What DEVICES you normally used to play digital game? *
Mark all that apply.
- O Personal computer
- O Laptop/notebook
- O Video game console (e.g. Xbox, PlayStation)
- O Smart phone (e.g. IPhone, Samsung Note)
- O Tablet PC (e.g. IPad)
- O Arcade
- O Others

i. What are your FAVOURITE <u>VIDEO GAMES</u> (List down THREE games)?
ii. What are your FAVOURITE <u>COMPUTER</u> GAMES (List down THREE games)?
iii. What are your FAVOURITE <u>FACEBOOK GAMES</u> (List down THREE games)?

I love to play the following TYPES OF GAMES: * *Mark only one oval per row.*

	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
Simulation (e.g. The Sims)	○	○	○	○	○
Racing (e.g. Need for speed: the run)	○	○	○	○	○
Sports (e.g. FIFA 2013)	○	○	○	○	○
Role-play (e.g. Final fantasy, diablo ii)	○	○	○	○	○
Action-adventure (e.g. Grand theft auto)	○	○	○	○	○
Strategy (e.g. Warcraft)	○	○	○	○	○
Fighting (e.g. Street Fighter)	○	○	○	○	○
Puzzle (e.g. Tetris, Zuma deluxe)	○	○	○	○	○
Shooter (e.g. Call of Duty, Counter-Strike)	○	○	○	○	○

What is your perception towards VIDEO/COMPUTER GAMES? Game in this section is referring to video/computer game. * *Mark only one oval per row.*

	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
Game is fun	○	○	○	○	○
Game is enjoyable	○	○	○	○	○
I love to play game	○	○	○	○	○
I love to play challenging game	○	○	○	○	○
I love to play interactive game	○	○	○	○	○
I love to play complex game	○	○	○	○	○
Game help me to develop cognitive skill	○	○	○	○	○
In game, I understand the problem	○	○	○	○	○
In game, I develop a plan	○	○	○	○	○
In game, I carry out a plan	○	○	○	○	○
In game, I look back at what I have done	○	○	○	○	○
Game help me to develop metacognitive skill	○	○	○	○	○
In game, I learn multitasking skill	○	○	○	○	○
In game, I learn land navigation skill	○	○	○	○	○
In game, I learn team work	○	○	○	○	○
In game, I learn problem-solving skill	○	○	○	○	○
In game, I learn concentration	○	○	○	○	○

What is your perception towards EDUCATIONAL COMPUTER GAMES? Edu Game in this section is referring to educational computer games. * *Mark only one oval per row.*

	Strongly Disagree	Disa gree	Not Sure	Agree	Strongly Agree
Edu game is the combination of educational and entertainment use	○	○	○	○	○
Edu game consist of training and practices	○	○	○	○	○
In Edu game, content is delivered straight forward	○	○	○	○	○
In Edu game, answers have to be memorised	○	○	○	○	○
Edu game help me to develop metacognitive skill	○	○	○	○	○
Edu game help me to learn from problem-solving experience	○	○	○	○	○
Edu game help me to learn from observation of the phenomena	○	○	○	○	○
Edu game can help me to learn from challenges and mistakes	○	○	○	○	○
Edu game enables learning in realistic context	○	○	○	○	○
Edu game enables learning with authentic activities	○	○	○	○	○
Tacit knowledge is explicit from decision made in Edu game	○	○	○	○	○
Knowledge is constructed through social interaction and collaboration in Edu game	○	○	○	○	○

(E) MATHEMATICS LEARNING & USE OF DIGITAL GAME TO LEARN MATHEMATIC

What is your perception towards MATHEMATICS learning? * *Mark only one oval per row.*

	Hardly Ever	Occasionall y	About Half the time	Usually	Nearly Always
I concentrate hard in mathematics.	○	○	○	○	○
I try to answer questions the teacher asks.	○	○	○	○	○
If I make mistakes, I work until I have corrected them.	○	○	○	○	○
If I can’t do a problem, I keep trying different ideas.	○	○	○	○	○

What is your perception towards use of TECHNOLOGY & use of COMPUTER GAME to learn MATHEMATICS? **Mark only one oval per row.*

	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
I am good at using computers.	○	○	○	○	○
I am good at using things like VCRs, DVDs, MP3s and mobile phones.	○	○	○	○	○
I can fix a lot of computer problems.	○	○	○	○	○
I am quick to learn new computer software needed for school.	○	○	○	○	○
I have a mathematical mind.	○	○	○	○	○
I can get good results in mathematics.	○	○	○	○	○
I know I can handle difficulties in mathematics.	○	○	○	○	○
I am confident with mathematics.	○	○	○	○	○
I am interested to learn new things in mathematics.	○	○	○	○	○
In mathematics you get rewards for your effort.	○	○	○	○	○
Learning mathematics is enjoyable.	○	○	○	○	○
I get a sense of satisfaction when I solve mathematics problems.	○	○	○	○	○
I like using computer game to learn mathematics.	○	○	○	○	○
Using computer game in mathematics is worth the extra effort.	○	○	○	○	○
Mathematics is more interesting when using computer game.	○	○	○	○	○
Computer games can help me learn mathematics better.	○	○	○	○	○

Thank You

Appendix C: Participants' Consent Forms

PARTICIPANT INFORMATION SHEET

You are being invited to participate in a study about the use of computer game to learn mathematics. Before you participate in this study, it is important for you to understand why the research is being done and what will it involve. Please take time to read the following information carefully. Should you have any questions or anything you do not understand, please do not hesitate to ask the researcher.

This study is being conducted as part of the PhD in Engineering program at University of Nottingham Malaysia Campus. In this study, you will be participated in an interview session asking about mathematics learning, computer usage, video/computer games and use of computer game to learn mathematics. Please be assured, the interview will be voice recoded and we will NOT be filming or recording you. Your participation will help us to understand potential use of computer game to learn mathematics.

Your participation is greatly appreciated. Please be assured that your data will be kept strictly confidential and will only be used for research purposes. Please also take note that scientific journals require data to be kept for five years after the study. Should you feel discomfort or decide to discontinue the study, you will be allowed to do so without giving a reason. You may also ask for your data to be destroyed.

If you have any questions about this research project, please feel free to contact the researcher, Yong Su Ting (SuTing.Yong@nottingham.edu.my), Professor Ian Harrison (Ian.Harrison@nottingham.edu.my) and Dr Peter Gates (Peter.Gates@nottingham.ac.uk).

Thank you for your participation.

Yours sincerely,

____

Yong Su Ting

____

Professor Ian Harrison & Dr Peter Gates

Parental Permission for Participation of a Child in a Research Study

University of Nottingham Malaysia Campus

Your child is being invited to take part in a research study on the use of computer game to learn mathematics. Before your child participates in this study, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. Please ask the researcher if there is anything you do not understand or if you would like further information.

This study is being conducted as part of the PhD in Engineering program at University of Nottingham Malaysia Campus. Your child will be participated in survey questionnaire/interview asking about mathematics learning, computer usage, video/computer games and use of computer game to learn mathematics. Please be assured, only the interview will be voice recoded and we will NOT be filming or recording your child. Your child's participation will help us to understand how children perceive the use of computer game to learn mathematics.

Your child's name will not be used when data from this study are published. Every effort will be made to keep research records and other personal information confidential.

Your child's participation will be greatly appreciated, but please be assured that your child's participation is completely voluntary. If at any time you decide that you do not want your child to continue to take part in the study, your child is free to withdraw.

If you have any questions about this research project, please contact the researcher, Yong Su Ting (SuTing.Yong@nottingham.edu.my) or supervisors, Professor Ian Harrison (Ian.Harrison@nottingham.edu.my) and Dr Peter Gates (Peter.Gates@nottingham.ac.uk).

Consent

I have read this parental permission form and been given a copy of this consent form to keep.

My child ______________________________________ has my consent to participate in this research study.

Name of Parent/Guardian: ________________________________

(Signature) Date: ________________

CONSENT FORM (TEACHER/STUDENT)

Researcher : Yong Su Ting (SuTing.Yong@nottingham.edu.my)
Supervisors : Professor Ian Harrison (Ian.Harrison@nottingham.edu.my)
Dr Peter Gates (Peter.Gates@nottingham.ac.uk)

School of Engineering, University of Nottingham Malaysia Campus

This study is conducted as part of a PhD in engineering programme at University of Nottingham Malaysia Campus. You will be given a survey questionnaire or being interviewed. We would like to ask for your consent to participate in this study.

Your cooperation in this research study is very much appreciated. Please be assured that your data will only be used for research documentation and all information will be kept strictly confidential.

The participant should complete the whole of this sheet himself/herself. Please circle your answers:

• I have read the Participant Information Sheet.	YES / NO
• The nature and purpose of the research project have been explained to me.	YES / NO
• I understand the purpose of the research project and my involvement in it.	YES / NO
• I understand that I may withdraw from the research study at any stage.	YES / NO
• I understand that while information gained during the study may be published, I will not be identified and my personal results will remain confidential.	YES / NO
• I understand that I will be audiotaped if I am involved in the interview session.	YES / NO
• I understand and agree to take part.	YES / NO

I have **read and understood** the information provided on this sheet. I understand that I am allowed to **withdraw** from the study without giving a reason. I understand that if I decide at a later date that my data should be **destroyed**, the researchers will honour requests directed to the School of Engineering, University of Nottingham Malaysia Campus.

"This study has been explained to me to my satisfaction, and I agree to take part. I understand that I am free to withdraw at any time."

Signature of the Participant: ___________ Date: ________________

Name (in block capitals): __________________________________

"I have explained the study to the above participant and he/she has agreed to take part."

Signature of researcher: _____________________ Date: ____________

CONSENT FORM (PARENT)

Researcher : Yong Su Ting (SuTing.Yong@nottingham.edu.my)
Supervisors : Professor Ian Harrison (Ian.Harrison@nottingham.edu.my)
Dr Peter Gates (Peter.Gates@nottingham.ac.uk)

School of Engineering, University of Nottingham Malaysia Campus

This study is conducted as part of a PhD in engineering programme at University of Nottingham Malaysia Campus. You will be interviewed. We would like to ask for your consent to participate in this study.

Your cooperation in this research study is very much appreciated. Please be assured that your data will only be used for research documentation and all information will be kept strictly confidential.

The participant should complete the whole of this sheet himself/herself. Please circle your answers:

• I have read the Participant Information Sheet.	YES / NO
• The nature and purpose of the research project have been explained to me.	YES / NO
• I understand the purpose of the research project and my involvement in it.	YES / NO
• I understand that I may withdraw from the research study at any stage.	YES / NO
• I understand that while information gained during the study may be published, I will not be identified and my personal results will remain confidential.	YES / NO
• I understand that I will be audiotaped during the interview session.	YES / NO
• I understand and agree to take part.	YES / NO

I have **read and understood** the information provided on this sheet. I understand that I am allowed to **withdraw** from the study without giving a reason. I understand that if I decide at a later date that my data should be **destroyed**, the researchers will honour requests directed to the School of Engineering, University of Nottingham Malaysia Campus.

"This study has been explained to me to my satisfaction, and I agree to take part. I understand that I am free to withdraw at any time."

Signature of the Participant: ________________ Date: ________________

Name (in block capitals): ________________________________

"I understand the nature of the project and I give consent for my child

____ [Name] to participate".

If there is a discrepancy between the wishes of the child and the parent, i.e. the child does not wish to participate but the parent wishes them to, then the choice of the participant (child) has priority.

"I have explained the study to the above participant and he/she has agreed to take part."

Signature of researcher: ______________________________ Date: __________

Appendix D: Demographic Information for Survey Questionnaire

Table A.1: Frequency Distribution of Respondents

M1 School	M2 School	TOTAL
116	59	175

Table A.2: Demographics information

		M1 School	M2 School	Total
Gender	**Male**	44 (38%)	23 (40%)	67 (39%)
	Female	72 (62%)	35 (60%)	107 (61%)
	TOTAL	**116 (100%)**	**58 (100%)**	**174 (100%)**
Type of Student	**Day Scholar**	60 (52%)	0 (0%)	60 (34%)
	Boarder	56 (48%)	59 (100%)	115 (66%)
	TOTAL	**116 (100%)**	**59 (100%)**	**175 (100%)**
Place of Residence	**Town**	98 (85%)	40 (70%)	138 (80%)
	Rural	17 (15%)	17 (30%)	34 (20%)
	TOTAL	**115 (100%)**	**57 (100%)**	**172 (100%)**

Table A.3: Demographic according to Ethnic Groups

Ethnic Groups	M1 School	M2 School	Total
Iban	32	4	36
Melanau	8	8	16
Kedayan	6	8	14
Kayan	9	2	11
Bidayuh	4	2	6
Kenyah	5	1	6
Kelabit	3	1	4
Lun Bawang	1	2	3
Bisaya	2	1	3
Malay	31	26	57
Chinese	10	0	10
Others	4	3	7

Table A.4: Demographic according to Hometown

Hometown	M1 School	M2 School	Total
Miri	86	27	113
Limbang	11	10	21
Bintulu	5	6	11
Kuching	6	3	9
Lawas	2	2	4
Sibu	1	1	2
Mukah	0	2	2
Belaga	2	0	2
Kapit	1	0	1
Sarikei	0	1	1
Sri Aman	0	1	1
Others	0	5	5

Table A.5: Frequency Distribution according to Ambition

Ambition	M1 School	M2 School	Total
Engineer	47	21	68
Medical Doctor	20	12	32
Teacher/Lecturer	5	6	11
Pharmacist	6	3	9
Pilot	5	3	8
Veterinary	2	3	5
Entrepreneur	2	2	4
Accountant	2	1	3
Architect	1	2	3
Lawyer	1	1	2
Dentist	2	0	2
Forensic Scientist	2	0	2
Musician	2	0	2
Others	13	4	17